Variability in Current Trauma Systems and Outcomes

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Abstract

Background: Complication rates may be indicative of trauma center (TC) performance. The complication rates between Level 1 and 2 TCs at the national level are unknown. Our study aimed to determine the relationship between American College of Surgeons (ACS)-verified and state-designated TCs and complications. Study Design and Methods: This was a cohort review of the National Sample Program (NSP) from the National Trauma Data Bank, the world’s largest validated trauma database. TCs were categorized by ACS or state Level 1 or 2. TCs not categorized as Level 1 or 2 were excluded. All 22 complications provided by the NSP were analyzed. Chi-square analysis was used with statistical significance defined as \( P < 0.05 \). Results: Of the 94 TCs in the NSP, 67 had ACS and 80 had state designations of Level 1 or 2. There were 38 ACS Level 1 TCs treating 87,340 patients and 29 ACS Level 2 TCs treating 35,763. There were 45 state Level 1 TCs treating 106,640 and 35 state Level 2 TCs treating 43,290. ACS Level 1 TCs had significantly higher complications compared to ACS Level 2 TCs (13.5% [11,776/87,340] vs. 10.1% [3,606/35,763], \( P < 0.0001 \)). In addition, state Level 1 TCs had significantly more complications compared to state Level 2 TCs (4.4% [4,681/106,640] vs. 1.6% [673/43,290], \( P < 0.0001 \)). Conclusion: Both ACS and state Level 2 TCs had significantly lower complication rates than ACS and state Level 1 TCs. Further investigations should look for the source and impact of this difference.

Keywords: Complication rates, National Trauma Data Bank, patient functionality, trauma center performance, trauma center variability

Introduction

Complications arising in trauma patients can have an impact on the patient as well as the health-care system, including effects on morbidity, health-related quality of life (HRQoL), length of stay, and financial costs. Considering this, the American College of Surgeons Committee on Trauma (ACS-COT) verification and state designation is influential in that it establishes a standard of care and distinction among trauma centers (TCs). These designations require a process of review of the TC and typically evaluate resources, volume, and educational commitment. The major difference between Levels 1 and 2 is that Level 1 TCs must include teaching and research efforts. The implementation of trauma systems as well as ACS verification and state designation has been shown to improve outcomes after traumatic injury.\(^1\) The variability of complication rates between Level 1 and 2 TCs is unknown; however, the clinical outcome difference between Level 1 and Level 2 statuses is often debated.

When evaluating complication rates, it is important to assess the corresponding mortality rates as this can reveal important information on TC performance, such as whether the TC had higher survival with complications. There is some evidence that Level 1 TCs have reduced mortality as compared to Level 2 centers. For instance, one study that investigated the effect of ACS TC verification on outcomes in patients with severe injuries found that Level 1 TCs have reduced mortality rates.\(^2\) Another study evaluated the association between various components that make up a trauma system and outcomes and determined that Level 1 TCs were associated with a reduction in risk-adjusted mortality compared with...
lower level centers. Alternatively, other studies have shown that Level 1 and Level 2 TCs perform similarly with regard to mortality. For example, a study that examined statewide outcomes and resource use in Level 1 and 2 TCs for patients with major injuries found that case fatality was similar in Level 1 and Level 2 TCs. Similarly, a study that assessed whether TC level designation (Level 1 versus Level 2) affects mortality rate for adult patients with blunt splenic injuries determined that the mortality rate for all patients was similar in Level 1 and Level 2 trauma centers.

While there is extensive evidence on the mortality comparison between Level 1 and Level 2 TCs, there is very little evidence on the relationship between a wide array of complications and Level 1 versus Level 2 TCs with no injury exclusions, in a national sample. The few studies that have evaluated complications have found conflicting results. One study examined a Canadian trauma system for trauma outcomes, including complications, in adults who required urgent surgical care and found that complications were lower in Level 2–4 centers than in Level 1 centers. Another study analyzed the impact of TC designation in the outcomes of only severely brain-injured patients and determined that Level 2 centers are not inferior to Level 1 centers in terms of complications. Further, one analysis that sought to determine if there was a difference in trauma victims in Ohio, taken to Level 1 versus Level 2 TCs, found that Level 1 centers had more complications. Similarly, another study looking at Pennsylvania TCs compared complications between Level 1 and Level 2 centers and also found that Level 1 centers had more complications, specifically, 35% higher odds of complications.

With this limited and conflicting evidence on the effect of TC level on complications, there is a critical need to evaluate this relationship further because complications are a substantial element in the overall outcome of patients. An increase in complications in either TC level may result in a decrease in HRQoL and could provide financial strain on the health-care system nationwide. An elevated complication rate needs to be evaluated to initiate quality assessment and improve patient safety. Our study aimed to determine the relationship between ACS-COT verification and state designation status for TCs and complications in a national sample with no injury exclusions. In the light of the complication findings, we aimed to critically analyze factors contributing to the higher complication rates in patients with both blunt and penetrating injuries in order to encourage better performance, safer training, and promote patient safety.

**Study Design and Methods**

A retrospective United States cohort review was done using the National Sample Program (NSP) from the National Trauma Data Bank (NTDB) – the largest validated trauma database in the nation – for the year 2013. This is the most current year of which all data were available at the inception of this study. Access to patient data was given by the ACS-COT. The NTDB is currently the largest registry of trauma patient data, containing voluntarily contributed data from over 900 TCs which undergo enhanced data validation screening. The NSP is a traumatic injury database from a nationally representative sample of trauma hospitals, which collects a wide variety of diagnostic and clinical indicators complementary to the NTDB. The NSP allows for reliability in computing national estimates with high confidence. All identifying information has been concealed to ensure confidentiality while including demographics, injury information, and outcomes to allow accurate analyses. This study received an exempt determination from our Institutional Review Board.

This study included 94 TCs with over 172,000 patients. Centers included community, university, and nonteaching hospitals with state designation and/or ACS level verification. TCs were categorized based on ACS-COT and state level. TCs that were both ACS and state-designated were reported in both ACS categories and state categories. TCs not categorized as ACS or state Level 1 or 2 were excluded. All 22 complications listed and provided by the NSP were directly presented, compared, and analyzed. Both blunt and penetrating injuries were examined. The Injury Severity Score (ISS) and the Revised Trauma Score (RTS) were collected and compared between different groups. TC volume (TCV) and adjusted mortality were compared between TCs to further adjust for complication rates. Adjusted mortality was determined by Trauma ISS methodology using observed over expected mortality (O/E) ratios, derived from the ISS and RTS. Observed deaths represent the actual number of patients who died, whereas expected deaths represent the sum of predicted risk of deaths of each institution’s trauma patients. SPSS Statistics version 20 (IBM Corp. Armonk, NY) was the software used for statistical analyses. Chi-squared analysis was used with a statistical significance defined as \( P < 0.05 \). This study was reported according to the STROBE guidelines.

**Results**

Overall, the 2013 NSP provided 94 TCs with 172,387 total trauma patients who had blunt or penetrating injuries. Of the trauma patients analyzed, 63.6% were male, 70.6% were white, and the average age was 41 years. Sixty-seven TCs in the 2013 NSP were designated as ACS Level 1 or 2 (38 ACS Level 1 TCs and 29 ACS Level 2 TCs) treating 123,103 patients. Of which, 87,340 were treated at an ACS Level 1 TC and 35,763 were treated at an ACS Level 2 TC. Moreover, 80 TCs in the 2013 NSP were designated as state Level 1 or 2 (45 state Level 1 TCs and 35 state Level 2 TCs) treating 149,930 patients. Of which, 106,640 were treated at a state Level 1 TC and 43,290 were treated at a state Level 2 TC. Overall the Level 1s have on average significantly higher TCV than Level 2 centers. Average annual TCV in ACS Level 1 TCs was significantly higher than ACS Level 2 TCs (2298 vs. 1,233, \( P < 0.05 \)). Similarly, average TCV in state Level 1 TCs was significantly higher
than state Level 2 (2369 vs. 1236, \(P < 0.05\)). When stratified by teaching status, the majority of Level 1 TCs were university and the majority of Level 2 TCs were community teaching TCs. In total, 74% of ACS and 76% of state Level 1 TCs were university TCs. By comparison, 66% of ACS and 57% of state Level 2 TCs were community teaching TCs.

Mean ISS was similar between ACS Level 1 versus Level 2 TCs (10.10 vs. 9.30, \(P > 0.05\)) and state Level 1 versus Level 2 TCs (9.60 vs. 9.20, \(P > 0.05\)). RTSSs were also similar between ACS Level 1 versus Level 2 TCs (7.50 vs. 7.56, \(P > 0.05\)) and state Level 1 versus Level 2 TCs (7.49 vs. 7.58, \(P > 0.05\)). A lower RTS would imply worse vital signs on admission. When adjusted using O/E mortality, ACS Level 1 TCs have a similar O/E compared to ACS Level 2 TCs (0.73 vs. 0.75, \(P = 0.36\)). State Level 1 TCs also have a similar O/E compared to state Level 2 TCs (0.70 vs. 0.74, \(P = 0.08\)).

Overall, ACS Level 1 TCs had significantly higher complications compared to ACS Level 2 TCs (13.5% [11,776/87,340] vs. 10.1% [3,606/35,290], \(P < 0.0001\)). In addition, state Level 1 TCs had significantly more total complications compared to state Level 2 TCs (4.4% [4,681/106,640] vs. 1.6% [673/43,290], \(P < 0.0001\)) [Figures 1 and 2]. Looking individually at the complications, the ACS Level 1 centers had significantly more complications in 15 of 22 areas, whereas state Level 1 centers had significantly more complications in 19 of 22 areas. There were 12 types of complications that both ACS Level 1 and state Level 1 centers had significantly more complications than their Level 2 counterparts. This list includes acute respiratory distress syndrome ACS 1 versus 2 (1.12% vs. 0.46%, \(P < 0.0002\)) and State 1 versus 2 (1.18% vs. 0.25%, \(P < 0.0005\)), unplanned intubation ACS (0.86% vs. 0.55%, \(P < 0.0001\)) and state (0.39% vs. 0.22%, \(P < 0.0006\)), unplanned return to the operation room (OR) ACS (0.32% vs. 0.24%, \(P = 0.03\)) and state (0.22% vs. 0.10%, \(P < 0.0004\)), unplanned return to the intensive care unit ACS (0.65% vs. 0.30%, \(P < 0.0005\)) and state (0.37% vs. 0.22%, \(P < 0.0003\)), cardiac arrest with resuscitative efforts ACS (0.71% vs. 0.61%, \(P = 0.04\)) and state (0.73% vs. 0.33%, \(P < 0.0009\)), severe sepsis ACS (0.38% vs. 0.26%, \(P = 0.002\)) and state (0.43% vs. 0.24%, \(P = 0.03\)) and state (0.22% vs. 0.10%, \(P < 0.0004\)), osteomyelitis.

### Table 1: Complications at American College of Surgeons-verified trauma centers

| Complications                  | Total | ACS Level I | ACS Level II | \(P\)   |
|--------------------------------|-------|-------------|--------------|---------|
| **Higher at Level 1**          |       |             |              |         |
| DVT                            | 980   | 260         | <0.0004      |         |
| Percentage                     | 1.12  | 0.73        |              |         |
| PNA                            | 2294  | 770         | <0.0002      |         |
| Percentage                     | 2.63  | 2.15        |              |         |
| DSSI                           | 140   | 19          | <0.0002      |         |
| Percentage                     | 0.16  | 0.05        |              |         |
| Severe sepsis                  | 332   | 94          | 0.002        |         |
| Percentage                     | 0.38  | 0.26        |              |         |
| SSSI                           | 180   | 49          | 0.01         |         |
| Percentage                     | 0.21  | 0.14        |              |         |
| OSSI                           | 203   | 61          | 0.03         |         |
| Percentage                     | 0.23  | 0.17        |              |         |
| DU                             | 505   | 135         | <0.0001      |         |
| Percentage                     | 0.58  | 0.38        |              |         |
| UTI                            | 1525  | 459         | <0.0008      |         |
| Percentage                     | 1.75  | 1.28        |              |         |
| ARDS                           | 981   | 166         | <0.0002      |         |
| Percentage                     | 1.12  | 0.46        |              |         |
| Unplanned intubation           | 754   | 196         | <0.0001      |         |
| Percentage                     | 0.86  | 0.55        |              |         |
| Unplanned return to the OR     | 279   | 87          | 0.03         |         |
| Percentage                     | 0.32  | 0.24        |              |         |
| Unplanned return to the ICU    | 564   | 106         | <0.0005      |         |
| Percentage                     | 0.65  | 0.30        |              |         |
| Cardiac arrest with resuscitative efforts | 621 | 217 | 0.04 |         |
| CRBSI                          | 116   | 14          | <0.0004      |         |
| Percentage                     | 0.13  | 0.04        |              |         |
| Osteomyelitis                  | 28    | 4           | 0.04         |         |
| Percentage                     | 0.03  | 0.01        |              |         |
| **Higher at Level 2**          |       |             |              |         |
| AKI                            | 525   | 270         | 0.002        |         |
| Percentage                     | 0.60  | 0.75        |              |         |
| MI                             | 217   | 118         | 0.01         |         |
| Percentage                     | 0.25  | 0.33        |              |         |
| DVT: Deep vein thrombosis, PNA: Pneumonia, DSSI: Deep surgical site infection, SSSI: Superficial surgical site infection, OSSI: Organ/space surgical site infection, DU: Decubitus ulcer, UTI: Urinary tract infection, ARDS: Acute respiratory distress syndrome, CA: Cardiac arrest, CRBSI: Catheter-related bloodstream infection, AKI: Acute kidney injury, MI: Myocardial infarction, ICU: Intensive care unit, ACS: American College of Surgeons, OR: Operation room

\(P = 0.61\), deep SSI ACS (0.16% vs. 0.05%, \(P < 0.0002\)) and state (0.20% vs. 0.13%, \(P = 0.17\)), and superficial SSI (0.21% vs. 0.14%, \(P = 0.01\)) and state (0.20% vs. 0.17%, \(P = 0.21\)), as shown in Tables 1 and 3 and Figure 3.

Two complication rates were higher in ACS Level 2 TCs than ACS Level 1 but conversely higher in state Level 1 TCs than Level 2. This includes acute kidney injury ACS 1 versus 2 (0.60% vs. 0.75%, \(P = 0.002\)) and State 1 versus 2 (0.82% vs. 0.36%, \(P < 0.0007\)) and myocardial infarction ACS 1 versus 2.
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**Table 2: Complications at state designated trauma centers**

| Complications                     | Total | State Level I | State Level II | P   |
|-----------------------------------|-------|---------------|----------------|-----|
| **Higher at Level 1**             |       |               |                |     |
| PE                                | Total # | 128           | 22             | 0.001 |
|                                   | Percentage | 0.34           | 0.25           |     |
| PNA                               | Total # | 748           | 158            | <0.0004 |
|                                   | Percentage | 1.97           | 1.82           |     |
| Severe sepsis                     | Total # | 165           | 3              | <0.0001 |
|                                   | Percentage | 0.43           | 0.03           |     |
| OSSI                              | Total # | 53            | 7              | 0.007 |
|                                   | Percentage | 0.14           | 0.08           |     |
| DU                                | Total # | 162           | 25             | <0.0003 |
|                                   | Percentage | 0.43           | 0.29           |     |
| ECS                               | Total # | 129           | 19             | <0.0002 |
|                                   | Percentage | 0.34           | 0.22           |     |
| UTI                               | Total # | 794           | 90             | <0.0002 |
|                                   | Percentage | 2.09           | 1.03           |     |
| ARDS                              | Total # | 449           | 22             | <0.0005 |
|                                   | Percentage | 1.18           | 0.25           |     |
| Unplanned intubation              | Total # | 148           | 19             | <0.0006 |
|                                   | Percentage | 0.39           | 0.22           |     |
| Unplanned return to the OR        | Total # | 85            | 9              | <0.0004 |
|                                   | Percentage | 0.22           | 0.10           |     |
| Unplanned return to the ICU       | Total # | 139           | 19             | <0.0003 |
|                                   | Percentage | 0.37           | 0.22           |     |
| Cardiac arrest with resuscitative efforts | Total # | 276           | 29             | <0.0009 |
|                                   | Percentage | 0.73           | 0.33           |     |
| AKI                               | Total # | 311           | 31             | <0.0007 |
|                                   | Percentage | 0.82           | 0.36           |     |
| CRBSI                             | Total # | 90            | 11             | <0.0007 |
|                                   | Percentage | 0.24           | 0.13           |     |
| Drug or alcohol withdrawal syndrome | Total # | 257           | 25             | <0.0001 |
|                                   | Percentage | 0.68           | 0.29           |     |
| Graft/prosthesis/flap failure     | Total # | 20            | 2              | 0.04  |
|                                   | Percentage | 0.05           | 0.02           |     |
| MI                                | Total # | 103           | 13             | <0.0003 |
|                                   | Percentage | 0.27           | 0.15           |     |
| Osteomyelitis                     | Total # | 15            | 0              | 0.01  |
|                                   | Percentage | 0.04           | 0.00           |     |
| Stroke/CVA                        | Total # | 192           | 20             | <0.0004 |
|                                   | Percentage | 0.51           | 0.23           |     |

**Table 3: Complications similar between ACS/ State Level 1 and Level 2 trauma centers**

| Complications                     | Total | State Level I | State Level II | P   |
|-----------------------------------|-------|---------------|----------------|-----|
| **ACS Level 1 and 2 TCs**         |       |               |                |     |
| PE                                | Total # | 284           | 92             | 0.05 |
|                                   | Percentage | 0.33           | 0.26           |     |
| ECS                               | Total # | 276           | 96             | 0.27 |
|                                   | Percentage | 0.32           | 0.27           |     |
| Drug or alcohol withdrawal syndrome | Total # | 724           | 290            | 0.75 |
|                                   | Percentage | 0.83           | 0.81           |     |
| Graft/prosthesis/flap failure     | Total # | 38            | 8              | 0.08 |
|                                   | Percentage | 0.04           | 0.02           |     |
| Stroke/CVA                        | Total # | 210           | 95             | 0.42 |
|                                   | Percentage | 0.24           | 0.27           |     |
| **Similar between state Levels 1 and 2** |       |               |                |     |
| DVT                               | Total # | 315           | 121            | 0.61 |
|                                   | Percentage | 0.83           | 1.39           |     |
| DSSI                              | Total # | 43            | 11             | 0.17 |
|                                   | Percentage | 0.11           | 0.13           |     |
| SSSI                              | Total # | 59            | 17             | 0.21 |
|                                   | Percentage | 0.16           | 0.20           |     |

PE: Pulmonary embolism, ECS: Extremity compartment syndrome, DVT: Deep vein thrombosis, DSSI: Deep surgical site infection, SSSI: Superficial surgical site infection, TCs: Trauma centers, ACS: American College of Surgeons, CVA: Cerebrovascular accident

2 (0.25% vs. 0.33%, P = 0.01) and State 1 versus 2 (0.27% vs. 0.15%, P < 0.0003), as shown in Tables 1 and 2.

**Discussion**

Complications arising from traumatic injury are serious and can result in critical consequences. In our study, ACS and state Level 1 TCs had significantly higher complications compared to ACS and state Level 2 TCs. While many might expect Level 2 TCs to have more complications than Level 1, this is not the case. Some might surmise that Level I TCs might take care of sicker and more severely injured patients, although our study analysis showed that average ISS and RTS were similar between Level 1 and 2 TCs. With similar injury severity and RTS, Level 1 TCs might be expected to perform better than Level 2 because of their access to more resources and more advanced education and training capabilities. Another concept of higher complication rates is that of “failure to rescue” (FTR). In recent years, FTR has become a quality metric for surgical care at TCs as defined by the Agency for Healthcare Research and Quality, and these too can be variable depending on institutional resources. There are other possible reasons to explain the higher complication rate in Level 1 TCs; nevertheless, it does not imply there should not be steps implemented to reduce the complications. We seek to critically analyze factors contributing to the higher complication rate at Level I TCs in order to encourage better performance, safer training, and promote better outcomes.

Similar to the present study, Cudnik et al. sought to determine whether there was a difference in patient outcome in trauma victims taken to Level 1 versus Level 2 TCs in Ohio. In their study, they found that patients taken to Level 1 centers had more complications. Furthermore, Glance et al. compared...
Therefore, while there is conflicting evidence on the relationship between TC level and complication rates, there is some evidence which suggests that Level 1 TCs have higher complication rates.

When analyzing complications against TCV in our study, both ACS and state Level 1 TCs have on average significantly higher volume than Level 2 centers. ACS and state Level 1 TCs both have about 2300 trauma patients annually, whereas ACS and state Level 2 TCs both have about 1200 trauma patients annually. The higher volume in Level 1 centers may contribute to the higher complication rates because higher volume, as some studies have demonstrated,[11-13] may be associated with worse outcomes. This is because, with high volume, there could be over demand of resources. Furthermore, in our study, ACS Level 1 and 2 and state Level 1 and 2 TCs performed similarly on O/E mortality.

There are various other characteristics of Level 1 TCs that may have contributed to the higher number of complications. This includes that Level 1 TCs may have more resources as compared to Level 2 centers. Access to additional resources possibly entails more monitoring of patients and perhaps better reporting of complications. Level 1 TCs may have more sophisticated performance improvement programs, which means that Level 1 centers are more likely to report complications. While Level 2 TCs could have had the same, or more, complications than Level 1 centers, they might not have as much reporting and thus seem to have lower complication rates.

Further, a component of obtaining Level 1 verification is teaching status. This suggests that the majority of Level 1 TCs have residency teaching programs. In our study, when stratified by teaching status, the majority of Level 1 TCs were university and the majority of Level 2 TCs were community teaching TCs. Residency training programs may have contributed to the higher rate of complications at Level 1 TCs because with teaching and training comes the risk of medical error and learning curves which might increase exposure to complications. Thus, the additional complications at Level 1 TCs may be the result of learning by resident doctors. This raises a potential concern about the educational and training process at university hospitals and should be taken into consideration towards improving the training process and patient safety.

Alternatively, a phenomenon known as the Will Rogers phenomenon may shed light on the higher incidence of complications in Level 1 TCs. The Will Rogers phenomenon is a term used to describe improvements in stage-specific cancer prognosis as a result of changing the criteria for assigning patients to the various stages of a disease.[14] Of note, this improvement in prognosis is not a change in outcome of individual patients but the trend of improvement by better classifications.[15] This phenomenon illustrates that the advanced detection of complications at Level 1 TCs may give the illusion that patients have more complications. Thus, Level 1 TCs receive more patients, diagnose more patients, but with increased diagnosis of complications likely due to the ability to detect more complications. In addition, in recent years, the concept of “FTR,” and the general consensus is that Level 1 TCs have an increased ability to diagnose and save patients.[10,16,17] The fact that Level 1 TCs save more patients might contribute to higher complication reporting because complications might have resulted in mortality in patients at lower level centers and thus were not reported. The increased ability to diagnose and save patients, along with the Will Rogers phenomenon, may have resulted in higher complication reporting in Level 1 TCs.
Moreover, variation in clinical practices may be an alternative explanation of the difference in complication rates between Level 1 and 2 TCs. Level 2 TCs may have vastly different practices in providing diagnoses, preventive treatment, or therapy to patients than Level 1 centers. These differences may account for differences in complication rates. Shaﬁ et al. identiﬁed structural characteristics of TCs that affect patient outcomes and concluded that variations in patient outcomes across TCs are likely related to variations in clinical practices.[18] Furthermore, variations inprehospital triage and under/over triage by TCs and by regions may play a role in the differences between complication rates at Level 1 and 2 TCs.

The higher complication rates found in Level 1 TCs require quality improvement because it is not just the survivability that plays into a patient’s outcome but also functionality. This is true for multiple types of trauma complications and has been addressed by previous studies.[19,20] More survivals with disabilities produce increases in health-care costs.[21] Furthermore, it is debated whether surviving with complications and disabilities negatively affects quality of life including disability-adjusted life year (DALY) and the HRQoL.[19,20] Due to this, all TCs need to improve and reduce their complication rates.

In this study, there were some limitations. In the analysis of retrospective data from the NTDB, limitations arise that are common to the use of any large dataset. This includes potential misclassiﬁcation of injuries or complications, inconsistency, unrepresentativeness, and variability. Another widely held issue with the NTDB is voluntary reporting and missingness. Elkbuli et al. evaluated such data consistency concerns in the NTDB and concluded that although the NTDB is a useful tool, this level of missing data elements needs to be reduced for further research efforts.[22]

Further limitations include that this study involved only 1-year of NTDB data. Other limitations include the complexity and variation of the ACS and state veriﬁcation process, reporting bias by NTDB, and that there may be a systematic error in that Level 2 TCs have less registry personnel to collect data. Further, the limitation exists that the NTDB only includes inhospital data. It is possible that out-of-hospital factors, such as patient transport times, may inﬂuence complications.

One question that is left for future research to address is whether survivability and functional outcomes/HRQoL are attainable in top quality TCs. Future research efforts should highlight and further evaluate the relationship between TC veriﬁcation and the severity of complications. Future studies should also include evaluation of long-term outcomes such as the DALY and the Quality Of Life Index. Beyond this, multiple levels such as Levels 1, 2, 3, and 4 should be evaluated to determine the characteristics of TCs that produce the best outcomes and the impact of higher complications in Level 1 TCs. Future investigations should utilize other data sources, such as the Trauma Quality Improvement Program, to determine the effect of prehospital variables and confounders on complications. Future studies could also evaluate complication rates stratified by injury type, insurance status, or injury severity.

**Conclusion**

Both ACS and state Level 2 TCs had signiﬁcantly lower overall complication rates than ACS and state Level 1 TCs. Higher complications at Level 1 centers might be due to characteristics speciﬁc to Level 1 centers such as volume, performance improvement reporting, and teaching status. Future studies should further investigate factors related to increased complication rates at TCs apart from them taking care of more severely injured patients and perhaps improve the educational, teaching, and residency training performance. Detailed explanations are needed in order to better the performance of TCs and produce survivors who can be functional and effective members of society.

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**Conflicts of interest**

There are no conﬂicts of interest.

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