Influence of a province-wide trauma system on motor vehicle collision process of trauma care and mortality: a 10-year follow-up evaluation

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Accepted for publication
Jan. 12, 2011

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DOI: 10.1503/cjs.016710

Background: Mature trauma systems have evolved to respond to major injury-related morbidity and mortality. Studies of mature trauma systems have demonstrated improved survival, especially among seriously injured patients. From 1995 to 1998, a province-wide trauma system was implemented in the province of Nova Scotia. We measured the proportion of admissions to a tertiary level trauma centre and the proportion of in-hospital deaths among patients with major injuries as a result of a motor vehicle collisions (MVCs) before and 10 years after provincial trauma systems implementation.

Methods: We identified major trauma patients aged 16 years and older using external cause of injury codes pertaining to MVCs from population-based hospital claims and vital statistics data. Individuals who were admitted to hospital or died because of an MVC in 1993–1994 (preimplementation), were compared with those who were admitted to hospital or died in 2003–2005 (postimplementation).

Results: Postimplementation, there was a 9% increase in the number of seriously injured individuals with primary admission to tertiary care. This increase was statistically significant even after we adjusted for age, head injury and municipality of residence (relative risk [RR] 1.09, 95% confidence interval [CI] 1.04–1.14). The probability of dying while in hospital in the postimplementation period decreased by 29% (adjusted RR 0.57, 95% CI 0.32–1.03), although this difference was not statistically significant.

Conclusion: Individuals seriously injured in MVCs in Nova Scotia were more likely to be admitted to tertiary care after the implementation of a province-wide trauma system. There was a trend toward decreased mortality, but further research is warranted to confirm the survival benefit and delineate other contributing factors.

Contexte : Les systèmes de traumatologie parvenus à maturité ont évolué pour répondre à la morbidité et à la mortalité liées à un traumatisme majeur. Des études portant sur des systèmes de traumatologie à maturité ont démontré une amélioration de la survie, spécialement chez les victimes d'un traumatisme grave. De 1995 à 1998, la Nouvelle-Écosse a implanté un système panprovincial de traumatologie. Nous avons mesuré le pourcentage des admissions à un centre de traumatologie tertiaire et le pourcentage des décès survenus à l'hôpital chez les patients victimes d'un traumatisme majeur à la suite d'un accident de la circulation avant l'implantation de systèmes provinciaux de traumatologie et 10 ans après.

Méthodes : Nous avons trouvé des patients victimes d'un traumatisme majeur âgés de 16 ans et plus en utilisant les codes E relatifs aux accidents de la circulation tirés des données représentatives des demandes de paiement des hôpitaux et des statistiques démographiques. Nous avons comparé les personnes admises à l'hôpital ou qui sont décédées des suites d'un accident de la circulation en 1993–1994 (avant l'implantation) à celles qui ont été hospitalisées ou qui sont décédées en 2003–2005 (après l'implantation).

Résultats : Après l'implantation, le nombre de personnes victimes d'un traumatisme grave hospitalisées d'abord en soins tertiaires a augmenté de 9 %. Cette augmentation était statistiquement significative même après correction en fonction de l'âge, du traumatisme crânien et de la municipalité de résidence (risque relatif [RR] 1,09, intervalle de confiance [IC] à 95 %, 1,04–1,14). La probabilité de mourir à l'hôpital au cours de la période qui a suivi l'implantation a diminué de 29 % (RR corrigé 0,57, IC à 95 %, 0,32–1,03), même si cette différence n'était pas statistiquement significative.

Conclusion : Les personnes victimes d'un traumatisme grave à la suite d'un accident de la circulation en Nouvelle-Écosse étaient plus susceptibles d'être admises en soins

tertiaires après l'implantation d'un système panprovincial de traumatologie. On a constaté une tendance à la baisse de la mortalité, mais une recherche plus poussée s'impose afin de confirmer les bienfaits pour la survie et de définir d'autres facteurs qui y contribuent.

In the first 4 decades of life, injury is the leading cause of mortality and morbidity among North Americans.[1,2] Because of its increased frequency in younger age groups, injury is also the leading cause of potential years of life lost.[2] In response to high rates of injury-related mortality and morbidity, the delivery of prehospital and hospital trauma care has changed substantially in recent decades.[3] Mature trauma systems, incorporating designated trauma centres, emergency medical services, trauma destination protocols to bypass nontrauma hospitals, triage, training and coordination of in-hospital trauma care teams,[4] have emerged to "facilitate and coordinate multidisciplinary system response to severely injured patients from the time of injury through the provision of definitive care."[5–8]

Studies of trauma system effectiveness have reported improved patient survival, particularly among seriously injured patients, and reduced time to definitive institutional trauma care.[2,9–22] The importance of trauma systems concepts and the key role they play in obviating the enormous burden of injury in society has been demonstrated in numerous studies, reviews and editorials but is rarely a studied health care issue in Canada.[13,20–26]

Between 1995 and 1998, the province of Nova Scotia, Canada, underwent a government-mandated transition from a province without a trauma system to one incorporating most of the components of a modern trauma and emergency medical service (EMS) system. Under the direction of Emergency Health Services, a division of the provincial Department of Health, a single integrated ground ambulance service was formed with a central, province-wide computerized communication and dispatch centre. In addition, an air medical critical care transport program, predicated on rotor wing configuration, was also implemented. The sole adult (≥ 16 yr) provincial tertiary care institution was officially designated as a tertiary trauma centre, 8 regional hospitals were designated as district trauma centres and a "24/7" multidisciplinary trauma team with dedicated trauma team leaders was instituted at the tertiary adult trauma centre. The principal trauma system implementation milestones are outlined in Box 1. In the 2007 Trauma Association of Canada accreditation guidelines for trauma systems, these hospital designations would most accurately be termed "level I centre" for the tertiary care hospital and "level II or III centres" for the respective designated regional hospitals.[27] Twenty-seven other nondesignated hospitals existed during the study period but were not "trauma designated" and were bypassed by provincial trauma EMS protocol for major trauma destinations.

To assess trauma system effectiveness we were interested in whether patients seriously injured in motor vehicle collisions (MVCs) were more likely to be admitted to the tertiary trauma centre in the postimplementation period (as per provincial trauma policy) and whether they had improved in-patient survival. The 8 designated regional trauma hospitals continued to play a key role in the trauma system design for stabilization of major trauma patients and for surgical intervention in single-system trauma injuries within their resource capabilities. We studied trauma resulting from MVCs for several reasons. This mechanism of injury is responsible for a large number of unintentional injuries and deaths in Nova Scotia, in the rest of Canada[13,28] and elsewhere[9,29] and also challenges all of the essential elements of a trauma system, including individuals, institutions, resources and prehospital systems.[9,17] In a study by Nathens and colleagues,[2] the greatest effect of trauma system implementation in the United States was observed when MVC-related trauma mortality was considered separately from overall trauma mortality from all causes.

The present study was undertaken as a follow-up to further evaluate the effectiveness of Nova Scotia's province-wide trauma system in improving outcomes related to MVC injuries. An earlier study evaluated the effect of trauma system implementation on MVC in-patient mortality and care immediately after implementation of a trauma system and demonstrated that significantly more severely injured individuals were being successfully

Box 1. Implementation timeline of province-wide trauma system in Nova Scotia

1995–1996

- Establishment of Emergency Health Services agency by provincial Department of Health to oversee all aspects of emergency medical services
- Establishment of single province-wide ground ambulance service with medical oversight

1996

- Establishment of a single province-wide air medical transport system
- Establishment of a single province-wide communications and dispatch centre for ground/air ambulance dispatch, with enhanced 911 capabilities, computer aided dispatch and medical based prearrival instructions and evidenced-based emergency medical services treatment protocols

1997

- Establishment of multidisciplinary tertiary care trauma team with dedicated trauma team leaders and medical director of trauma at single adult (> 16 yr) tertiary care trauma care

1998

- Establishment of Provincial Trauma Program with accountability for treatment protocols, destination policies, injury prevention, trauma education and research with full trauma registry. Establishment of rooftop helipad at province's single level 1 adult trauma centre

brought to the province's single tertiary (level 1) trauma centre; however, in that study we were unable to demonstrate a mortality reduction for in-hospital major trauma patients in the tertiary centre.[30] Nathens and colleagues[9] suggested that at least 10 years of trauma system maturity is required to show a significant reduction (8%) in trauma mortality independent of other secular trends in injury control; thus, the present study was performed a decade after trauma system implementation.

Methods

This retrospective observational study compared residents of Nova Scotia who were admitted to hospital and survived or died as a result of an MVC before trauma system implementation (Jan. 1, 1993, to Dec. 31, 1994), to those who were admitted to hospital and survived or died 10 years after trauma system implementation (Jan. 1, 2003, to Dec. 31, 2005) in the province's sole tertiary (level 1) adult trauma centre. The methodology used in this study has been reported previously.[30] Briefly, patients were identified from population-based hospital claims and vital statistics data using external cause of injury codes (E-codes) pertaining to MVCs as defined within the International Classification of Diseases, 9th Revision Clinical Modification (ICD-9-CM)[31] and the International Classification of Diseases and Related Health Problems, 10th Revision, Canadian Enhancement (ICD-10-CA;[32] for a listing of E-codes for both ICD-9-CM and ICD-10-CA, see Appendix 1, Table S1, available at cma.ca/cjs). This mapping list of codes was verified by 2 of us (S.A.K. and J.M.T.). Individuals under the age of 16 years were excluded because the development of trauma care initiatives and protocols in the province's sole pediatric tertiary care institution were not concurrent with the overall provincial trauma system implementation.

Hospital claims data were organized into episodes of care such that admissions occurring within 1 day of each other (usually because of patient transfer) were considered to be part of the same episode of care. We obtained diagnostic codes and patient age from the first admission of the episode, and information on patient disposition at discharge was obtained from the final admission of the episode. Length of stay was calculated as the total number of days across all admissions of the episode.

We used a list of 5 "index" injuries as a proxy for injury severity,[12] since administrative data do not contain immediate measures of injury severity (such as the Injury Severity Score [ISS]). These index injuries are serious and require intensive prehospital and acute care management. The 5 index injuries were head injury, chest injury, spleen/liver injury, pelvic fractures and femur/tibia fractures. Their corresponding ICD-9-CM codes and ICD-10-CA codes are listed in Appendix 1, Table S2, available at cma.ca/cjs. The verification of matching codes was performed by 2 of us (S.A.K. and J.M.T.). Patients with 1 or more of these injury codes in any of the diagnostic code fields were considered to have an index injury, and those with 3 or more index injuries were considered to have multiple injuries. Although ISS were not available for this analysis, it is generally accepted that more severely injured patients, as described in our "index injuries," have improved outcomes when treated definitively at higher level or tertiary care trauma centres.[14,33] This paradigm is based on both trauma destination polices for EMS as well as higher level transfer of the major trauma patient after stabilization at the sending institutions before tertiary care transfer. These index injuries have been used in the past to evaluate trauma system effectiveness when injury severity data were not available.[11,12,30]

We considered only the first episode of care pertaining to an MVC in our analysis. Episodes of care with a primary admission to the provincial rehabilitation centre or with a diagnostic code indicating that the primary reason for the admission was rehabilitation were excluded.[11] Patients who were alive at the time of hospital discharge with a length of stay of less than 3 days[13] or with no[11] index injury were also excluded. All patients who died during their episode of care in hospital were included regardless of length of stay or type of injury.[13]

We obtained ethical approval to conduct this study from the Capital Health Research Ethics Board.

Statistical analysis

We compared the characteristics of patients admitted before and after trauma system implementation using χ^2 tests for categorical variables and the Wilcoxon rank sum test for continuous variables. Log binomial regression was used to estimate relative risk (RR) for the relation between primary admission to level 1 tertiary care and time period.[34,35] We performed a logistic regression analysis to evaluate the relation between in-hospital death and time period. For both outcomes, potential confounding variables tested for inclusion in adjusted models were age, sex, residence in the municipality where the level 1 trauma centre was located, number of index injuries, head injury and presence of 1 or more comorbidities (defined using the Charlson Comorbidity Index[36–38]). All potential confounding variables related to exposure (time period) or outcome (primary admission to tertiary care or in-hospital death) at $p < 0.20$ were entered into a starting multivariate model, and a backward stepwise selection approach was used. Only those variables whose removal changed the RR for time period by 5% or more were retained in the final model. We calculated mortality rates per 100 000 population (age ≥ 16 yr) from vital statistics data using Statistics Canada midyear population estimates for Nova Scotia, with the study years as denominator data. We used SAS Version 8.2 for all data preparation, descriptive statistics and regression models.

Results

A total of 3160 hospital admissions owing to MVC injuries were extracted from hospital claims databases for the 5 years of interest, resulting in 2989 episodes of care. After limiting the file to only the first hospital episode per patient and excluding rehabilitation episodes, there were 2808 records. There were 1002 unique episodes of care available for analysis after excluding patients with no index injuries or with a length of stay in hospital of fewer than 3 days (this was not applied to patients who died in hospital).

Table 1 shows patient and injury characteristics by implementation time period. Compared with patients who were admitted preimplementation, those admitted postimplementation were older, were more likely to have multiple index injuries but less likely to have the index head injury (although the head injuries were more severe and associated with greater mortality), and were more likely to have a primary admission to the tertiary trauma centre within 24 hours of injury. There was no significant unadjusted difference in hospital mortality for these major MVC trauma patients in the preimplementation versus postimplementation periods.

Table 2 shows the probability of primary admission to the provincial tertiary trauma centre in the postimplementation period and predictors thereof. After controlling for age, head injury and municipality of residence, individuals injured in an MVC in the postimplementation time period were 9% more likely to have a primary admission to tertiary care (RR 1.09, 95% CI 1.04–1.14) than individuals injured preimplementation.

Table 3 indicates that, although the results were not statistically significant, the probability of dying while in the tertiary care hospital following MVC trauma tended to decrease in the postimplementation period after controlling for age, multiple index injuries, head injury, comorbidities and primary admission to tertiary care. The in-hospital death rate in our study cohort indicates a decrease in the postimplementation time period (from 68.5 per 1000 episodes of care preimplementation to 48.5 per 1000 postimplementation) despite the fact that patients were older and had more multiple index injuries. The adjusted relative risk was 0.57 (95% CI 0.32–1.03), which can be interpreted as 0.57 probability of death postimplementation relative to preimplementation (Table 3). The overall MVC mortality (including deaths that occurred out of hospital and at the scene) in Nova Scotia for patients aged 16 years and older decreased by 31% (from 13.03 per 100 000 preimplementation to 8.95 per 100 000 postimplementation).

Table 1. Patient and injury-related characteristics by time period

Characteristic	Time; no. (%)* Preimplementation *n* = 467	Postimplementation *n* = 535	*p* value
Median age at admission, yr	34	42	0.020
Median length of stay, d	10	10	0.28
Sex			0.040
Male	321 (68.7)	335 (62.6)	
Female	146 (31.3)	200 (37.4)	
Municipality			0.63
TTC municipality	128 (27.4)	154 (28.8)	
Non-TTC municipality	339 (72.6)	381 (71.2)	
Vital status at discharge			0.18
Dead	32 (6.9)	26 (4.9)	
Alive	435 (93.2)	509 (95.1)	
No. of index injuries			< 0.001
≥ 3	17 (3.6)	57 (10.6)	
1–2	450 (96.4)	478 (89.4)	
Head injury			0.001
Yes	156 (33.4)	128 (23.9)	
No	311 (66.6)	407 (76.1)	
Comorbidity			0.26
Yes	32 (6.9)	47 (8.8)	
No	435 (93.1)	488 (91.2)	
Primary admission to level 1 tertiary care			< 0.001
Yes	249 (53.3)	385 (72.0)	
No	218 (46.7)	150 (28.0)	
Admitted to tertiary care within 24 hr			< 0.001
Yes	267 (57.2)	392 (73.3)	
No	200 (42.8)	143 (26.7)	

TTC = tertiary trauma centre.
*Unless indicated otherwise.

Discussion

The results of this study indicate that the number of seriously injured MVC patients in Nova Scotia admitted to the

Table 2. Primary admission to tertiary trauma centre by implementation period and other covariates

Variable	Unadjusted RR (95% CI)	Adjusted RR (95% CI)*
Time period		
Postimplementation	1.35 (1.22–1.49)	1.09 (1.04–1.14)
Preimplementation	1.00	1.00
No. of index injuries		
≥ 3	1.41 (1.27–1.56)	N/A
1–2	1.00	
Head injury		
Yes	1.32 (1.20–1.44)	1.08 (1.03–1.13)
No	1.00	1.00
Municipality		
TTC municipality	1.52 (1.40–1.66)	1.12 (1.07–1.18)
Non-TTC municipality	1.00	1.00
Vital status at discharge		
Dead	1.33 (1.17–1.51)	N/A
Alive	1.00	

CI = confidence interval; N/A = not applicable; RR = relative risk; TTC = tertiary trauma centre.
*Adjusted model includes implementation time period, head injury, municipality of residence and age (not shown).

only provincial adult tertiary trauma centre (level 1) in the postimplementation increased significantly. Although the increase was modest (9%), it was both statistically and clinically significant and indicates the success of appropriate (significantly injured patients) and effective system implementation (those severely injured patients being delivered to tertiary care). This was true for primary admission to tertiary care and for admission to tertiary care within 24 hours of injury. Mortality has been the most frequently used outcome measure in trauma system studies;[13–15] however, other measurements of process of care, such as an increase in the proportion of seriously injured patients brought to a higher level of care, are also indicative of mature system functioning. Similar results to ours were reported in another Canadian study by Sampalis and colleagues,[13] who found an increase in the proportion of patients with moderate and major trauma who were admitted to tertiary care after trauma system regionalization, although that study was primarily urban, whereas our study was panprovincial and included a considerable rural component. This effect of trauma system implementation, bringing larger numbers of seriously injured patients to highest level care, has also been noted in other studies.[10,12,14]

We found that the risk of dying in hospital following major MVC trauma decreased in the 10 years postimplementation, although this decrease was not statistically significant. The profile of patients admitted to the single tertiary trauma centre in Nova Scotia changed between the pre- and postimplementation periods. Patients admitted postimplementation were more likely to be older, have multiple injuries and have fewer but more severe head injuries. The overall population of Nova Scotia remained essentially stable (5% variance only) in both phases of this study. No change in the net hospital numbers or configuration in the province that may have impacted on referral patterns for major trauma occurred pre- or postimplementation.

Table 3. Mortality by implementation period and other covariates

Variable	Unadjusted RR (95% CI)	Adjusted RR (95% CI)*
Time period		
Postimplementation	0.69 (0.41–1.18)	0.57 (0.32–1.03)
Preimplementation	1.00	1.00
No. of index injuries		
≥ 3	2.87 (1.39–5.93)	1.70 (0.75–3.86)
1–2	1.00	1.00
Head injury		
Yes	5.86 (3.32–10.33)	5.62 (3.03–10.41)
No	1.00	1.00
Primary admission to level 1 TTC		
Yes	2.93	3.56 (1.65–7.66)
No	1.00 (1.47–5.87)	1.00
Comorbidity		
Yes	2.64 (1.28–5.45)	2.46 (1.09–5.59)
No	1.00	1.00

CI = confidence interval; RR = relative risk; TTC = tertiary trauma centre.
*Adjusted model includes implementation time period, multiple index injuries, head injury, primary admission to level 1 TTC, comorbidity and age (not shown).

Nathens and colleagues[9] have shown that trauma system maturity must occur over a 10-year period for a significant (8%) decrease in mortality to occur independent of secular trends in other injury prevention initiatives. Others have demonstrated a larger effect on mortality reduction of up to 25%, with severely injured patients being treated in trauma centres.[16,33,39] As the pre- and postimplementation periods in our study occurred about a decade apart, we expected a more robust demonstration of mortality reduction than that demonstrated (RR 0.57, 95% CI 0.32–1.03). Using the methodology of Kypri and colleagues[40] in which they note that the evaluation of effectiveness of important health policy changes (in our case, trauma system implementation) is often associated with insufficient data for full evaluation. They suggest methods of determining possible effect by adjusting population sizes.[40] If we increased our study population 10-fold and assumed our same pre- and postimplementation rates, the unadjusted RR would have been 0.71 (95% CI 0.61–0.83), rendering our statistical conclusion significant.

Limitations

Limitations of our study include sample size (n = 1002), which may have been inadequate to demonstrate a statistical difference in the 2 phases of care, as discussed previously. A further limitation is that the reduction in mortality may also have been attributable to changes in vehicle safety features, changes in driving regulations and other secular factors that were unaccounted for in this study. Our method for identifying major trauma was based on precedents in the literature,[11,12] but it is a limitation that we were unable to directly use ISS to identify major trauma patients. Nevertheless, we found very close agreement in the number of seriously injured patients from MVC trauma in our study compared with provincial trauma registry data for the study period (Ms. Beth Sealy, Nova Scotia Trauma Registry: personal communication, 2009). This suggests that the criteria we used to identify major trauma patients did not underestimate the true number. Observational studies using administrative data have inherent weaknesses that limit inference and causation but contribute to demonstration of association and hypothesis generation as this study purports to do. Although we attempted to control for confounding variables in our regression model, it is possible that further unmeasured confounders existed. Finally, we did not control for the secular changes during the time period that contribute to obviation of injury burden, such as injury prevention initiatives (engineering, enforcement and education), in our analysis.

This study attempted to evaluate a province-wide and

population-based health care system intervention. Unlike the previous Canadian study on this topic, which was exclusively urban in design,[13] our study (and its earlier phase) involved the entire province, including both rural and urban settings. A limitation of our earlier study was that we may have evaluated the system effectiveness "too soon" (only 2 years postimplementation).[30] Several further system developments occurred in Nova Scotia since the postimplementation period examined in our earlier study, including a rooftop helipad at the single adult tertiary care centre, the use of helicopter response for scene MVCs, the use of comprehensive evidenced-based medical protocols for the province's paramedics and the refinement of the province-wide trauma destination policy for all major trauma patients and patients with head injuries.[41]

Conclusion

With comprehensive, province-wide trauma system implementation, greater numbers of patients with MVC-associated major trauma are being brought expeditiously to definitive (tertiary) care in Nova Scotia. A statistically nonsignificant trend toward decreased mortality was demonstrated among seriously injured patients admitted to hospital as a result of MVCs. Trauma system implementation should be further studied to determine its effectiveness in other Canadian jurisdictions, independent of other factors to assist with investment in acute care versus other injury control initiatives.

Acknowledgements: This study was supported by a research grant from the Nova Scotia Health Research Foundation. Special thanks for review of the manuscript is given to Mark Asbridge and for preparation of the manuscript to Corinne Burke.

Competing interests: None declared.

Contributors: J.M. Tallon and D.B. Fell designed the study. J.M. Tallon and S.A. Karim acquired the data. J.M. Tallon, D.B. Fell and S.A. Karim wrote the article. All authors analyzed the data, reviewed the article and approved its publication.

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