Road Collisions as a Cause of Traumatic Spinal Cord Injury in Ireland, 2001–2010

Éimear Smith, MD, MRCPI,¹ Michael Brosnan, BA, MSc (Econ),²
Catherine Comiskey, PhD,³ and Keith Synnott, FRCS⁴

¹Spinal Cord System of Care, National Rehabilitation Hospital, Dun Laoghaire, Co. Dublin, Ireland;

²Road Safety Authority, Ballina, Co. Mayo, Ireland; ³Centre for Practice & Healthcare Innovation, School of Nursing & Midwifery, Trinity College Dublin, Dublin, Ireland; ⁴Department of Spinal & Orthopaedic Surgery, Mater Misericordiae University Hospital, Dublin, Ireland

Background: Road collisions remain the leading cause of traumatic spinal cord injury (TSCI) in the world. Half of all TSIs in Ireland in 2000 were caused by road collisions. Since then, there has been a downward trend in road fatalities coincident with implemented road safety strategies. **Objective:** To examine the incidence of TSCI resulting from road collisions from 2001 to 2010. **Method:** This is a retrospective study using the hospital inpatient enquiry database of the tertiary referral center, which houses the national spinal injuries unit. Information retrieved included total numbers of patients with TSCI and number of TSIs due to road collisions from 2001 through 2010, age groups affected, and the gender balance. **Results:** Over the 10-year period studied, the incidence rate of TSCI due to road collisions declined, although this did not reach statistical significance. The largest numbers of all TSIs and TSIs due to road collisions were in the 20- to 29-year age category and the male gender. **Conclusions:** As mortality due to road collisions declined, so did the number of TSIs from the same etiology. An impactful road safety campaign is likely to have influenced these trends. **Key words:** epidemiology, road collisions, road safety, traumatic spinal cord injury

Worldwide, road collisions remain the leading cause of traumatic spinal cord injury (TSCI). Except for Eastern Europe, South Asia, and Oceania, road collisions were the most common cause of TSCI in all World Health Organization (WHO) regions from 1959 to 2008.¹ In Western Europe, road collisions accounted for 46% of all TSIs during that time period.¹ TSCI due to road collision is typically associated with males younger than 30 years of age.^{2–5} In Ireland, the only published study of TSCI epidemiology revealed that 23 of 46 (50%) incidents in 2000 were due to road collisions.⁶ Of persons injured in road collisions, 24% were car drivers, 11% were car passengers, 9% were motor bike users, and 4.5% were cyclists; there was a single motor cycle passenger and a single pedestrian.⁶ March, May, and September were the months associated with the most TSIs of all causes.⁶

In the late 1990s, the need was identified in Ireland for a strategic approach to road safety due to the high number of road fatalities. The first road safety strategy (1998 to 2002) set out the parameters for this approach that centered on the 3 main road safety interventions of education, engineering, and enforcement. The road safety strategy from 2007 to 2012 coincided with the establishment of the Road Safety Authority, a specialist agency under the auspices of the Department of Transport. Over the last decade, there has been relative success in reducing the impact of road traffic collisions on Irish society. In 2000, there were 110 fatalities and 3,180 injuries per million population and 247 fatalities and 7,159 injuries per million vehicles registered. In 2010, these numbers had fallen to 47 fatalities and 1,850 injuries per million population and 88 fatalities and 3,423 injuries per million vehicles registered. The road safety target of no

Corresponding author: Dr. Éimear Smith, National Rehabilitation Hospital, Rochestown Avenue, Dún Laoghaire, Co. Dublin, Ireland; phone: 0035312355528; fax: 0035312854370; e-mail: eimear.smith@nrh.ie

Top Spinal Cord Inj Rehabil 2014;20(2):158–165
© 2014 Thomas Land Publishers, Inc.
www.scijournal.com

doi: 13.1310/sci2002-158

more than 252 deaths per year by the end of 2012 was achieved 4 years ahead of schedule, with 186 fatalities provisionally reported in 2011.

In recent years, the Road Safety Authority's high-profile media campaigns have been supportive of interventions relating to education, engineering, and enforcement. These interventions correspond to increased resources for the Irish Police (An Garda Síochána). The Garda Traffic Corps increased to 1,200 officers (from 580) in 2008. This enforcement strategy was enhanced by legislation to reduce the legal blood alcohol level for driving from 0.08% to 0.05% and to 0.02% for novice and professional drivers, the introduction of mandatory alcohol testing (a form of random breath testing) and the addition of newer road safety offences to the penalty points system that was originally established in 2002. The use of a comprehensive safety camera initiative, which commenced in 2011, has supported An Garda Síochána in reducing speeding on Irish roads at known locations where speed has been a factor in fatal and serious injury collisions.

The education strategy for road safety targets all levels of society. Formal road safety education is now established in primary and secondary schools, at third level institutions, and at a community level, where specific programs exist for individuals not involved in formal education. The Road Safety Authority also supports educational campaigns that focus on improved driver training and testing programs, which are now being implemented in Ireland. The improvement in Ireland's infrastructure (there are now well-designed motorways connecting the main urban and industrial regions of the country) has also contributed to Ireland's success in improving road safety. The Road Safety Authority has developed media campaigns to inform older drivers who have not passed their driving test recently about how to safely use this improved infrastructure.

It is reasonable to assume that as the number of fatalities and injuries from road traffic collisions have fallen since 2000, so has the number of TSCIs. The objective of this study, therefore, was to examine the incidence of TSCI resulting from road collisions from 2000 to 2010, coincident with the implementation of an impactful road safety strategy.

Methods

In the acute phase, almost all TSCIs in Ireland are managed in one center, the National Spinal Injuries Unit at the Mater Misericordiae University Hospital (MMUH), Dublin. In this retrospective study, the hospital inpatient enquiry (HIPE) database of the MMUH was used to gather information on the total number of TSCIs and number of injuries sustained in road collisions from 2001 to 2010 inclusive. The HIPE database is based on the WHO's International Classification of Diseases. The numbers retrieved from HIPE were those newly injured with TSCI who were being discharged from the MMUH and transferred to the National Rehabilitation Hospital. Our prime objective was to examine trends over the 2001-2010 decade, as 2000 has been analyzed previously.⁶ However, to compare changes within age groups, we included 2000, as this allows for 2 time periods of almost equal length (2000-2004 and 2005-2010).

For 2000-2004, ICD-9 was used; for 2005-2010, ICD-10 was used. In the ICD-9, codes 806 (fracture of the spine with injury of the spinal cord) and 952 (injury of the spinal cord without apparent spinal fracture) were used to identify patients with TSCI, and codes e810-825 and e829 were used to identify those injuries caused by road collisions. In the ICD-10, TSCIs were identified within code categories S14 (injury of nerves and spinal cord at neck level), S24 (injury of nerves and spinal cord at thoracic level), and S34 (injury of nerves and lumbar spinal cord at abdominal, lower back and pelvic levels); codes V02-89 were used to identify injuries caused by road collisions.

The number and incidence rate per 100,000 of population of total TSCIs and TSCIs due to road collisions were prepared for each year that the most relevant census data were available. This included the censuses of 2002⁷ and 2006⁸ and the census of 2011⁹ for rates in 2010. The computation of incidence rates across time removed any changes that may have been due to an increasing or decreasing overall population size in the study timeframe. For each incidence rate, simple 95% confidence intervals were computed based on the binomial distribution and large samples, as per Merrill.¹⁰ This enabled the rates to be compared statistically. To compare changes in rates by gender,

Figure 1. Number of traumatic spinal cord injuries (TSCIs) due to road collisions and due to other causes.

we computed incidence rates for TSCIs due to road collisions by gender. However, due to the very small sample sizes, confidence intervals were not computed for the female rate in 2010.

Finally, to identify any changes in numbers within age groups across time, we compared the proportion of cases within relevant age bands between the first and second half of the decade. A *z* test for the difference in incidence within each age group was conducted based on the 2-tailed null hypothesis that incidence within age groups between the periods 2000–2004 and 2005–2010 did not differ. A power analysis was conducted to ascertain whether sample sizes were sufficient to detect a statistically significant difference in 2 independent incidence rates. Based on Cohen,¹¹ a total of 63 cases was needed within each of the 2 groups to detect a medium (0.50) effect size or a difference in 2 incidence rates with a power of 80% ($\beta = 0.80$) and for a type I error of $\alpha = 0.05$.

Results

The total number of TSCIs in Ireland remained constant over the period from 2001 to 2010. The number of TSCIs due to road collisions, relative to

the total number, is shown in **Figure 1**. Analysis of the basic incidence rates of all TSCIs demonstrated only minor variations between census years.^{7–9} However, it can be seen within **Table 1** that the incidence rate of TSCIs due to road collisions more than halved during the period from 2006 to 2010, decreasing from 0.590 to 0.240 per 100,000 of population. This reduction of 0.35 in the proportion would be considered by Cohen¹¹ to be statistically a small effect. Analysis of the corresponding 95% confidence intervals for the 2006–2010 period illustrates that the confidence intervals for the 2 time periods overlap; there was no statistically significant difference in the observed rates detected and the results from the power analysis were of insufficient numbers to detect a difference.

Males accounted for 69% to 85% of all patients sustaining TSCIs and for 70% to 88% of patients sustaining TSCIs due to road collisions during each year of the study period of 2001–2010. Comparing incidence rates within males and within females over the same time period revealed a similar pattern in the period of 2006 to 2010, with rates reducing by more than half. There was a practical drop in TSCIs due to road collisions among males

Table 1. Incidence rates of traumatic spinal cord injury (discharged from hospital) from all causes and from road collisions from 2001 to 2010

Year	Population	Total no. of TSCIs			No. of TSCIs due to road collisions		
		All	Incidence rate per 100,000 population	Incidence rate, 95% CI	All	Incidence rate per 100,000 population	Incidence rate, 95% CI
2002	3,917,336	55	1.404	1.033, 1.775	23	0.587	0.347, 0.827
2006	4,234,925	63	1.488	1.120, 1.855	25	0.590	0.359, 0.822
2010	4,581,269	58	1.266	0.940, 1.592	11	0.240	0.098, 0.382

Note: TSCI = traumatic spinal cord injury.

and among females, but confidence intervals for the rates continued to marginally overlap; this drop in rate was not detected as statistically significant. Comparing rates across genders revealed practical and statistically significant differences in prevalence rates between males and females. These results are presented in **Table 2**.

Mean age of patients sustaining TSCIs from all causes was 43 years (*SD* 3.6). Mean age of those who sustained TSCI due to road collisions was 36 years (*SD* 2.9). The highest incidence of TSCIs due to all causes and due to road collisions occurred in the 20- to 29-year age category, as shown in **Figure 2**. The age distribution of cases and the *z* test of incidence rates across time are presented in **Table 3**. None of the changes in incidence rates per age group were found to be statistically significant.

Discussion

In most countries, road collisions have been the leading cause of TSCI for several years, including Australia, Denmark, France, Greece, Italy, Japan, Nigeria, Sierra Leone, Turkey, United States, and

Zimbabwe.¹²⁻²⁰ In the United States, road collisions accounted for 48.8% of TSCIs between 2000 and 2004 and for 45.4% between 2005 and 2008.¹²

It was reported that road collisions accounted for 50% of TSCIs in Ireland in 2000.⁶ Over the period of this study, a decade during which there was implementation of a road safety strategy and a decrease in road mortality, there was a clear downward trend in the number of TSCIs arising from road collisions, although this has not been proven to be statistically significant. In Denmark, it was observed that a falling proportion of TSCIs due to road collisions coincided with the introduction of speed limits in 1973 and the compulsory use of seat belts in 1976.¹⁶ In Australia, road deaths were reduced through public health measures, including random breath testing, seat belt and helmet laws, and graduated licensing; coincident with this decline in the numbers of road deaths, there was a decline in the number of TSCIs resulting from road collisions.²¹ It has been suggested that a reduction in incidence of 3% per year is a realistic goal of safety strategies²¹; this has been surpassed in Ireland over the past decade.

Table 2. Incidence rates of traumatic spinal cord injury (TSCI) from road collisions, by gender, from 2001 to 2010

Year	Population Males/Females	No. of TSCIs due to road collisions by gender					
		Males	Incidence rate per 100,000 population	Incidence rate, 95% CI	Females	Incidence rate per 100,000 population	Incidence rate, 95% CI
2002	1,945,187/ 1,972,149	18	0.925	0.498, 1.353	5	0.254	0.031, 0.476
2006	2,118,209/ 2,116,716	20	0.944	0.530, 1.358	5	0.236	0.029, 0.443
2010	2,268,698/ 2,312,571	9	0.397	0.138, 0.656	2	0.086	—

Figure 2. All traumatic spinal cord injuries (TSCIs) due to all causes and road collisions per age group, 2001-2010 inclusive.

The failure to implement safety measures and the use of alcohol and drugs are known to be influential factors in road collisions causing TSCIs. In one study, 22% of road collision victims

reported using safety measures, such as a seatbelt or a motorcycle helmet.² The largest percentage of injuries resulting from nonuse of safety measures was found in the <25 age group (85%), although

Table 3. Incidence of traumatic spinal cord injury (TSCI) from road collisions from 2000 to 2004 and from 2005 to 2010 by age

Age groups, years	2000-2004		2005-2010		Z value ^c
	TSCIs due to road collisions	Incidence rate per 100,000 population ^a	TSCIs due to road collisions	Incidence rate per 100,000 population ^b	
15-19	24	7.66	13	4.48	1.566
20-29	41	6.40	43	6.01	-1.003
30-39	22	3.69	17	2.53	0.452
40-49	12	2.30	14	2.43	-0.758
50-59	8	1.87	4	0.85	0.966
60-69	9	3.13	4	1.23	1.199
70-79	1	0.50	7	3.31	-2.345
80-89	2	1.99	3	2.66	-0.595

^aBased on the 2002 census of population.

^bBased on the 2006 census of population.

^cValue of >1.96 or <-1.96 is significant.

the percentage was also high in other age groups: 76% in 25 to 39 year olds, 77% in 40 to 54 year olds, and 70% in >55 year olds.² In a Japanese study, 29.8% of persons who did not wear a seat belt sustained a complete SCI whereas 19.6% of seat belt users had a complete injury, a statistically significant difference.¹⁹ Alcohol was reported as possibly contributing to TSCI in nearly 50% of cases tested and drug use in 14% of cases in one region of the United States.² In this study, we have not recorded data on seat belt nonuse or alcohol use, the influence of these factors in serious road collisions has been investigated in Ireland. According to the Road Safety Authority, 94% of car users in Ireland are now wearing seat belts, but 16% of car drivers and 41% of front seat car passengers who were killed in collisions were not using a seat belt.²² In another study by the Road Safety Authority, it was found that alcohol as a factor in fatal road traffic collisions fell significantly after the introduction of mandatory alcohol testing in July 2006 (36.5% in 2003 to 15.5% in 2007).²³

The mean age of persons who sustained TSCIs from road collisions in our study was lower than that for the entire group of TSCIs, as has been noted in previous studies.^{2,15} It was our observation that the largest number of patients who sustained TSCIs from all causes and from road collisions were in the 20- to 29-year age group and that males accounted for the greater proportion of those injured. The association between younger age groups and road collisions has been reported previously,^{2,3,5} as has the higher risk for males.⁴ The drop in numbers over time, when analyzed by age and gender, did not reach statistical significance. In addition to the small sample size, the changing population age structure in Ireland, where there is a general trend toward older age increase, may have contributed to this. However, an in-depth analysis of population age in Ireland is beyond the scope of this article.

There are a number of limitations to this study. Analysis for the year 2010 was based on census figures for 2011,⁹ as a census did not take place in Ireland in 2010. The retrospective nature of data collection is not ideal. Cases were identified from the HIPE system (which is based on the International Classification of Disease); we did not check the health care records, as was done

in previous studies.^{24,25} Difficulties with data collection based on ICD codes have been reported previously; it has been suggested that the use of the ICD-9 leads to overestimation of number of TSCI cases while use of ICD-10 leads to omission.^{24,25} A further difficulty with our data collection method is that HIPE is not linked to the Road Safety Authority database, which is developed from police collision reports. This database includes information about the collision that would be helpful to this study, particularly regarding the vehicle type used by the injured person. A final limitation of this study is that it may not have captured all cases of TSCI in Ireland and does not include children. As in other studies, individuals who sustained TSCIs and died at the scene of trauma or in their local hospital, prior to transfer to the National Spinal Injuries Unit, were not included. Occasionally, a patient with TSCI is not admitted to the National Spinal Injuries Unit and is directly referred to the national center for spinal cord injury rehabilitation (National Rehabilitation Hospital) or, if less severely injured, he or she might recover adequately from an incomplete injury to be discharged home with nonspecialist outpatient therapy.

In Ireland, there is no national SCI registry or trauma registry. Such databases exist in Australia, Canada, and to some degree in the United States.²⁶⁻²⁸ Data collection should be less complicated in a country as small as Ireland, with one specialist acute spinal cord injury center and one specialist rehabilitation center, compared with a large country such as France where there are approximately 150 units.²⁹ This study on one aspect of TSCI epidemiology reinforces the need for the development of a TSCI registry in Ireland, adhering to recommended methods of data collection,³⁰ the inclusion of the International Spinal Cord Society (ISCoS) core dataset³¹ and the use of the International Classification of External Cause of Injury (ICECI),³² as endorsed by ISCoS and WHO.³³

Conclusions

Road collisions as a cause of TSCI have reduced since 2000. Road safety legislation and awareness are very likely to have influenced this trend. The

establishment of a national TSCI registry that collects the appropriate information accurately is vital for ongoing preventive measures in the future.

Acknowledgments

Conflict of interest: The authors of this study declare no conflict of interest.

Previous publication: This research was presented as a poster at the ISCoS 2012 Scientific Meeting.

Additional contributions: Helen Nolan, HIPE Office, Mater Misericordiae University Hospital.

REFERENCES

1. Cripps RA, Lee BB, Wing P, Weerts E, Mackay J, Brown D. A global map for traumatic spinal cord injury epidemiology: Towards a living data repository for injury prevention. *Spinal Cord*. 2011;49:493-501.
2. Burke DA, Linden RD, Zhang YP, Maiste AC, Shields CB. Incidence rates and populations at risk for spinal cord injury: A regional study. *Spinal Cord*. 2001;39:274-278.
3. Ravaud J-F, Delcey M, Desert J-F; the Tetrafigap group. The Tetrafigap study on the long-term outcome of tetraplegic spinal cord injured persons, part II: Demographic characteristics and initial cause of injury. *Spinal Cord*. 2000;38:164-172.
4. Hagen EM, Eide GE, Rekand T, Gilhus NE, Gronning M. A 50-year follow-up of the incidence of traumatic spinal cord injuries in Western Norway. *Spinal Cord*. 2010;48:313-318.
5. Couris CM, Guilcher SJT, Munce SEP, et al. Characteristics of adults with incident traumatic spinal cord injury in Ontario, Canada. *Spinal Cord*. 2010;48:39-44.
6. O'Connor RJ, Murray PC. Review of spinal cord injuries in Ireland. *Spinal Cord*. 2006;44:445-448.
7. Central Statistics Office. Census 2002. <http://www.cso.ie/en/media/csoie/census/documents/2002preliminary.pdf>
8. Central Statistics Office. Census 2006. <http://www.cso.ie/en/media/csoie/census/documents/2006PreliminaryReport.pdf>
9. Central Statistics Office. Census 2011. <http://www.cso.ie/en/media/csoie/census/documents/Prelim,complete.pdf>
10. Merrill R. *Fundamentals of Epidemiology and Biostatistics: Combining the Basics*. Burlington, MA: Jones and Bartlett Learning; 2013.
11. Cohen J. Quantitative methods in psychology: A power primer. *Psychol Bull*. 1992;112(1):155-159.
12. De Vivo MJ, Chen Y. Trends in new injuries, prevalent cases and ageing with spinal cord injury. *Arch Phys Med Rehabil*. 2011;92:332-338.
13. O'Connor PJ. Survival after spinal cord injury in Australia. *Arch Phys Med Rehabil*. 2005;86:37-47.
14. Karacen I, Koyuncu H, Pekel O, et al. Traumatic spinal cord injuries in Turkey: A nation-wide epidemiological study. *Spinal Cord*. 2000;38:697-701.
15. Pagliacci MC, Celani MG, Zampolini M, et al. An Italian survey of traumatic spinal cord injury. The Gruppo Italiano Studio Epidemiologico Mielolesioni. *Arch Phys Med Rehabil*. 2003;84:1266-1275.
16. Biering-Sorensen F, Pedersen V, Clausen S. Epidemiology of spinal cord lesions in Denmark. *Paraplegia*. 1990;28:105-118.
17. Draulans N, Kiekens C, Roels E, Peers K. Etiology of spinal cord injuries in Sub-Saharan Africa. *Spinal Cord*. 2011;49:1148-1154.
18. Ravaud J-F, Delcey M, Desert J-F; the Tetrafigap group. The Tetrafigap study on the long-term outcome of tetraplegic spinal cord injured persons, part II: Demographic characteristics and initial cause of injury. *Spinal Cord*. 2000;38:164-172.
19. Shingu H, Ohama M, Ikata T, Katoh S, Akatsu T. A nationwide epidemiological survey of spinal cord injuries in Japan from January 1990 to December 1992. *Paraplegia*. 1995;33:183-188.
20. Divanoglou A, Seiger A, Levi R. Acute management of traumatic spinal cord injury in a Greek and a Swedish region: A prospective, population-based study. *Spinal Cord*. 2010;48:488-482.
21. O'Connor PJ. Prevalence of spinal cord injury in Australia. *Spinal Cord*. 2005;43:42-46.
22. *Road Collision Facts 2008*. Ballina, Co. Mayo, Ireland: Road Safety Authority; January 2010
23. Pre-Crash Behaviour in Fatal Road Collisions, Report No. 1 Alcohol. Research Department, Road Safety Authority; September 2011. <http://www.rsa.ie/Documents/Press%20Office/Review%20of%20Pre-crash%20Behaviour%20in%20Fatal%20Road%20Collisions%20Alcohol%20FinalFriday16Updated.pdf>
24. Van Asbeck FWA, Post MWM, Pangalila RF. An epidemiological description of spinal cord injuries in the Netherlands in 1994. *Spinal Cord*. 2000;38:420-424.
25. Dahlberg A, Kotila M, Leppanen P, Kautiainen H, Alaranta H. Prevalence of spinal cord in Helsinki. *Spinal Cord*. 2005;43:47-50.
26. O'Connor PJ. Development and utilisation of the Australian spinal cord injury register. *Spinal Cord*. 2000;38:597-603.
27. Noonan VK, Kwon BK, Soril L, et al. The Rick Hansen spinal cord injury registry (RHSCIR): A national patient-registry. *Spinal Cord*. 2012;50:22-27.
28. DeVivo MJ, Go BK, Jackson AB. Overview of the national spinal cord injury statistical centre database. *J Spinal Cord Med*. 2002;25:335-338.
29. Albert T, Ravaud J-F; the Tetrafigap group. Rehabilitation of spinal cord injuries in France:

- A nationwide multicentre study of incidence and regional disparities. *Spinal Cord*. 2005;43:357-365.
30. Wyndaele M, Wyndaele J-J. Incidence, prevalence and epidemiology of spinal cord injury: What learns a worldwide literature survey? *Spinal Cord*. 2006;44:523-529.
31. DeVivo M, Biering-Sorensen F, Charlifue S, et al. International spinal cord injury core data set. *Spinal Cord*. 2006;44:535-540.
32. Lee BB, Cripps RA, Woodman RJ, et al. International classification of external cause of injury, the WHO's family of international classifications and maps to the 9th & 10th revisions of the international classifications of disease. *Spinal Cord*. 2010;48:498-503.
33. Biering-Sorensen F, Bickenbach JE, El Masry WS, Officer A, van Groote PM. ISCoS-WHO collaboration. International perspectives of spinal cord injury (IPSCI) report. *Spinal Cord*. 2011;49:679-683.