Analysis of trends in the Florida Trauma System (1991-2003): Changes in mortality after establishment of new centers

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Background. *This study analyzes trends in hospitalization and outcome for adult, elderly, and pediatric trauma victims in the Florida Trauma System (FTS) from 1991 to 2003, during which time the number of centers nearly doubled from 11 to 20.*

Methods. *Administrative data was queried for all admissions with at least one trauma related discharge. Patients were stratified by age as pediatric (age, 0 to 15 years), adult (age, 16 to 64 years), or elderly (age, >64 years). Volume of admissions, severity, and mortality were analyzed over time. A logistic regression model was used to test the existence of an organizational experience curve after the designation of a new trauma center.*

Results. *Injury-related hospitalizations increased for the elderly, stayed the same for adults, and declined for children. As the system matured, a larger percentage of victims, particularly the most severely injured, were triaged to trauma centers, indicating more effective triage. In contrast to adults and pediatric patients, the majority of elderly trauma victims were managed at non-trauma centers. The trauma mortality rate per 1,000 population among the elderly increased during the study period ($P < .01$). Multivariate analysis indicated that for adult and pediatric victims it took up to 3 years after the designation of trauma center status before the odds of mortality reached parity with that of established centers.*

Conclusions. *The FTS has grown with its population and has matured to treat a larger percentage of trauma victims. Trauma victims transported to established trauma centers (4+ years) have a survival advantage compared to their counterparts transported to newly created centers. The reduction in the odds of mortality does not occur immediately after trauma center designation.*
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THE MAJORITY of studies analyzing the difference in expected mortality between patient populations treated at either designated trauma centers (DTCs) or non-trauma hospitals (NCs)[1-14] found a lower probability of mortality for trauma victims at DTCs. This observation has been the major stimulus to increase access to DTCs, and to coordinate DTC interaction into a functional trauma care system. It takes time, however, for a newly designated DTC to realize a reduction in mortality as its trauma population changes in terms of volume and injury severity. These changes require both increased resources and adaptation in administrative and clinical protocols, which may be unanticipated at the time a hospital begins to seek designation as a DTC, implying the existence of an organizational experience curve. Effectiveness of a trauma system, therefore, is contingent upon the number of DTCs per population, distribution of DTCs to optimize patient access, and "maturation" of DTCs to a steady state of performance that assures maximum

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survival advantage for the severely injured patient. Having established that trauma center designation does impart a survival advantage, we sought to investigate the effect of a rapidly increasing population on the function of our state trauma system in terms of DTC volume, demographics, and outcome. As additional DTCs were recruited into the system, we evaluated differences in mortality at new DTCs compared to their established counterparts, and the time interval that newly designated centers required to achieve parity with established centers.

Florida trauma centers. Florida's first trauma legislation, passed in 1982, required the Department of Health and Rehabilitative Services to define criteria for trauma center designation, verify hospital compliance with these criteria, and designate appropriately qualified hospitals as Level I, II, or Regional Pediatric Trauma Referral Centers (RPTRC). In 1991, the initial year of this study, there were 11 DTCs. Six additional centers were established between 1992 and 1994 whereas 3 others were added in, respectively, 1997, 1998, and 2000. The Florida Trauma System is an "inclusive system" in that participation in the system is voluntary on the parts of hospitals, numbers of centers are not determined by central administration, and geographic distribution of centers is not regulated. Twenty-two years after the 1982 legislation, the state's trauma system is mature and includes multiple interrelated and coordinated initiatives dedicated to prevention, pre-hospital care, acute care facilities, and post discharge longitudinal follow up. Florida currently has 21 DTCs, the 21st having been officially designated in March 2005. The 19 Level I and II trauma centers provide similar immediate medical specialty staffing, and differ in that Level I programs are expected to engage in active regional programs of education and research. Every Level I center is also required to meet all requirements for designation as a RPTRC.

DATA AND METHODS

This analysis combines information from the Florida Inpatient Hospital Discharge and Financial Datasets compiled by Florida's Agency for Health Care Administration (AHCA). The datasets cover all acute care hospitals in the state. The discharge dataset contains demographic and case-mix related characteristics, including age, gender, ethnic origin, up to 9 diagnoses and procedures, source of admission, and discharge status of all hospitalized patients. The financial dataset contains data concerning hospital expense categories for overall operations or patient care only.

Study population. The study population was defined to identify serious injury based on ICD-9CM codes. These included: 1) fractures of the skull, neck, and trunk, intracranial injury, and spinal cord injuries (800-809, 850-854, and 952); 2) other fractures (810-829); 3) internal injury of the thorax, abdomen, or pelvis (860-869); 4) injury of blood vessels (900-904); and 5) burns (940-949). For this analysis, trauma alert patients were defined as those with any of the above injuries and who were designated as emergency admissions in the administrative dataset. Moreover, patients with a primary diagnosis code historically not associated with risk of mortality were excluded. The latter determination was made using survival risk ratios (SRRs) that measure the proportion of victims with a specific ICD-9CM code that survive after admission. For example, during the study period, there were over 5,000 admissions, emergency and non-emergency cases, associated with fractures of one or more phalanges of the hand (ICD-9CM 816.xx), none resulting in mortality. These admissions were excluded to assure results were not influenced unduly by cases that are not associated with a risk of mortality.

The International Classification Injury Severity Scores (ICISS) method was used to estimate the severity and, by extension, individual patient risk of mortality, associated with specific injuries. The ICISS were calculated from SRRs derived from all years in the dataset excluding the year during which the patient was discharged from the hospital to avoid potential bias. Thus, the 2003 SRRs were calculated using the 1991-2002 data, the 2002 SRRs were calculated using the 1991-2001, 2003 data, and so forth. A lower ICISS indicates a greater risk of mortality, implying increased severity.[15-17]

Study methods. To assess the effect of a growing population on the function of the trauma system, 3 hypotheses were tested.

1. Population growth and system maturation resulted in a larger proportion of trauma victims being treated in DTCs over time, especially the more severely injured segment of the trauma victim population.
2. Average mortality rate across the trauma system will stabilize over time as more aggressive treatment was implemented by DTCs (survival advantage of triage to a trauma center).
3. A time lag in the reduction in mortality rate of injury existed after the conversion from NC to DTC status.

Data from the fourteen year period from 1991 to 2003 was used in the analysis. The first two hypotheses were tested by analyzing trauma admissions in

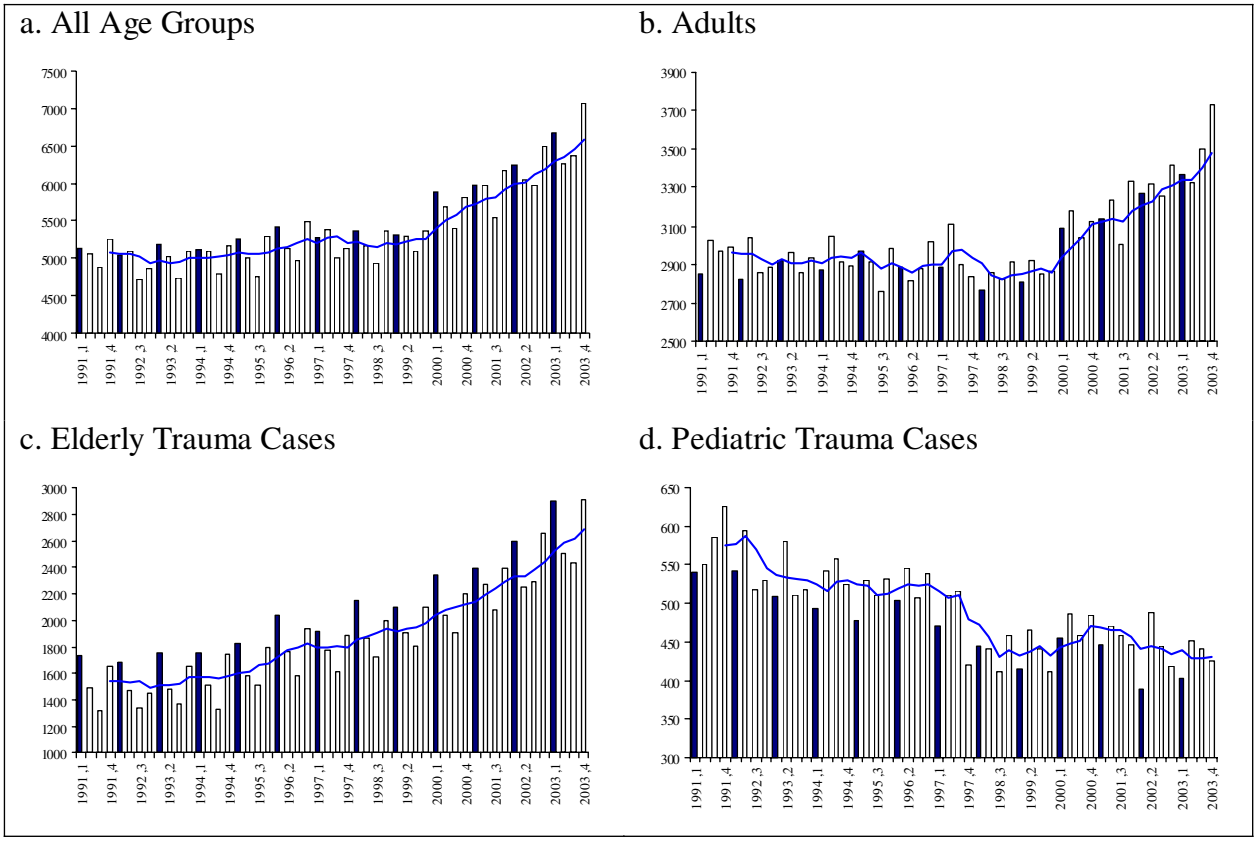

Fig 1. Number of trauma cases (1991-2003).

general, severity of trauma admissions, and mortality of severely injured victims. Trends were analyzed using linear regression.

The third hypothesis was tested using a multivariate logistic model to examine whether a time lag existed in mortality rate reduction after conversion of an NC to DTC. The dependent variable was dichotomous with a value of 1 if a patient died and 0 if the patient survived. The primary independent variable of interest was the number of years that elapsed since designation as a trauma center. Two models were executed separately to test the hypothesis. In the first specification a variable indicating the actual number of years elapsed since designation as a trauma center indicates whether an organizational experience curve exists. The second specification seeks to determine the duration of any experience curve by including five dummy variables indicating whether an individual hospital had been a DTC for less than 1 year, 1 to 2 years, 2 to 3 years, 3 to 4 years, and 4 to 5 years. In each case, the comparison group in this experiment was the set of DTCs that had been accredited for over 5 years.

Other explanatory variables in the model controlled for the influence of the type of DTC, trauma volume, general hospital quality (measured by the dollar value of resources devoted to patient care per inpatient day), distance between the DTC and patients' place of residence, patient age, gender and ethnic origin, injury severity, and primary injury type.

A Chow-Test for structural breaks was used to determine whether the coefficients in a regression model were the same in different sub-samples.[18] This approach showed significant differences in mortality risk based on age.[19-23] Therefore, the model was estimated and analyzed separately for children, adults, and the elderly according to Florida trauma triage criteria. Victims aged 0 to 15 years were categorized as pediatric patients (PED), victims aged 16 to 64 years were classified as adults (ADLT), whereas individuals 65 years of age and older were categorized as elderly (ELD).

RESULTS OF DESCRIPTIVE ANALYSIS OF TRENDS

Trauma admissions. Figure 1 shows the quarterly trend for trauma cases in all Florida hospitals from 1991 to 2003. The first quarter of each year is indicated by a solid bar, followed by outlined bars

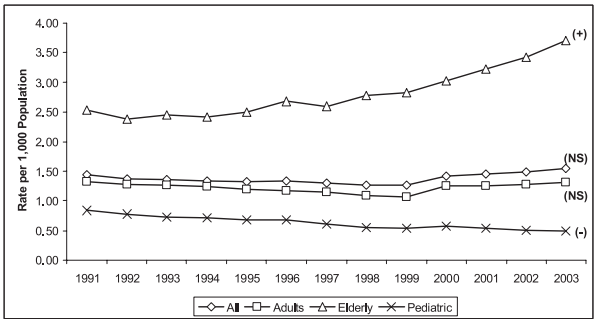

Fig 2. Trauma cases per 1,000 population.

for the remaining three quarters. The solid line flowing from left to right is the annual moving average of trauma cases. Fig 1 *A* includes all cases and indicates a clear seasonal pattern, with a steady reduction in the number of trauma cases during the second and third quarters, followed by a sharp increase during the last quarter of each year. The trend also indicates steady growth in the number of trauma hospitalizations, particularly since 1998. Figs 1 *B* to *D* indicate that the seasonal trend was driven by the elderly.

The trend shown in Figs 1 *A* and *C* indicate an additional burden on the state trauma system annually in the first and fourth quarters. The non-elderly adult trauma population exhibited significant fluctuations within each year but followed no clear seasonal pattern. The pediatric trauma population exhibited a pattern tending to spike during the second and third quarters that include the summer months when children are not in school.

Figure 2 shows the rate of trauma admissions per 1,000 people in the state for the study period. Results of linear regression analysis are indicated by showing a significant increase or decrease as either (+) or (−), whereas a non-significant trend is marked as (NS). The rate of trauma admission in the overall ($P = .16$) and ADLT populations ($P = .74$) did not change. The elderly, however, experienced a steady statistically significant increase in the rate of trauma-related hospitalizations during the study period ($P < .01$). In contrast, children experienced a decrease in the rate of trauma hospitalizations during the study period ($P < .01$).

Distribution of trauma hospitalizations. Figure 3 shows the distribution of trauma cases between DTCs and NCs. The overall trend supports the hypothesis that the percentage of trauma cases treated at DTCs increased as the system matured. The strength of the trend, however, differed by age. The addition of 6 DTCs from 1992 to 1994 in Broward, Palm Beach, and Lee Counties is seen clearly in Figs 3 *A*, *B*, and *D*, affecting primarily ADLT and PED victims.

Severity. Figure 4 demonstrates the mean ICISS Ps for trauma victims transported to either DTCs or NCs. As expected, the ICISS Ps of patients transported to DTCs was lower, reflecting a greater injury severity level. The mean ICISS for DTC patients exhibited greater fluctuation over time compared to NC patients. This trend was particularly true in the elderly, which showed very little fluctuation in the NC segment of the patient population.

Figure 5 illustrates the percentage of the most severely injured patients, defined by an ICISS Ps as less than or equal to 0.25, transported to either DTCs or NCs. Each chart includes an annual moving average, and demonstrates that the proportion of the most severely injured patients transported to DTCs did increase as the system matured. The trend was strongest for ADLT trauma victims.

Whereas the proportion of the most severely injured ELD patients transported to DTCs also increased over time, the quarterly fluctuations were much more dramatic. The distribution of PED patients between DTCs and NCs (Fig 4 *D*) showed no discernible trend over time. Nonetheless, in most periods, the majority of the most severely injured PED patients were treated at DTCs.

Mortality. Figure 6 shows the mortality rate for the most severely injured patients (ie, ICISS Ps ≤0.25). The pattern associated with non-elderly adult patients illustrates a relatively stable risk of mortality for DTC compared to NC patients (Fig 6 *B*). The mortality rates for the elderly show a similar difference in the relative quarterly fluctuations. Elderly NC patients tended to experience a high degree of fluctuations in the risk of mortality, though not as clearly as ADLT patients. The pediatric sample of patients with ICISS less than 0.25 was small, resulting in extreme fluctuation for both the DTC and NC groups. In at least 1 period, there were 0 patients in the ICISS less than or equal to 0.25 category.

Figure 7 shows the mortality rate per 1,000 people in the state for the study period. Linear regression results are again illustrated by showing a significant increase or decrease as either (+) or (−) whereas a non-significant trend is marked as (NS). Overall, the mortality rate per 1,000 people did not change during the study period ($P = .97$). However, there were notable differences between the age groups. The trend in the mortality rate per 1,000 people for ADLT, although negative, was not significant ($P = .15$).

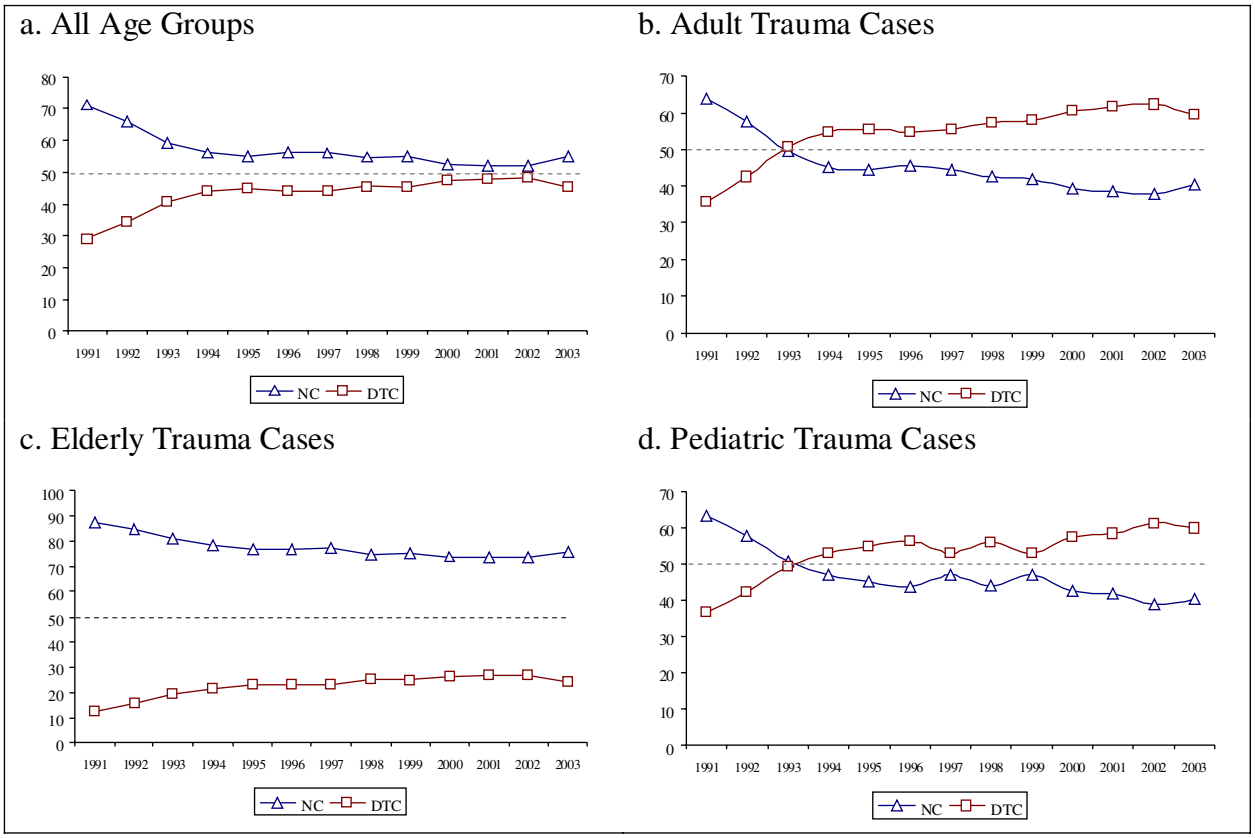

Fig 3. Percentage distribution of trauma victims to DTC and NC.

However, ELD experienced a strong upward trend in the mortality rate per 1,000 people ($P <$ .01). In contrast, the rate for PED decreased over time ($P <$ .01).

RESULTS OF MULTIVARIATE ANALYSIS: THE ROLE OF EXPERIENCE

The multivariate model was executed separately for 2 different specifications of the time elapsed since trauma center designation. The results are shown in the Table. Only the estimates associated with the time variables are shown in the Table. The statistical control factors are discussed in previous reports and are not included here to conserve space but are available from the authors on request. The first set of equations contained a single variable indicating the number of years elapsed. This specification allows testing of the hypothesis that more established centers, indicating greater organizational experience, were associated with lower odds of mortality. The results indicate that the odds of mortality declined significantly as organizational experience increased in the ADLT and PED equations. Although the time elapsed variable had a negative coefficient in the ELD equation, the trend was not significant at the $\alpha = .05$ level.

In the second specification of the model, the number of years elapsed was replaced by a series of dichotomous variables indicating the passage of 0 to 1, 1 to 2, 2 to 3, 3 to 4, and 4 to 5 years. This specification was used to determine whether the gains from experience occurred one time or in stepwise fashion. The time elapsed variables exhibit a clear trend in the ADLT equations and indicate that experience played an important role in outcome. On average, ADLT patients admitted to new DTCs had a higher probability of mortality compared to their counterparts admitted to more established institutions. The difference, as measured by the estimated coefficients, showed a small increase from the 0 to 1 to the 1 to 2 years variables, and a declining pattern thereafter. The odds-ratios for the variables indicating 0 to 1, 1 to 2, 2 to 3, 3 to 4, and 4 to 5 years elapsed since DTC designation were, respectively, 1.43, 1.66, 1.59, 1.28, and 1.09.

These results differed for the ELD as the coefficients on the first 3 time-elapsed variables were not statistically significant, indicating that more established DTCs did not have a different mortality rate than more recently designated centers. In the pediatric equation the estimated coefficient of the

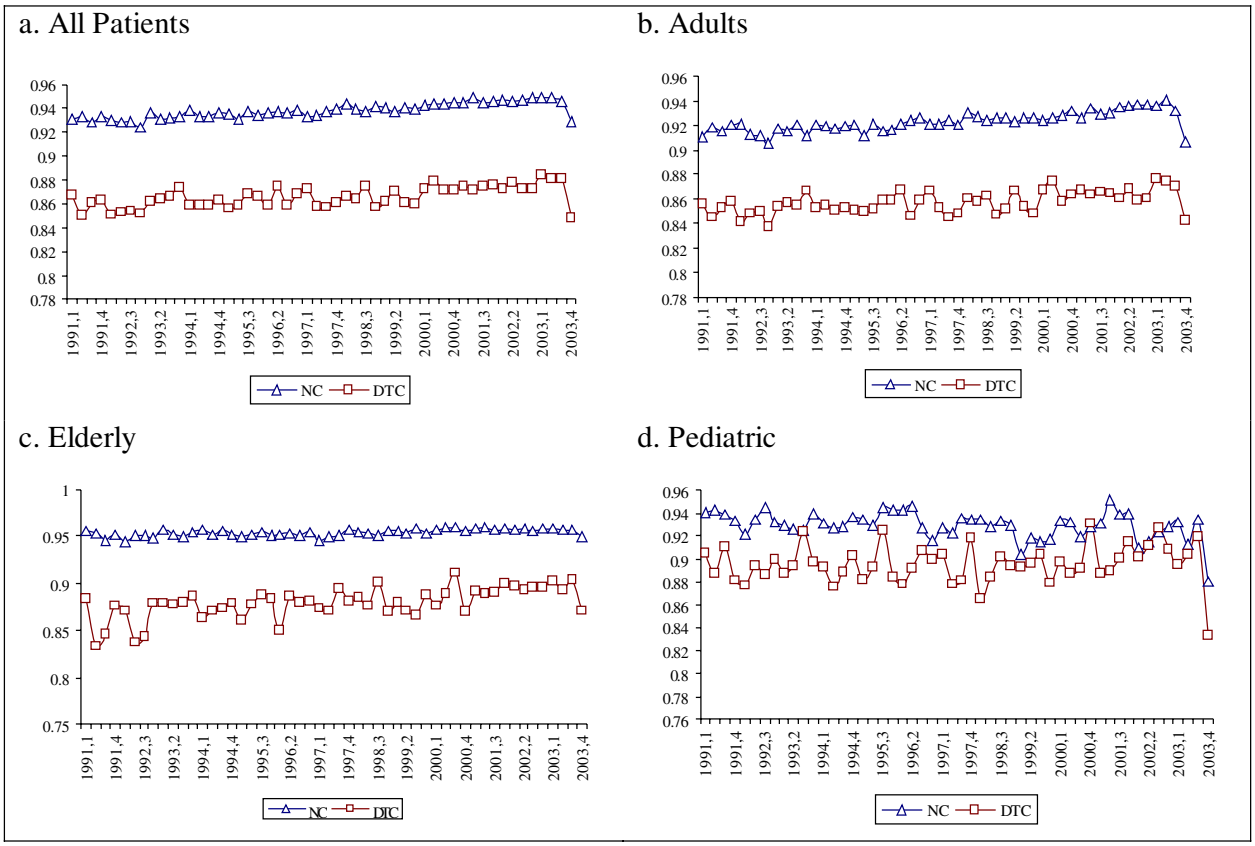

Fig 4. Mean ICISS level of DTC and NC patients (1991-2003).

less-than-1-year variable indicated that centers with less than 1 year experience had a higher mortality rate than more established centers. The results for the remaining time variables, however, were not consistent. Although the 2 to 3 years variable again had a significant coefficient, the others do not.

DISCUSSION

Trends. This trend analysis of an established state trauma system demonstrates areas of dramatic change as well as evolving challenges to future function. Many of these trends are unique to specific patient age groups. Trauma admissions increased for ELD (relative and absolute), decreased for PEDS (relative and absolute), and were unchanged for ADLT (absolute). Unlike PEDS and ELD, ADLT trauma hospitalizations did not exhibit a seasonal pattern. Trauma hospitalizations for the elderly peaked in winter, whereas those of children peaked in summer. The influx of elderly into the state during the late fall and winter months probably explains the former pattern. Furthermore, the fourth quarter, which is associated with holidays during which travel is common, is associated with an increase in traffic accidents.

The overall proportion of trauma cases treated at DTCs increased over time. Of interest is the decreased percentage of cases treated at DTCs versus NCs during the last year of the analysis. The decrease is only in relative terms; because the absolute number of trauma patients treated in DTCs increased by 0.79% from 2002 to 2003, whereas trauma patients treated in NCs increased by 12.8%. The proportion of severely injured victims treated at DTCs increased by 10% compared to 87% at NCs. This relative decline at DTCs may reflect a temporary fluctuation but could also indicate that some DTCs in the system had reached or exceeded their capacity during the last year of the analysis.

The mean severity level of trauma victims transported to DTCs increased for all age groups. The difference in the mean level of severity between DTC and NC patients was significant ($\alpha = 0.05$) for all age groups. The consistency in NCs severity averages may reflect the shunting effect of trauma alert criteria and paramedic triage decisions, such that patients transported to NCs were determined to be less severely injured and, therefore, were a somewhat more homogeneous population. The trends indicate a greater non-adjusted mortality

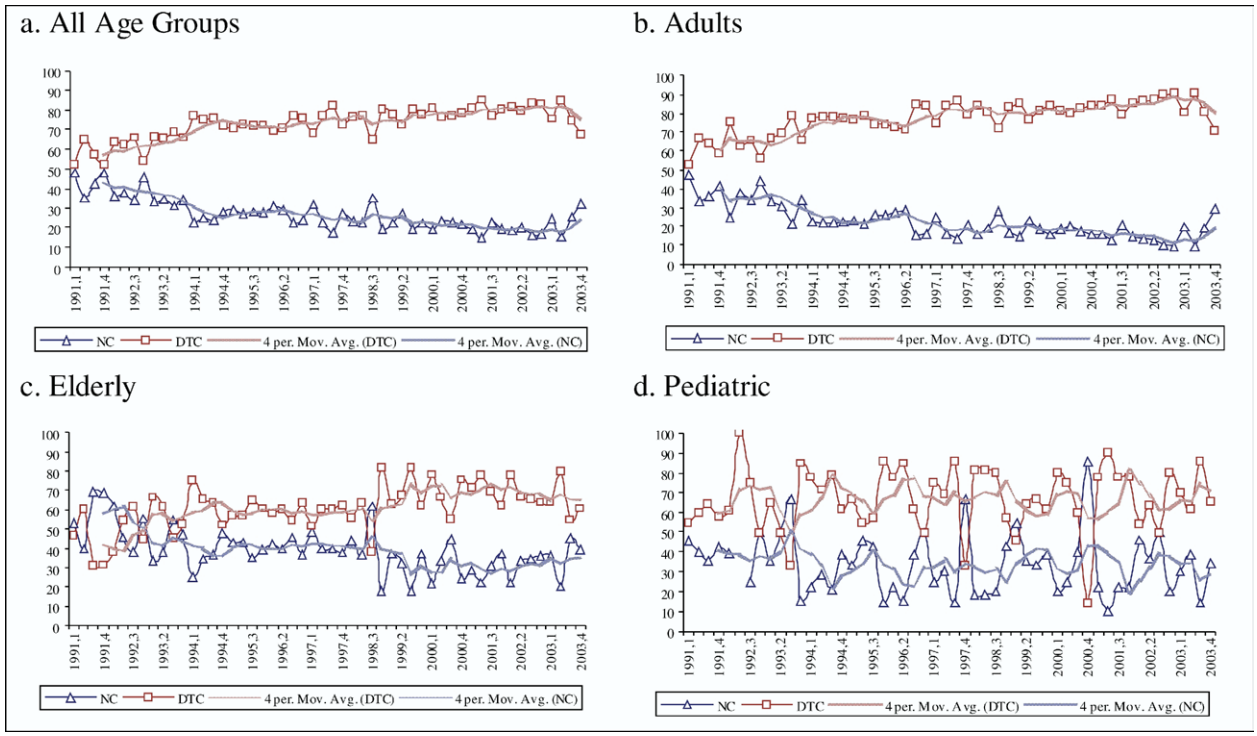

Fig 5. Percentage distribution of the most severely injured patients (ICISS ≤0.25) between DTC and NC (1991-2003).

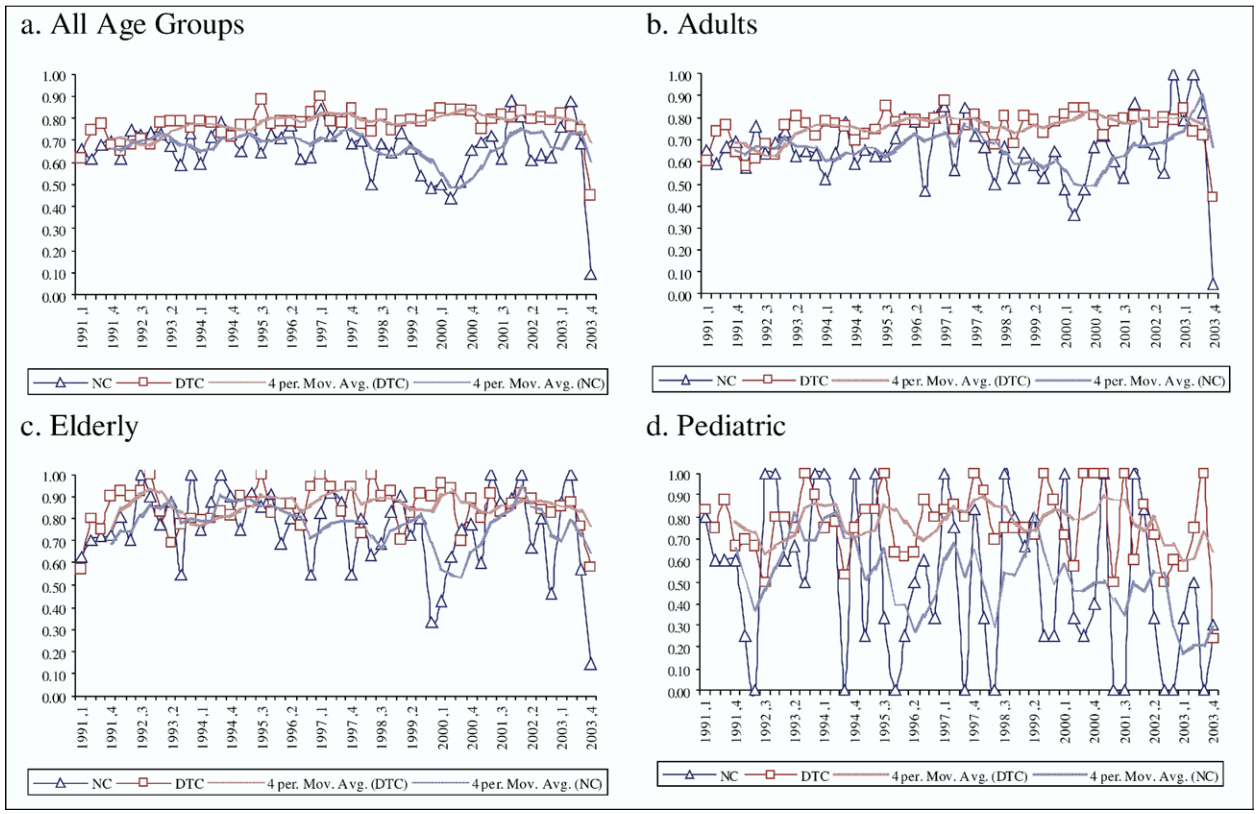

Fig 6. Mortality of severely injured (ICISS ≤0.25) trauma patients.

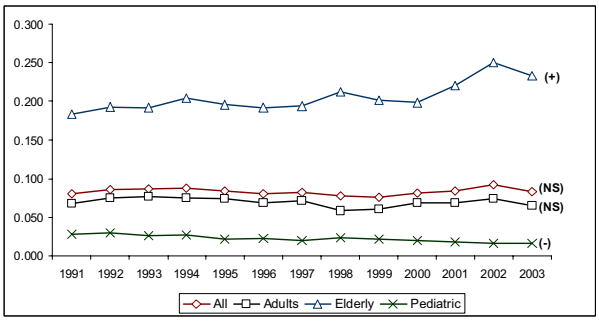

Fig 7. Mortality rate per 1,000 population.

rate for trauma victims treated at DTCs. Selection bias or risk adjustment in the triage decisions that determine whether a trauma victim will be transported to either a DTC or NC explain these results.[24,25] The existence of this bias results in patients transported to DTCs having a systematically greater probability of mortality. Despite this, the mortality rate per 1,000 people in the state actually declined for PEDS and ADLT, albeit not significantly for the latter. In contrast, the rate increased sharply for ELD during the same period.

It is noteworthy that the smallest increases in the rate of triage to DTCs took place for the elderly. From 1991 to 2001, the number of older drivers (over 70 years) who were killed in Florida traffic crashes increased by 70%. Florida led the nation in the number of older drivers killed in 2001 (The Road Information Program 2003).[26] Despite this, elderly trauma patients were less likely to be transported to a DTC, and the percent managed in DTCs remained constant over the 14-year study period in spite of an almost doubling of the number of trauma centers. Increased injury rate and fatalities per 1,000 population among Florida's elderly reflect both low trauma triage rates to DTCs and shortfalls in effective injury prevention. The finding that triage of the elderly patients to NTC occurred concomitantly with an increased injury mortality rate for this group suggests that under triage of elderly patients, a vulnerable and increasing population, is occurring, and this increased mortality is a shortcoming of the system. Stated differently, more effective triage of elderly trauma victims to appropriate treatment sites, ie, DTCs versus NTCs, could improve significantly the survival rate for this cohort. This finding, although descriptive, suggests a survival advantage for patients triaged to a DTC. This observation has been confirmed in a separate analysis of the Florida Trauma System.[27]

To further explore the differential between the elderly and the rest of the population, the trend in the 2 most frequent reasons for trauma-related hospitalization (in both DTC and NTC) were examined; these were fractures and internal injuries of the thorax, abdomen, and pelvis (Fig 8). The percentage of the elderly hospitalized for fractures is substantially larger compared to the rest of the population. On the other hand, the percentage of elderly hospitalized with internal injuries to the thorax, abdomen, and pelvis is significantly smaller. In both cases, the percentage of hospitalization due to fractures increased slightly over time. It is noteworthy that, in absolute terms, hospitalizations due to internal injuries to the thorax, abdomen, and pelvis increased for both populations. The largest increase was associated with the elderly; the annual average number of cases increased by 17% between the first (1991-1996) to the second (1997-2003) half of the study period. The overall population experienced an increase of only 4%.

The general downward trend in the number of pediatric trauma cases may reflect the different epidemiology of childhood injury. Because this trend analysis was restricted to emergency cases and those related to non-zero risk of mortality, it excluded a large proportion of children admitted as "non-emergency cases," or with diagnoses that are not associated with any risk of mortality.

Multivariate model. Improvements in performance with experience are referred to commonly as organizational experience or learning curves,[28-33] and have been identified in various industries, including medical institutions.[34,35] The shape of the learning curve, whether it represents a one time improvement or a stepwise process, may have important implications for regulations and policy implementation.

Our results define the existence of an important organizational learning curve for new DTCs, especially in care of injured ADLTs. The variables indicating elapse of 0 to 1, 1 to 2, 2 to 3, 3 to 4, and 4 to 5 years since DTC designation are associated with estimated odds-ratios of, respectively, 1.43, 1.66, 1.59, 1.28, and 1.09. The coefficients decline steadily after the first full year and become statistically insignificant by the fourth year after DTC designation. Stated differently, adult patients transported to centers with four years or more experience as a DTC have a lesser mortality rate after controlling for the influence of quality, distance, severity, patient demographics, and type of injury.

For the pediatric population, organizational experience as a DTC is also important. The results, however, indicate a shorter adjustment period. The reasons for this finding include epidemiologic factors associated with the types of injuries and demo-

Table. Logistic regression results

	Adults Aged 16 to 64 years	Elderly Aged 65 and over	Children Aged 0 to 15 years
Years elapsed	−0.050*(<.001)	−0.018(.088)	−0.085*(.038)
DTC 0 to 1 year	0.360*(.001)	0.102(.277)	0.784*(.017)
DTC 1 to 2 years	0.506*(<.001)	0.113(.213)	0.176 (.618)
DTC 2 to 3 years	0.463*(<.001)	0.151(.083)	0.665*(.027)
DTC 3 to 4 years	0.249*(.018)	−0.094(.352)	0.313 (.337)
DTC 4 to 5 years	0.084 (.455)	−0.007(.942)	−0.019 (.953)

DTC, designated trauma center.
*Significant at the α = .05 level. Values in parentheses are *P*-values

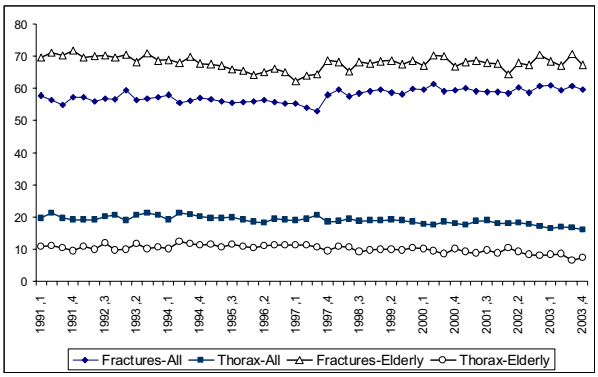

Fig 8. Percentage of trauma hospitalizations due to fractures or internal injuries of the thorax, abdomen, and pelvis.

graphic characteristics. The influence of organizational behavior was not significant for elderly patients. This surprising finding warrants additional research but is likely the result of epidemiologic characteristics concerning their injuries, consistently low proportion of triage to DTC, and demographic composition.

Because this analysis was based on administrative data, it suffers from the inherent restrictions that accompany using information collected for reasons other than research. For example, when examining the probability of mortality, the data do not allow controlling for the physiologic condition of trauma victims. Risk stratification using ICISS, however, does introduce the effect of physiologic derangement associated with the various injury diagnoses used to calculate survival risk ratios. Nonetheless, the results presented here should be of value to policy makers, hospital administrators, and providers at all levels in trauma systems in planning the future of the system.

The trauma system offers a number of advantages to the citizens of Florida and neighboring states. These include the opportunity for triage of severely injured patients to DTC that are organized for trauma care. The statewide triage rate for injured patients to DTC in 2003 was 38%. This number is lower than it should be but reflects an uneven geographic distribution of trauma centers. The effect of DTC availability on triage rates was shown when a new center was added recently to an underserved area. The statewide triage rate increased, soon after the opening of the DTC, to nearly 50%. In addition, trauma centers house specialty services such as burn care, spine injury and disease care, hand surgery, and comprehensive rehabilitation services that were scarce in Florida before implementation of the trauma system. Moreover, the trauma system is the "backbone" of medical response to disasters. This fact was amply demonstrated in 2004 when Florida was struck by 4 major hurricanes. The trauma system has several inherent disadvantages as well. The system is inherently unstable and vulnerable to changes in the health care economy. Moreover, there is no system to provide effectively incentives for hospitals to join the trauma system. Finally, the presence of a DTC in a community may lead to over-triage of less severely injured patients to the DTC leading to inadequate capacity in the DTC.

CONCLUSIONS

In Florida, the annual number of trauma victims increased among non-elderly adults and the elderly from 1991 to 2003. For the elderly, the upward trend is both absolute and relative to the size of the population. For children, trauma hospitalizations decreased both in absolute terms and as a percentage of the population. On average, adult patients admitted to more established DTCs had a lesser probability of mortality compared to trauma victims admitted to newly designated trauma institutions. To a lesser extent, organizational behavior is also important concerning pediatric trauma outcomes. This finding was not observed in the elderly populations. Reductions in the odds of mortality after trauma center designation are not immediate.

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REFERENCES

1. Kane G, Wheeler NC, Cook S, Englehardt R, Pavey B, Green K, et al. Impact of the Los Angeles County Trauma System on the survival of seriously injured patients. J Trauma 1992;32:576-83.
2. Hedges JR, Mullins RJ, Zimmer-Gembeck M, Helfand M, Southard P. Oregon Trauma System: change in initial admission site and post-admission transfer of injured patients. Acad Emerg Med 1994;1:218-26.
3. Mullins RJ, Veum-Stone J, Helfand M, Zimmer-Gembeck M, Hedges JR, Southard PA, et al. Outcome of hospitalized injured patients after institution of a trauma system in an urban area. JAMA 1994;271:1919-24.
4. Barquist E, Pizzutiello M, Tian L, Cox C, Bessey PQ. Effect of trauma system maturation on mortality rates in patients with blunt injuries in the Finger Lakes region of New York State. J Trauma 2000;49:63-70.
5. Mullins RJ, Veum-Stone J, Hedges JR, Zimmer-Gembeck MJ, Mann NC, Southard PA, et al. Influence of a statewide system on location of hospitalization and outcome of injured patients. J Trauma 1996;40:536-46.
6. Sampalis JS, Lavoie A, Boukas S, Tamim H, Nikolis A, Frechette P, et al. Trauma center designation: initial impact on trauma-related mortality. J Trauma 1995;39:232-9.
7. Rogers FB, Osler TM, Shackford SR, Martin F, Healey M, Pilcher D. Population-based study of hospital trauma care in a rural state without a formal trauma system. J Trauma 2001;50:409-14.
8. Mann NC, Cahn RM, Mullins RJ, Brand DM, Jurkovich GJ. Survival among injured geriatric patients during construction of a statewide trauma system. J Trauma 2001;50:1111-6.
9. Abernathy JH 3rd, McGwin G Jr, Acker JE 3rd, Rue LW 3rd. Impact of a voluntary trauma system on mortality, length of stay, and cost at a level I trauma center. Am Surg 2002;68:182-92.
10. Melton SM, McGwin G, Abernathy JH, MacLennan P, Cross JM, Rue LW. Motor vehicle crash-related mortality is associated with prehospital and hospital-based resource availability. J Trauma 2002;54:273-9.
11. Reilly JJ, Chin B, Berkowitz J, Weedon J, Avitable M. Use of a state-wide administrative database in assessing a regional trauma system: the New York City experience. J Am Coll Surg 2004;198:509-18.
12. Mullins RJ, Mann NC, Hedes JR, Worrall W, Jurkovich GJ. Preferential benefit of implementation of a statewide trauma system in one of two adjacent states. J Trauma 1998;44:609-17.
13. Nathens AB, Jurkovich GJ, Rivara FP, Maier RV. Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. J Trauma 2000;48:25-31.
14. O'Keefe GE, Jurkovich GJ, Copass M, Maier RV. Ten-year trend in survival and resource utilization at a Level I trauma center. Ann Surg 1999;229:409-15.
15. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma score and injury score. J Trauma 1987;27:370-8.
16. Osler T, Rutledge R, Deis J, Bedrick E. ICISS: an International Classification of Disease-9 based injury severity score. J Trauma 1996;41:380-8.
17. Rutledge R, Osler T. The ICD-9-based illness severity score: a new model that outperforms both DRG and APR-DRG as predictors of survival and resource utilization. J Trauma 1998;45:791-9.
18. Chow G. Tests of equality between sets of coefficients in two linear regressions. Econometrica 1960;28:591-605.
19. Scheetz LJ. Effectiveness of prehospital trauma triage guidelines for the identification of major trauma in elderly motor vehicle crash victims. J Emerg Nurs 2003;29:109-15.
20. Demetriades D, Sava J, Alo K, Newton E, Velmahos GC, Murray JA, Belzberg H, Asensio JA, Berne TV. Old age as a criterion for trauma team activation. J Trauma 2001;51:754-7.
21. McMahon DJ, Schwab CW, Kauder D. Comorbidity and the elderly trauma patient. World J Surg 1996;20:1113-20.
22. Phillips S, Rond PC III, Kelly SM, Swartz PD. The failure of triage criteria to identify geriatric patients with trauma: results from the Florida Trauma Triage Study. J Trauma 1996;40:278-83.
23. Pudelek B. Geriatric trauma: special needs for a special population. AACN Clin Issues 2002;13:61-72.
24. McClellan M, McNeil BJ, Newhouse JP. Does more intensive treatment of acute myocardial infarction in the elderly reduce mortality?: analysis using instrumental variables. JAMA 1994;272:859-66.
25. McConnell KJ, Newgard GD, Mullins RJ, Arthur M, Hedges JR. Mortality benefit of transfer to level I versus level II trauma centers for head-injured patients. Health Serv Res 2005;40:435-57.
26. The Road Information Program. Designing roadways to safely accommodate the increasing mobile older driver: a plan to allow older Americans to maintain their independence. Washington DC; July 2003. Available at http://www.tripnet.org/OlderDrivers2003Study.PDF
27. Flint L, Orban B, Durham R, Wolfson J, Pracht E, Kallenborn C, et al. A comprehensive assessment of the Florida Trauma System, 2005. Available from: URL: http://www.doh.state.fl.us/demo/Trauma/PDFs/Final_Trauma_Assessment_Report.pdf
28. Alchian A. Reliability of progress curves in airframe production. Econometrica 1963;31:679-93.
29. Rapping L. Learning and World War II production function. Rev Econ Stat 1965;47:81-6.
30. Joskow PL, Rozanski GA. The effects of learning by doing on nuclear plant operating reliability. Rev Econ Stat 1979;61:161-8.
31. Joskow PL, Rose NL. The effects of technological change, experience, and environmental regulation on the construction cost of coal-burning generating units. Rand J Econ 1985;16:1-27.
32. Yelle L. The learning curve: historical review and comprehensive survey. Decision Sci 1979;10:302-28.
33. Argote L, Epple D. Learning curves in manufacturing. Science 1990;247:920-4.
34. Laffel GL, Barnett AI, Finkelstein S, Kaye MP. The relation between experience and outcome in heart transplantation. N Engl J Med 1992;327:1220-5.
35. Hannan EL, Racz M, Ryan TJ, McCallister BD, Johnson LW, Arani DT, et al. Coronary angioplasty volume-outcome relationships for hospitals and cardiologists. JAMA 1997;7:892-8.