

National Inventory of Hospital Trauma Centers

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TRAUMA SYSTEMS ARE DESIGNED to provide an organized and coordinated response to injury.¹⁻⁴ Fully operational trauma systems ensure a continuum of care involving public access to the system, out-of-hospital emergency medical services, and timely triage and transport to definitive acute care and rehabilitation. Fundamental to the trauma system infrastructure is a network of hospitals committed to treating individuals with injuries that span the spectrum of severity.

In 1976, the American College of Surgeons Committee on Trauma (ACS/COT) developed criteria for categorizing hospitals according to the level of trauma care available (BOX).² Increasingly, states are using these guidelines as a basis for designating or certifying hospitals as trauma centers. In states without formal trauma systems, hospitals have voluntarily sought verification by the ACS/COT. Numerous studies have documented the beneficial effects of trauma systems and trauma centers.⁵⁻⁹ Nathens et al⁵ estimate that full implementation of a trauma system is associated with an 8% decrease in mortality from motor vehicle traffic deaths. Other studies suggest that when

See also p 1566.

Context Trauma centers benefit thousands of injured individuals every day and play a critical role in responding to disasters. The last full accounting of the number and distribution of trauma centers identified 471 trauma centers in the United States in 1991.

Objective To determine the number and configuration of trauma centers and identify gaps in coverage.

Design, Setting, and Subjects Interviews with trauma center directors (September 2001 to April 2002), data from the American Hospital Association's Annual Survey of Hospitals (2000), and the US Health Resources Administration's Area Resource File (2001) were used to determine characteristics of trauma center hospitals and the geographic areas they serve in all 50 states and in the District of Columbia. Characteristics of trauma centers were examined by level of care and compared with nontrauma centers. Hospitals are designated or certified as trauma centers by a state or regional authority or verified as trauma centers by the American College of Surgeons Committee on Trauma. Trauma centers that treat only children (n=31) were excluded.

Main Outcome Measure Total number of trauma centers and number of trauma centers per million population.

Results In 2002, there were 1154 trauma centers in the United States, including 190 level I centers and 263 level II centers. Several states have categorized every hospital with an emergency department at some level of trauma care while others have designated a limited number of level I and level II centers only. The number of level I and II centers per million population ranges from 0.19 to 7.8 by state. When compared with nontrauma center hospitals, trauma centers are larger, more likely to be teaching hospitals, and more likely to offer specialized services.

Conclusions Although the availability of trauma centers has improved, challenges remain to ensure the optimal number, distribution, and configuration of trauma centers. These challenges must be addressed, especially in light of the recent emphasis on hospital preparedness and homeland security.

JAMA. 2003;289:1515-1522

www.jama.com

the most severely injured patients are treated at trauma centers, the reduction in the proportion of deaths judged preventable can exceed 50%.⁷

Trauma centers that benefit the thousands of individuals who are injured every day also play a critical role in responding to mass casualties and disasters resulting from conventional weapons of mass destruction. As part of the larger trauma system, trauma centers are organized to respond to unplanned multiple casualties that often tax existing resources and use a team approach that involves specialists from

throughout the hospital. They also have established linkages with emergency medical service personnel, fire and police departments, and participate in an

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Box. American College of Surgeons Committee on Trauma Classification System of Trauma Center Level²

Level I

Provides comprehensive trauma care, serves as a regional resource, and provides leadership in education, research, and system planning.

A level I center is required to have immediate availability of trauma surgeons, anesthesiologists, physician specialists, nurses, and resuscitation equipment. American College of Surgeons' volume performance criteria further stipulate that level I centers treat 1200 admissions a year or 240 major trauma patients per year or an average of 35 major trauma patients per surgeon.

Level II

Provides comprehensive trauma care either as a supplement to a level I trauma center in a large urban area or as the lead hospital in a less population-dense area.

Level II centers must meet essentially the same criteria as level I but volume performance standards are not required and may depend on the geographic area served. Centers are not expected to provide leadership in teaching and research.

Level III

Provides prompt assessment, resuscitation, emergency surgery, and stabilization with transfer to a level I or II as indicated.

Level III facilities typically serve communities that do not have immediate access to a level I or II trauma center.

Level IV/V

Provides advanced trauma life support prior to patient transfer in remote areas in which no higher level of care is available.

The key role of the level IV center is to resuscitate and stabilize patients and arrange for their transfer to the closest, most appropriate trauma center level facility.

Level V trauma centers are not formally recognized by the American College of Surgeons, but they are used by some states to further categorize hospitals providing life support prior to transfer.

existing network of hospitals with whom they regularly communicate both online and offline, share data through regional and state registries, and collaborate in system-wide quality-improvement activities.

However, there has not been a full accounting of the number and distribution of trauma centers in the United States since 1991.¹⁰ Since that time, the number of states with formal trauma systems has increased from 21 to 35 and the landscape of trauma center coverage in the United States has changed. In this article, we describe the development of a comprehensive inventory of trauma centers in the United States and use the inventory to describe the distribution of trauma centers by state and to identify gaps in trauma center coverage.

Organizational and resource characteristics of trauma centers are examined by level of care and compared with nontrauma centers.

METHODS

Development of the Trauma Center Inventory

The inventory was developed by the American Trauma Society's Trauma Information Exchange Program as a first step toward establishing a national network of trauma centers to be used for ongoing communication and collaboration among centers across state boundaries. The process of identifying trauma centers necessarily differed for states that have formal trauma systems and those that do not. In states that currently designate or certify trauma centers at either the state or regional level, trauma

centers were identified through discussions with the appropriate lead agencies. In states that do not have a formal process for designating or certifying trauma centers, hospitals were identified as being trauma centers if they reported being verified by the ACS/COT.² Hospitals that are self-designated trauma centers without any outside verification of resources or capabilities were excluded from the inventory.

Since a trauma center can be both designated by a state or regional authority and verified by the ACS/COT, all trauma centers in the inventory can be categorized into 3 mutually exclusive groups: (1) centers that are designated or verified by a state or regional authority only; (2) centers that are both designated by a state or regional authority as well as verified by the ACS/COT; and (3) centers that are verified by the ACS/COT, but located in states that do not formally designate or verify trauma centers.

Each hospital identified as having a trauma center was surveyed by telephone to confirm its status as a trauma center and to collect the (1) name, address, and Web site of the center; (2) name of the lead agency, year of last designation/certification, level of care for adult and pediatric trauma, and if, and by whom, an on-site evaluation is required for designation or certification, and if the center has been designated/certified by a lead agency in the state; (3) ACS level of care for adult and pediatric trauma; and (4) characteristics of the trauma registry supported by the center, including software used, whether the center contributes to a state or regional registry, and whether the center contributes to the National Trauma Data Bank.¹¹

Interviews were conducted by a person with more than 20 years of experience as a trauma program manager who made telephone calls between September 2001 and April 2002. Care was taken by the interviewer to make contact with the most knowledgeable person at each hospital. Typically, the interviewer asked to speak with the trauma coordinator, the trauma pro-

gram manager, or the trauma director. If that person could not be identified, the interviewer asked for the director of the emergency department, the hospital's medical director, or the director of nursing. All hospitals in the inventory were successfully surveyed.

All trauma centers were classified into 1 of 5 levels ranging from a level I trauma center that provides comprehensive trauma care to the most severely injured to a level IV/V trauma center that provides initial evaluation and assessment with transfer to a higher level of care when necessary. The following approaches were followed when there were discrepancies between the trauma center level reported by the hospital, the state, and the ACS/COT. In states with formal trauma systems, the level assigned to the hospital was the level reported by the state. In states without formal trauma systems, the level assigned to the hospital was the level verified by the ACS/COT (TABLE 1). It is important to emphasize that the definition of level varies somewhat by state. Although all states use the ACS/COT criteria as a foundation for their designation or certification process, some have modified the criteria making them more or less stringent. In the few states that do not formally classify trauma centers into levels, the lead agency was asked to provide a best approximation of the level of each center as defined by ACS/COT criteria.

Hospital Characteristics

Organizational characteristics and available services of the hospital in which each trauma center is located were obtained from the American Hospital Association's (AHA's) Annual Survey of Hospitals.¹² All but 11 level IV/V trauma centers were identifiable in the AHA database; 2 of these were classified as critical access hospitals and 6 as clinics. For each trauma center hospital, the AHA survey extracted (1) type of ownership; (2) participation in a health care system and/or hospital network; (3) number of beds staffed and set up; (4) presence of resident physician training program; and (5) membership in the

Table 1. Trauma Centers by State or Regional Designation/Certification and ACS Verification Status by Level of Trauma Care

Level of Center	Designated or Certified by State or Region		ACS Verification Only	All Centers
	Not ACS Verified	ACS Verified		
I	101	48	41	190
II	183	51	29	263
III	236	8	7	251
IV and V	450	0	0	450
All	970	107	77	1154

Abbreviation: ACS indicates American College of Surgeons.

Council of Teaching Hospitals of the Association of American Medical Colleges. Centers were also characterized according to their provision of medical/surgical intensive care, magnetic resonance imaging, cardiac catheterization laboratory, computed tomography, open heart surgery, transplantation services, burn care, and rehabilitation care.

Data were also obtained from 2001 US Health Resources Administration's Area Resource File¹³ and were used to classify each center according to the region of the country and the rurality of the county in which the center was located. Rurality was characterized by urban influence codes developed by the US Department of Agriculture that distinguish metropolitan counties by their population and nonmetropolitan areas by their adjacency to metropolitan areas and the size of the largest city in their area.¹⁴

Analysis

In this analysis, we exclude hospitals that are designated or verified as trauma centers that treat children only (n=31). Many level I and II centers included in this study treat both children and adults. The number of trauma centers and their distribution by level was first examined by state. Within each state, intercensal estimates of the 2001 population¹⁵ were used to compute the number of centers (total and level I and II only) per million population. Hospital characteristics were compared across levels of trauma center and between hospitals with and without trauma centers. χ^2 Statistics were used to test whether differences were statistically significant. Nontrauma center

hospitals were identified as all nonfederal, short-term, acute-care hospitals with 25 beds or more that responded to the AHA Annual Survey of Hospitals in 2000 (n=3373).

RESULTS

Number and Geographic Distribution of Trauma Centers

As of April 2002, 35 states and the District of Columbia had formally designated or certified trauma centers (TABLE 2). Two of the states, Arkansas and Wyoming, had only recently implemented a formal process of designation and were in the process of designating centers at the time of the survey. Only those centers in these 2 states that had been designated as of April 2002 are included. Another state, Massachusetts, was in the process of changing from a system in which regional emergency medical service agencies designated centers to one in which designation was implemented at the state level. Since the procedures for state-wide designation were still under development at the time of the survey, included hospitals in Massachusetts had ACS verification. The number of states that designate or certify trauma centers has increased from 21 in 1991 to 35 in 2002.^{16,17}

A total of 1154 adult trauma centers were identified in the 50 states and the District of Columbia, including 190 level I and 263 level II centers (Table 1). Only 839 (72.7%) of 1154 trauma centers included in the inventory were identified in the AHA survey as having a certified trauma service. Furthermore, 531 of 3373 nontrauma centers indicated in the AHA survey that they had a certified trauma service.

Of the 1154 trauma centers identified, 1077 (93.3%) are designated or certified by a state or regional authority (Table 1). Of these, 107 (9.9%) are also ACS verified, including 48 (32.2%) of 149 state/region designated level I centers and 51 (21.8%) of 234 state/region designated level II centers. An additional 77 hospitals are verified only by ACS.

The distribution of trauma centers across the United States is displayed in the FIGURE. Every state in the country has at least 1 center of some level, and all but 1 state (Arkansas) have at least 1 level I or II center (Table 2). The number of level I and II centers per million population varies widely, however, ranging from 0.19 to 7.8 (Table 2). Six states

(Washington, Oregon, Oklahoma, Iowa, Delaware, and Colorado) have categorized all or nearly all short-term general medical/surgical hospitals with 25 beds or more with a 24-hour/7 day per week emergency department into 1 of 5 levels of trauma care (Table 2 and Figure). An additional 4 states (Texas, Mississippi, Connecticut, and North Dakota) have categorized over half of their hospitals into 1 of 4 categories of trauma care. Twenty-four states do not maintain any level III, IV, or V trauma centers. All but 1 of 10 states that have categorized 50% or more of their hospitals as trauma centers began designating centers after 1991.

Table 2. Number of Trauma Centers per Million Population by State

	Year of First Designation/ Certification	All Levels		Level I and II Only	
		No. of Centers	Per Million Population	No. of Centers	Per Million Population
Formal Trauma System*					
Alaska	1996	1	1.60	1	1.60
Arkansas†	2002	1	0.37	0	0
California	1980	54	1.59	41	1.21
Colorado	1998	62	14.41	11	2.56
Connecticut	1995	16	4.70	13	3.82
Delaware	1998	7	8.93	1	1.28
District of Columbia	1976	3	5.24	3	5.24
Florida	1985	17	1.06	17	1.06
Georgia	1981	13	1.59	9	1.10
Hawaii	1995	1	0.83	1	0.83
Illinois	1988	61	4.91	61	4.91
Iowa	2001	116	39.64	12	4.10
Louisiana	1991	2	0.45	2	0.45
Maine	1998	3	2.35	3	2.35
Maryland	1978	9	1.70	7	1.32
Massachusetts†	2002	7	1.10	5	0.79
Mississippi	2000	64	22.50	6	2.11
Missouri	1987	29	5.18	19	3.40
Nevada	1988	3	1.50	2	1.00
New Hampshire	1997	12	9.71	5	4.05
New Jersey	1981	10	1.19	10	1.19
New Mexico	1986	3	1.65	1	0.55
New York	1990	45	2.37	45	2.37
North Carolina	1982	11	1.37	9	1.12
North Dakota	1993	27	42.04	5	7.79
Oklahoma	2001	102	29.56	3	0.87
Oregon	1987	45	13.15	7	2.05
Pennsylvania	1986	25	2.04	25	2.04
South Carolina	1980	23	5.73	6	1.50
Tennessee	1988	13	2.28	9	1.58
Texas	1993	183	8.78	21	1.01
Utah	1985	4	1.79	4	1.79
Virginia	1981	12	1.70	7	0.99
Washington	1993	79	13.40	11	1.87
West Virginia	1985	14	7.74	4	2.21
Wyoming†	2001	7	14.18	2	4.05
No Formal Trauma System					
Alabama		2	0.45	2	0.45
Arizona		1	0.19	1	0.19
Idaho		1	0.77	1	0.77
Indiana		3	0.49	3	0.49
Kansas		3	1.12	3	1.12
Kentucky		4	0.99	2	0.49
Michigan		12	1.21	12	1.21
Minnesota		6	1.22	6	1.22
Montana		3	3.33	3	3.33
Nebraska		3	1.75	3	1.75
Ohio		23	2.03	20	1.76
Rhode Island		1	0.95	1	0.95
South Dakota		2	2.65	2	2.65
Vermont		1	1.64	1	1.64
Wisconsin		5	0.93	5	0.93

*Defined as states with legislative authority to designate/verify and in which designation/verification has taken place.
†Indicates that as of April 2002, state is in process of designating trauma centers.

Comparison of Trauma Centers With Nontrauma Centers

The distribution of trauma centers by region of the country and rurality is similar to the distribution of non-trauma center hospitals (TABLE 3).

When compared with hospitals without trauma centers, hospitals with trauma centers are significantly more likely to be public hospitals and less likely to be private for-profit institutions (Table 2). Trauma centers are larger than non-trauma center hospitals. A higher percentage of trauma centers have a significant commitment to teaching programs, which is reflected in the percentage that are members of the Council of Teaching Hospitals. In addition, a higher percentage of trauma center hospitals offer specialized services.

Comparisons Across Levels of Trauma Centers

Level I and II trauma centers are significantly more likely than level III and IV/V centers to be located in metropolitan areas. More than 90% of level I and II hospitals are located in metropolitan areas compared with 49% of level III and only 16% of level IV/V (Table 3). Level III and IV/V centers are more common in the South (due in large measure to the large numbers of levels III through V centers in Texas and Oklahoma). These levels are far less common in the Northeast and Midwest.

Distribution of trauma centers by ownership varies by level of care (Table 3). The majority of level IV/V centers are publicly owned hospitals, whereas level II centers are predominantly private and not for profit. More than three quarters of level I and II hospitals are members of health care systems compared with 55.5% of level III and 34.8% of level IV/V. The percentage participating in hospital networks is also higher for level I and II centers compared with level III and IV/V center hospitals. Average number of beds also varies significantly by level of trauma center, with higher levels being located in larger hospitals. Ninety percent of level I centers have residency programs and three quarters are members of Council of Teaching Hospitals. A much smaller percentage of level II centers have residency programs or are members of the Council of Teaching Hospitals.

The percentage of hospitals offering special services also varies significantly by level of trauma center, with level IV/V centers offering far fewer services compared with other levels of trauma centers and when compared with nontrauma centers more generally (Table 3).

Although all trauma centers support a trauma registry, not all contribute to a state or regional registry. Hospitals not contributing to a state or regional registry are more likely to be level I or II centers in states without a formal trauma system. Less than 10% of all trauma centers are currently contributing to the National Trauma Data Bank, although the percentage of level I and II centers contributing to the National Trauma Data Bank (19%) is higher than for level III and IV/V centers (2%). The type of registry software used varies substantially. Collector (Digital Innovation, Inc, Forest Hill, Md) is the most widely used software (used by 27% of centers), followed by Trauma One (Lancet Technology, Inc, Boston, Mass) (13%), and Trauma! (Digital Innovation, Inc) (13%).

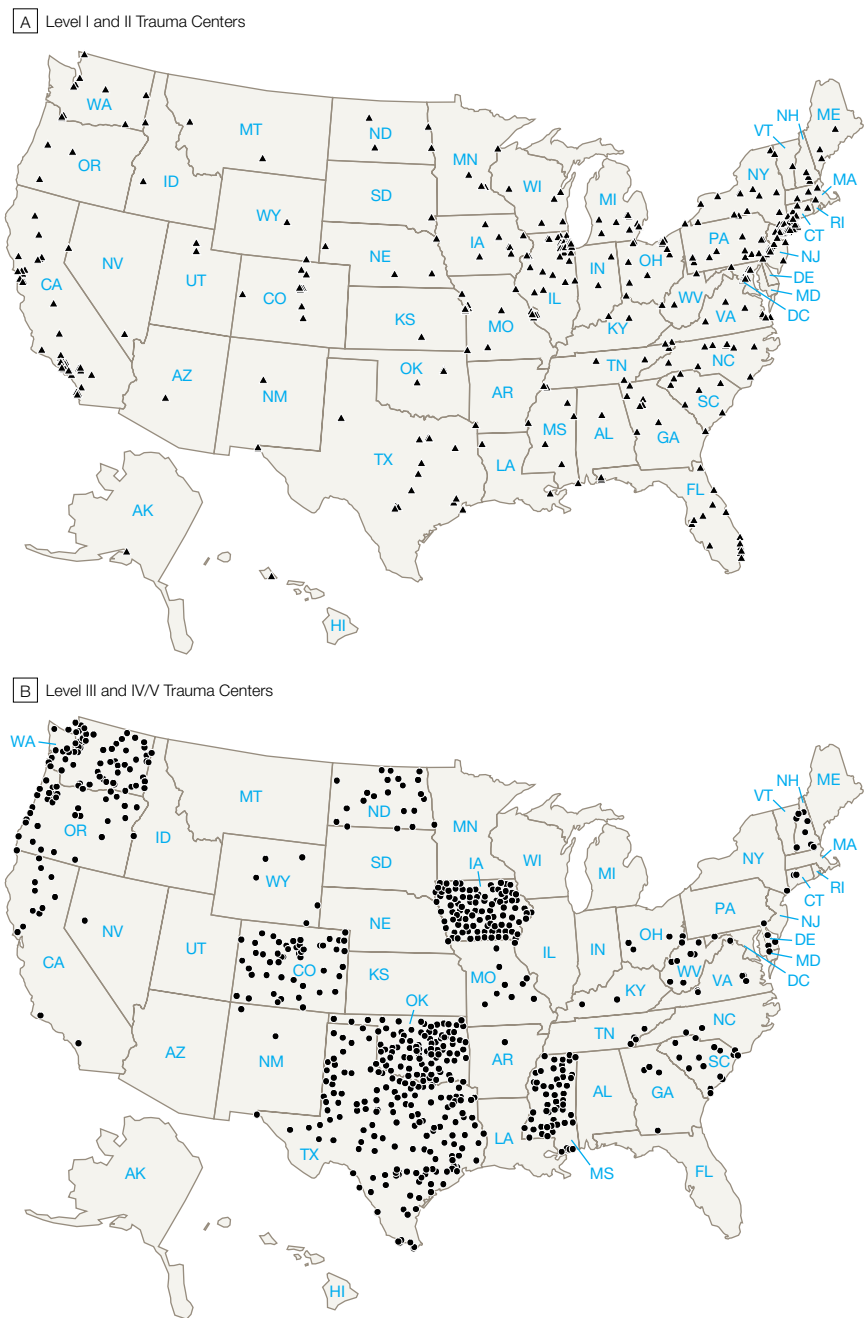
COMMENT

The results of this national inventory show that the number of trauma cen-

ters has more than doubled since 1991. At that time, 471 trauma centers were identified (165 level I centers; level II, 209; level III, 76; and level IV/V, 21).¹⁰ Although the largest increase has been in the number of level III and IV/V cen-

ters (97 in 1991 compared with 701 in 2002), the number of level I and II centers alone has increased by 21% (from 374 in 1999 to 453 in 2002). This increase in level I and level II centers reflects a growing commitment on the part

Figure. Trauma Centers in the United States Plotted by ZIP Code



Centers in the same ZIP code are indicated by a single marker.

of states to develop and maintain formal trauma systems. Even in states without formal systems of care, hospitals have voluntarily sought verification by the ACS/COT so that today all states

have at least 1 hospital that has made a substantial commitment to the care of the injured. For example, in 1991, a smaller share of trauma centers (24%) were located in the South compared with

nontrauma center hospitals (39%).¹⁰ This is no longer the case and reflects the more recent development of organized systems of trauma care in the South. However, there is wide variation by

Table 3. Geographic and Organizational Characteristics of Trauma Centers and Nontrauma Centers

	Level of Trauma Center				P Value*	All Levels (n = 1154)	Hospital Without Trauma Center (n = 3373)	P Value†
	I (n = 190)	II (n = 263)	III (n = 251)	IV to V (n = 450)				
Region								
Northeast	55 (28.9)	53 (20.1)	12 (4.8)	0 (0)	<.001	120 (10.4)	515 (15.3)	<.001
Midwest	55 (28.9)	96 (36.5)	35 (13.9)	104 (23.1)		290 (25.1)	1002 (29.7)	
South	57 (30.1)	51 (19.4)	136 (54.2)	236 (52.4)		480 (41.6)	1275 (37.8)	
West	23 (12.1)	63 (24.0)	68 (27.1)	110 (24.4)		264 (22.9)	581 (17.2)	
Rurality (as defined by urban influence codes)								
Metropolitan area, population by millions					<.001			<.001
Large (≥1)	119 (62.6)	115 (43.7)	37 (14.7)	29 (6.4)		300 (26.0)	1053 (31.5)	
Small (<1)	68 (35.8)	123 (46.8)	86 (34.3)	41 (9.1)		318 (27.6)	798 (23.8)	
Nonmetropolitan area, population by thousands								
Adjacent to metropolitan area					<.001			<.001
City ≥10	0 (0)	9 (3.4)	43 (17.1)	30 (6.7)		82 (7.1)	271 (8.1)	
No city ≥10	1 (0.5)	1 (0.4)	15 (6.0)	120 (26.7)		137 (11.9)	437 (13.0)	
Not adjacent to metropolitan area								
City ≥10	2 (1.1)	15 (5.7)	48 (19.1)	30 (6.7)	95 (8.2)	214 (6.4)		
No city ≥10	0 (0)	0 (0)	22 (8.8)	200 (44.4)	222 (19.2)	575 (17.2)		
Ownership								
Public	65 (34.2)	25 (9.5)	57 (22.7)	276 (61.3)	<.001	423 (36.6)	746 (22.1)	<.001
Private								
Not for profit	120 (63.2)	226 (85.9)	154 (61.4)	141 (31.3)		641 (55.6)	2052 (60.8)	
For profit	5 (2.6)	12 (4.6)	40 (15.9)	33 (7.3)	90 (7.8)	575 (17.1)		
Bed size								
<100	0 (0)	2 (0.8)	81 (32.3)	386 (85.8)	<.001	469 (40.6)	1473 (43.6)	<.001
100-299	19 (10.0)	125 (47.5)	133 (52.9)	59 (13.1)		336 (29.1)	1477 (43.8)	
300-499	70 (36.8)	94 (35.7)	33 (13.2)	4 (0.9)		201 (17.4)	313 (9.3)	
≥500	101 (53.2)	42 (16.0)	4 (1.6)	1 (0.2)		148 (12.9)	110 (3.3)	
Participation‡								
Hospital care system	136 (80.5)	176 (76.2)	126 (55.5)	139 (34.8)	<.001	577 (56.2)	1657 (56.8)	.75
Hospital network	70 (41.4)	97 (42.0)	78 (34.1)	112 (28.1)	<.001	357 (34.8)	945 (32.5)	.18
Teaching status§								
COTH member	137 (75.7)	30 (12.0)	1 (0.4)	0 (0)	<.001	168 (15.2)	100 (3.0)	<.001
Residency program	163 (90.1)	121 (48.4)	30 (12.5)	8 (1.8)	<.001	322 (29.1)	395 (11.7)	<.001
Services								
Intensive care unit	174 (99.4)	235 (98.7)	220 (93.2)	203 (48.2)	<.001	832 (77.8)	2402 (77.3)	.75
Computed tomography	174 (99.4)	235 (98.7)	227 (96.2)	326 (77.4)	<.001	962 (90.0)	2823 (90.8)	.37
Magnetic resonance imaging	157 (89.7)	197 (82.8)	175 (74.2)	112 (26.6)	<.001	641 (59.9)	1713 (55.1)	.006
Cardiac catheter laboratory	168 (96.0)	204 (85.7)	137 (58.0)	26 (6.2)	<.001	535 (50.0)	1128 (36.3)	<.001
Open heart surgery	155 (88.6)	154 (64.7)	59 (25.0)	7 (1.7)	<.001	375 (35.0)	551 (17.7)	<.001
Organ/tissue transplantation	115 (65.7)	43 (18.1)	27 (11.4)	2 (0.5)	<.001	187 (17.5)	180 (5.8)	<.001
Burn care	74 (42.3)	11 (4.6)	4 (1.7)	1 (0.2)	<.001	90 (8.4)	48 (1.5)	<.001
Registration								
State or local registry¶	153 (84.1)	234 (92.9)	236 (96.7)	446 (99.8)	<.001	1069 (95.0)		<.001
National Trauma Data Bank#	50 (26.4)	37 (14.2)	10 (4.1)	4 (0.9)	<.001	101 (8.8)		<.001

Abbreviation: COTH, Council of Teaching Hospitals.
 *Distribution across trauma center levels.
 †Difference of distribution between trauma and nontrauma centers.
 ‡Missing data for 127 trauma center hospitals and 453 nontrauma center hospitals.
 §Missing data for 47 trauma center hospitals and 14 nontrauma center hospitals.
 ||Missing data for 84 trauma center hospitals and 265 nontrauma center hospitals.
 ¶Missing data for 29 trauma center hospitals.
 #Missing data for 12 trauma center hospitals.

state in both the availability and configuration of hospital trauma resources. The results of this survey suggest the need for several aggressive steps to improve day-to-day care of the injured and bolster the infrastructure needed to adequately respond to mass casualties and disasters when they occur.

First, despite the encouraging growth in trauma system development, gaps in trauma center coverage remain and must be addressed. The geographic distribution of trauma centers highlights the areas of the country where availability of trauma center care is limited. More refined measures of access are needed to identify more adequately underserved areas (eg, percentage of the population that resides within 15 to 30 minutes of a trauma center), as individuals in some parts of the country do not currently benefit from the care afforded by a trauma center. Poor access to trauma center care is particularly acute in more rural areas of the country.

Second, to ensure effective and efficient systems of care, evidence-based guidelines are needed to establish the optimal number of level I and II trauma centers. The fundamental principle underpinning regional trauma systems is that the concentration of the most severely injured patients in a limited number of specialty care facilities (ie, level I or II trauma centers) will increase patient volumes and experience at these centers and thus improve patient outcomes. While increasing evidence supports this principle, there is disagreement as to the optimal volume needed to ensure adequate experience.¹⁸⁻²² The ACS/COT has promulgated 1 set of criteria, recommending that level I centers treat approximately 1200 trauma patients annually, of whom 240 should be major trauma (defined as patients with Injury Severity scores >15).^{2,23} However, a recent study by Nathens et al¹⁸ suggests that improvements in mortality are associated with trauma center volumes of at least 650 major trauma patients.

Applying these criteria to previously published, population-based estimates of the rate of major trauma patients discharged (44 per 100 000 person-

years)²⁴ suggests the need for only 1 to 2 level I or II trauma centers per million population. Our inventory indicates that in states with formal trauma systems, the number of level I and II trauma centers varies from less than 1 to more than 7; 8 states have more than 3 level I and II centers per million population. The consequences of having a large number of trauma centers has been illustrated by Nathens et al,²⁴ who showed a strong correlation between the density of trauma centers and individual trauma center volumes. In a comparison of 18 states for which patient-level hospital discharge data were available, the annual number of major trauma patients treated at level I and II trauma centers ranged from 348 in the state with the least number of level I and II centers to 52 in the state with the most number.

In addition to having implications for volume performance criteria, variations in the number and density of trauma centers may have significant cost implications associated with the unnecessary duplication of expensive resources. However, political realities and resource constraints may dictate the need to share volumes of major trauma patients across a larger number of centers than what is dictated strictly on the basis of need. Priority should be given to the development of methods for optimizing trauma center placement that take into account demand for trauma services, geography, and local constraints such as resource availability, weather conditions, and traffic patterns. Quantitative location techniques hold promise for optimizing trauma center resource allocation and should be considered in the development of sound trauma system policy, which will ultimately save lives and reduce costs.²⁵

In addition to establishing the optimal number and distribution of level I and II trauma centers, it will be important to define the appropriate role for level III and IV/V trauma centers and the benefits and possible disadvantages of inclusive systems of trauma care in which every hospital with a 24-hour/7-day per week emergency department is categorized at some level of

trauma center care. Level III and IV/V hospitals have traditionally played a critical role in more rural areas in which no level I or II centers are immediately accessible. Since the early 1990s, however, the number of level III and IV/V centers has proliferated in both urban and rural areas in an attempt to develop more inclusive systems. If these hospitals are fully integrated into the trauma system and well-defined criteria are operationalized for transporting the most severely injured patients directly to a level I or II center when at all possible, inclusive systems may provide a substantial advantage, especially in light of the recent emphasis on disaster preparedness. Since it is well-known that individuals involved in a disaster will present at the hospitals that are geographically closest to the disaster site, an inclusive network of hospitals may be of more value than a system that recognizes the capabilities of a more limited number of level I and II centers. Level I and II trauma centers will continue to serve an important role in providing definitive care to the most severely injured patients in a disaster, but they must be integrated into a larger community-wide response. However, there are concerns that poorly managed inclusive systems could encourage an initial evaluation of a severely injured trauma patient at a lower level trauma center and then transfer the patient to a higher level trauma center, which would result in time delays that could have deleterious effects on patient outcome.²⁶⁻²⁸

This inventory was conducted at a time when the threats to trauma systems and trauma center viability have never been greater. Increasing numbers of uninsured, declining reimbursement for both physicians and hospitals, soaring malpractice premiums, and new limits on resident physician hours have contributed to a tenuous environment for trauma centers. While these trends are affecting the health care system more broadly, trauma centers are particularly vulnerable because they treat a disproportionate share of uninsured and underinsured patients and

have high standby costs. To remain open, trauma centers are being forced to subsidize surgical specialists for on-call availability. To meet the demands of injuries that occur daily as well as respond to the needs of homeland security, communities must recognize the need to support these systems by revenues outside traditional patient care funding.

CONCLUSION

Although the availability of hospital trauma resources has improved, several challenges remain in determining the optimal number and configuration of these resources. It is imperative these challenges be addressed, especially in light of the recent emphasis on hospital preparedness. The role of trauma centers in responding to disasters must be more adequately addressed in the criteria for trauma center designation or verification. Although existing criteria address the resources necessary for a coordinated response to mass casualties, re-

cent events have defined new threats of vastly different scope and character, which dictate the need for organized approaches for response and strong linkages with public health.²⁹

Previous disasters (natural and man-made) indicate that traumatic injury is a major threat. The infrastructure for treating patients' injuries must predate the disaster to provide an adequate response to acts of terrorism. Investing in the existing trauma system infrastructure so that it is fully operational when needed to respond to infrequent but unpredictable disasters will be cost-effective in the long term. The inventory described herein is a first step in building this network. It will be maintained and used as a basis for establishing ongoing communications among centers and to encourage ongoing federal, state, and local ensurance of a comprehensive system that serves everyone.

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Funding/Support: This work was supported in part by grant H28/CCH319122 from the Centers for Disease Control and Prevention, Center for Injury Prevention and Control.

Acknowledgment: We appreciate the efforts of Maurine C. Goehring, RN, who supervised the telephone interviews with the trauma centers. We are also grateful to the members of the Trauma Information Exchange Program Advisory Committee for their guidance and input: John W. Ashworth III, MHA, University of Maryland Medical Center; Edward E. Cornwell, MD, Johns Hopkins School of Medicine; Linda Degutis, DrPH, Yale School of Medicine; John Fildes, MD, University of Nevada School of Medicine; Maurine C. Goehring, MSN, Trauma Research and Education Foundation; Lenworth M. Jacobs, MD, University of Connecticut School of Medicine; Mark E. King, West Virginia Office of Emergency Medical Services; J. Wayne Meredith, MD, Wake Forest University School of Medicine; John A. Morris, Jr, MD, Vanderbilt University Medical Center; Kevin C. Nolan, Navigant Consulting Inc; Richard B. Ponder, Johnson & Johnson; Richard Schwartz, The Advisory Board Company; and Robert V. Walker, DDS, University of Texas Southwestern Medical School.

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