Traumatic spinal cord injuries – incidence, mechanisms and course

Summary

Background. The main purpose of this article is to provide an overview of demography, neurological level of injury, completeness of injury, incidence, prevalence, injury mechanisms as well as lethality and causes of death associated with traumatic spinal cord injuries.

Material and method. A literature search was carried out in PubMed, with the search words «traumatic spinal cord injury»/«traumatic spinal cord injuries» together with «epidemiology», and «spinal cord injury»/«spinal cord injuries» together with «epidemiology».

Results. The reported annual incidence of traumatic spinal cord injuries varies from 2.3 per million in a Canadian study to 83 per million in Alaska. The prevalence is given as ranging from 236 per million in India to 1800 per million in the USA. The average age at the time of injury varies from 26.8 years in Turkey to 55.5 years in the USA. The ratio of men to women varies from 0.9 in Taiwan to 12.0 in Nigeria. The most frequent cause of injury is traffic accidents and falls. Patients with traumatic spinal cord injuries have a higher lethality compared with the normal population. The main causes of death today are respiratory problems, heart disease and suicide.

Interpretation. There are large geographical differences in reported incidence, prevalence and lethality. This is attributable to differences in definition, inclusion, classification and patient identification procedures in the various studies, together with geographical and cultural differences and differences in pre-hospital and hospital treatment.

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By definition, a spinal cord injury is an acute traumatic injury to the spinal cord that leads to varying degrees of motor and/or sensory deficits and paralysis (1). Although injury of the cauda equina is included, the definition excludes isolated injuries to other nerve roots (2). The condition can lead to life-long loss of function and reduced quality of life, as well as increased morbidity and mortality. Knowledge about incidence, prevalence and clinical consequences is essential for planning treatment and care programmes for this group of patients, in hospitals as well as in local communities. Knowledge of the mechanisms of injury is important for prevention. This article provides an overview of demography, level of injury, completeness of injury, incidence, prevalence and mechanisms of injury, as well as lethality and causes of death from traumatic spinal cord injury.

Knowledge basis

We have undertaken a literature search in PubMed with the following combinations of search terms: «traumatic spinal cord injury AND epidemiology», «traumatic spinal cord injuries AND epidemiology», «spinal cord injury AND epidemiology» and «spinal cord injuries AND epidemiology». The search was restricted to articles published prior to 1 April 2011, but with no limit backwards in time. No restrictions were placed on language, age at the time of injury or research design, although the articles had to be available in full-text versions, either on the Internet or through the Bergen University Library.

A search for «traumatic spinal cord injury AND epidemiology» returned 140 articles, of which four were review articles. A search for «traumatic spinal cord injuries AND epidemiology» resulted in 38 articles, of which one was a review article. A search for «spinal cord injury AND epidemiology» returned 1 346 articles, of which 186 were review articles. Finally, a search for «spinal cord injuries AND epidemiology» returned 1 833 articles, of which 243 were review articles.

We reviewed the abstracts of all articles that had a relevant title. If the abstract proved to be relevant, the full text was retrieved whenever available. Articles that referred to particular age groups (such as children or only elderly patients) were not included in the overview of studies of incidence and prevalence. Most population-based studies included only patients over 16 years, and only a minority referred to all age groups.

After a review of the full text of literature published prior to April 2011, we identified 78 articles describing incidence (1, 3–79), 17 articles on prevalence (5, 10, 11, 38, 40–42, 80–89), 73 that included age at the time of injury (1, 3, 5–12, 14, 17–25, 27, 30, 31, 33–37, 39, 40, 44, 46, 47, 51, 52, 57–66, 68–75, 85, 90–108), 99 with gender distribution (1, 3–12, 14, 15, 17–25, 27–40, 42, 44, 45, 47, 48, 50–54, 57–79, 85, 90–118), 93 that included mechanisms of injury (1, 3–6, 8–12, 14, 15, 17–22, 24, 25, 27, 28, 30–41, 44, 45, 47, 48, 50–54, 57–70, 72–79, 92–98, 100–104, 107, 108, 110, 111, 113–125), 42 that included lethality (1, 6, 19, 25, 29, 40, 64, 65, 73, 75, 88, 99, 100, 102, 103, 107, 109, 111, 114, 121, 123,

Main message

- There are large variations in the incidence and prevalence of traumatic spinal cord injuries across the world.
- Traffic accidents and falls are the main causes of injury.
- Patients run an increased risk of early death, and life-long follow-up is important.
- The most important causes of death today are respiratory problems, heart disease and suicide.

126–146), 105 that included level of injury (1, 3–79, 85, 90–118), seven that included clinical picture (20, 24, 90, 147–150) and 15 articles on causes of death (6, 75, 80, 123, 127, 129, 137, 151–158). Three of the reviewed articles are not indexed in PubMed, but have been included to make the overview as complete as possible (38, 78, 91).

The articles were selected and the data extracted by the first author (EMH). The selection was based on the author's knowledge of this medical field and with a view to the articles that are included in international overviews. Several review articles on this topic have been published in English in recent years. In particular, our article has drawn on the review articles published by Cripps et al. (159), Wyndaele & Wyndaele (160) and Chiu et al. (162).

Epidemiology

Large variations in incidence, prevalence, gender distribution, mechanism of injury, level of injury, and completeness of injury have been reported from various parts of the world with regard to spinal cord injuries (159–163).

Incidence

Reported annual incidences range from 2.3 per million in a Canadian study to 83 per million in Alaska (Table 1) (1, 3–89, 85, 90–118). This is due to differences in definition, inclusion, classification and procedures for identification of patients, as well as geographical and cultural differences (163, 164). The risk of traumatic spinal cord injury is 2.5 times higher in rural than in urban areas (36).

Even within Europe there are large variations. The highest reported incidence is in Portugal (57.8 per million) (25) and in Russia (44.0 per million) (32), while it is lowest in Italy (2.3 per million) (21). Three incidence studies are available from Norway (5–7). Gjone & Nordlie found an incidence of 16.5 per million inhabitants in 1974–75 (7), while Lidal et al. reported an incidence of 4.5 per million inhabitants for the period 1961–82 (6). Our study from Sogn og Fjordane and Hordaland counties detected an incidence of 13.9 for the period 1952–2001 (5). On average, the incidence increased from 5.9 per million in the period 1952–61 to 21.2 per million in the period 1992–2001 (5). The incidence of traumatic spinal cord injury caused by traffic accidents increased during the period of observation, especially among men under 30 years. With regard to traumatic spinal cord injuries caused by falls, the incidence increased among men over 60 years (5).

Prevalence

Relatively few prevalence studies of traumatic spinal cord injuries have been published (Table 2) (5, 10, 11, 38, 40–42, 80, 89). The lowest prevalence is found in India, with 236 per million (86), and the highest in the US, with 1 800 (84). Only three prevalence studies are available from Europe, all of which are from the Nordic countries. Dahlberg et al. found a prevalence of 280 per million in Helsinki in 1999 (10), while Knutsdottir reported a prevalence of 316 per million in Iceland in 1989 (11). We found a prevalence of 365 per million inhabitants in Sogn og Fjordane and Hordaland counties in 2002 (5).

Age

Average age at the time of injury varies from 26.8 years in a study from Turkey (98) to 55.5 years in Oklahoma, USA (51) (Table 1). Several studies have found an increase in average age at the time of injury in recent decades; in particular, there is an increasing number of injuries among people above 60 years. In the National Spinal Cord Injury Statistical Centre Database (US), the average age at the time of injury was 29 years in 1970 and 37 years in 2005 (91, 165). The proportion of people who are injured after the age of 60 increased from 5 % to 13 % during the same period (165).

We found that in Western Norway, the average age increased from 40.2 years in the period 1952–56 to 48.9 years in the period 1997–2001, for women from 24.7 years to 57.7 years, and for men from 41.5 years to 46.3 years (5).

Gender

There are large variations in the gender distribution (Table 1). Most studies show a preponderance of men. In studies from Taiwan and Iran, spinal cord injuries occur with equal frequency among both genders (71, 85). The largest preponderance of men is found in studies from Sierra Leone and Nigeria (ratio 11–12: 1) (64, 100). The three studies from Norway show a male/female ratio of 4.7–5.0: 1 (5–7).

Table 1: Overview of reported annual incidences (number per million inhabitants), age at the time of injury and gender distribution of traumatic spinal cord injuries, by geographical region. The referenced studies report one or more of the following variables: incidence, age at the time of injury and gender distribution.

Region	Period of observation	Incidence	Ager at the time of injury (years)	Gender distribution (m : w)
Nordic countries (1–10)	1952–2008	4.5–26.3	27.9–47.9	2.7–5.0
Western Europe (6, 11–27)	1960–2007	2.3–57.8	34.5–50.0	1.6–7.7
Central Europe (28, 29)	1975–2008	14.5–28.5	44.2	2.8–3.3
Eastern Europe (30, 31)	1989–96	29.7–44.0	34.2	1.8–3.6
Alaska (32)	1991–93	–	35.0	5.0
Canada (33–38, 109)	1947–2002	2.3–52.5	34.5–42.2	1.5–4.5
USA (39–62, 110, 111)	1970–2005	23.7–77.0	28.7–55.5	1.0–5.6
Latin America (63–66)	1986–2002	–	30.3–37.5	4.1–6.3
Oceania (67)	1985–94	–	38.3	6.5
North Africa/ Middle East (68–76, 112)	1974–2008	12.1–44.0	26.8–35.5	1.0–8.3
West Africa (77–84, 113, 114)	1973–2008	3.4	30.0–37.9	2.0–12.0
Southern Africa (85–87, 115)	1963–94	11.7–48.5	28.0–35.6	3.5–9.0
Pacific Asia (88, 89)	1988–92	28.6–40.2	48.6	4.1–4.5
East Asia (90–96, 116)	1977–2008	14.6–73.0	36.2–54.6	0.9–7.5
Southeast Asia (97)	1989–94	–	32.8	5.6
South Asia (98–104, 117)	1994–2007	–	28.3–32.8	1.8–7.6
Australasia (105–108, 118)	1978–2007	14.5–49.1	–	2.7–4.9

Mechanisms of injury

The European -International Spinal Cord Society (ISCoS) and its American counterpart (the American Spinal Injury Association ASIA), have together developed an international data set for the registration of spinal cord injuries (166). In Norway we are using ICD-10 (International Classification of Diseases, version 10) as a diagnostic coding system. ICD-10 contains codes for the registration of external causes of diseases, injuries and deaths, but has not been applied in all countries; for example, in the US the ICD-9 is still being used. Different subdivisions of mechanisms of injury have therefore been applied in international literature, although most studies have classified mechanisms of injury as traffic accidents, falls, sports accidents and other accidents (159–163).

In most countries, traffic accidents are the most common mechanism (159–163). The largest proportion has been observed in West Africa, at 89 % (113). The lowest proportions are found in Greenland, at 4 % (3), as well as in Pakistan and Nepal, both at 7 % (76, 117).

Falls account for the other main mechanism of traumatic spinal cord injuries (159–163). These include a broad range of incidents, from falls from a large height at the workplace or with suicidal intent, to patients slipping on the bathroom floor in their own homes (5). The lowest proportion is reported from South Africa, at 3 % (115), and the highest from Pakistan and Nepal, both at 82 % (76, 117). In Western Norway, the most frequent mechanisms of injury were falls (45.5 %) and traffic accidents (34.2 %) (5).

Violence is a frequent cause of traumatic spinal cord injuries in South Africa, where it accounts for 61–62 % (66,115) of the cases, whereas all studies from Europe report less than 5 % – with the exception of Greenland, where violence was the cause in 11 % of the cases (3). In the US, violence mainly related to gunshot injuries has been the cause of 12–23 % of traumatic spinal cord injuries, with a peak in the first half of the 1990s (165).

Sports accidents causing spinal cord injuries occur most frequently during diving, gymnastics and rugby (159–163). From Russia, it has been reported that 33 % of all accidents occurred during gymnastics (31), whereas in Australia, diving accidents have dominated (167). An increasing number of people are injured in accidents while paragliding (168).

The large variations in mechanisms of injury reported by various studies may be due to geographical and cultural differences, although different definitions, methods of data collection and study designs may also explain some of the variance.

Anatomical level and completeness of injury

Level of injury

The anatomical level of injury in the spinal cord is divided into high (cervical) and low injuries (thoracic, lumbar and sacral) (2, 169). The neurological level of injury is defined as the most caudal segment of the spinal cord that has normal function (2, 169). The neurological assessment is important for clinical diagnosis, monitoring and prediction of functional outcomes. In 10–15 % of the patients with traumatic spinal cord injury there is a difference between the anatomical and the neurological levels of injury because of multi-level injuries, vascular pathologies and/or a spinal-cord oedema following from the injury (170). The neurological level of injury is classified according to the American Spinal Injury Association (ASIA) Impairment Scale A-E (169, 171) (Box 1).

The proportions of high (cervical) and low (thoracic or lumbar-sacral) injuries vary in different studies. From China, it is reported that 5 % of the patients have sustained high injuries (69), compared to 92 % in Turkey (98). These variations between the countries may partly be explained by reference to different causal patterns, although the availability of treatment, geographically and financially, may have contributed to a general underreporting of traumatic spinal cord injuries in a number of countries. We believe that because of socio-economic conditions, patients with cervical injuries will have reduced chances of reaching a hospital alive in many countries (such as China).

Lethality

Lethality is defined as the ratio between the number of deaths from a certain disease or injury and the total number of cases of the disease or injury over a given time interval. In the Western world, lethality from traumatic spinal cord injury in the acute phase declined from 30 % in the 1960s to 6 % in the 1980s (135, 152). Despite this patients with traumatic spinal cord injuries still run an increased risk of premature death (172–175). The standardised mortality ratio (SMR) is the

Box 1

The American Spinal Injury Association (ASIA) Impairment Scale A–E (169)

- *ASIA A* – No motor or sensory function is preserved below the level of injury (and in the sacral segments S4–S5)
- *ASIA B* – Sensory but not motor function is preserved below the neurological level (includes the sacral segments S4–S5)
- *ASIA C* – Motor function is preserved below the neurological level, but too little to represent a practically usable function (more than half of key muscles below the neurological level have a muscle grade less than 3)
- *ASIA D* – Motor function is preserved below the neurological level, to an extent that provides practically usable function (at least half of key muscles below the neurological level have a muscle grade of 3 or more on a scale from 0 to 5)
- *ASIA E* – Motor and sensory functions are normal (169, 171)

ASIA A implies a complete injury, ASIA B–D describe incomplete injuries.

Table 2: Overview of reported prevalence (number per million inhabitants) of traumatic spinal cord injuries, by geographical region

Region	Period of observation	Prevalence
Nordic countries (5, 10, 11)	1973–2002	280–365
Western Europe	–	–
Central Europe	–	–
Eastern Europe	–	–
Canada (38)	2001–02	1 173
USA (40–42, 80–84)	1935–94	473–1 800
Latin America	–	–
Oceania	–	–
North Africa/Middle East (85)	2003–08	440
West Africa	–	–
Southern Africa	–	–
Pacific Asia	–	–
East Asia	–	–
Southeast Asia	–	–
South Asia (86)	1986	236
Australasia (87–89)	1987–98	370–680

Table 3: Overview of reported lethality within one year and more than ten years after a traumatic spinal cord injury, by geographical region

Region	Period of observation	One-year lethality (%)	≥ 10-year lethality (%)
Nordic countries (6, 126–129)	1952–2008	0,0–2,5	2,5–43,4
Western Europe (19, 25, 126, 130–132)	1948–2007	18,8–56,0	7,1–50,0
Central Europe (29)	2005–08	10,3	–
Eastern Europe	–	–	–
Alaska	–	–	–
Canada (109, 121, 133)	1975–2007	4,0	3,0–10,7
USA (1, 40, 111, 123, 134–141)	1940–2004	8,0–61,0	14,3–53,9
Latin America (142, 143)	1986–2005	10,9–29,2	–
Oceania	–	–	–
North Africa/ Middle East	–	–	–
West Africa (64, 99, 100, 102, 114, 144, 145)	1973–2008	11,0–84,0	83,0
Southern Africa (65, 103)	1963–94	13,0–49,0	–
Pacific Asia	–	–	–
East Asia (73)	1986–90	10,1	–
Southeast Asia (75)	1989–94	16,0	–
South Asia (107)	2003–07	10,7	–
Australasia (88, 146)	1955–98	5,7	9,0–14,3

ratio between observed deaths and expected deaths in a reference population. A Finnish study reported an increased risk of death among patients with traumatic spinal cord injuries, with a SMR of 3.56 for women and 2.54 for men (128). Lidal et al. found a SMR of 1.8 for men and 4.9 for women with traumatic spinal cord injuries who had been admitted to Sunnaas Hospital (6).

In our study from Western Norway, we found that patients with traumatic spinal cord injuries had an increased risk (SMR) of death of 1.85, compared to others of the same gender and age (129). The SMR was highest during the first ten years after the injury. The group with complete injury had a shorter average life expectancy than the group with incomplete injuries (SMR 4.23 versus 1.25). Women had a reduced life expectancy compared to men (SMR 2.88 versus 1.72). The average time elapsing form injury to death was 6.9 years for patients with cervical injuries and 8.2 years for patients with lower injuries (129).

In Denmark, people with spinal cord injuries had a considerable decline in mortality compared to the normal population during the period from 1953–71 to 1972–91 (127).

Early death is defined as death occurring as a result of injury within 30 days (176). Most follow-up studies of traumatic spinal cord injuries are from rehabilitation centres that receive patients many months after the time of injury. Many studies therefore choose to exclude all those who die within one year of their injury, and define one year after the time of injury as the distinction between early and late death (6, 165).

Table 3 provides an overview of reported lethality within one year and more than ten years after a traumatic spinal cord injury, by geographical regions. These studies include only patients who arrived in the hospital alive. The Nordic countries have the lowest reported lethality within one year of the injury (Table 3) (1, 6, 19, 25, 29, 40, 64, 65, 73, 75, 88, 99, 100, 102, 103, 107, 109, 111, 114, 121, 123, 126–146).

Causes of death

Causes of death are defined as diseases or injuries that directly or indirectly have caused deaths in a population. In Norway, Statistics Norway compiles the official statistics on causes of death. Eurostat has prepared the European shortlist of causes of death, as a tool for international comparisons of mortality data. The list contains 65 groups of causes of death, and can be used for ICD-9 and ICD-8 as well as ICD-10 (177).

During the last 50 years, the causes of late death after a spinal cord injury have changed significantly. Previously, urosepsis was the most common cause of death after a traumatic spinal cord injury (157), while today the most common causes include respiratory problems, heart disease and suicide (129). Pneumonia is the most common cause of death among patients with cervical spinal cord injuries and patients over 60 years (54). Suicide is a frequent cause of death among patients with thoracic, lumbar and sacral injuries (178).

In a Danish study, the most common causes of death included respiratory diseases (especially pneumonia), suicide and ischemic heart disease (127). Among patients admitted to Sunnaas Hospital in the period from 1961 to 1982, the most common causes of death were pneumonia or influenza (16 %), ischemic heart disease (13 %) and urogenital diseases (13 %) (6).

In a study from Western Norway, the cause-specific standardised mortality ratio was 1.96 (95 % CI 1.22–3.15) for respiratory disease and 5.79 (95 % CI 3.11–10.75) for suicide and poisoning (129). Women had a considerably higher total standardised mortality ratio for suicide and poisoning. The risk of dying from respiratory disease was highest among patients with cervical injuries, while suicide and poisoning occurred most frequently among those with low, incomplete injuries in this study as well (129).

Children with spinal cord injuries

Very few available population-based studies include children. A Finnish study estimated the average annual incidence to 1.9 per million in the age group 0–18 in the period from 1997 to 2006 (179). A Swedish study reported an annual incidence of 4.6 per million children (120). In the study from Western Norway, altogether 3.9 % of the injured children were aged 0–14 years at the time of injury, while 13.1 % were aged 15–19 years (180). The main mechanism of injury in children was car and pedestrian accidents, while adolescents were injured in car and motorcycle accidents. The incidence of traumatic spinal cord injuries among children has remained low, while the incidence among adolescents has increased significantly over the last 50 years (180).

Elderly people with spinal cord injuries

Older patients with traumatic spinal cord injuries have an increased frequency of complications, higher mortality, poorer prognoses and a lower potential for rehabilitation than the younger generation (181, 182).

In our study from Western Norway we investigated the mechanisms of injury among patients who were injured at the age of over 60 and who were rehabilitated at the Department of Neurology, Haukeland University Hospital, in the period from 1952 to 2001 (183). The proportion of elderly increased during the last five years of the study period. Falls were the most frequent mechanism of injury (77 %). For more than a third of these, the height of the fall was less than one metre. Altogether 80 % sustained incomplete injuries and achieved a considerable improvement in function during the primary rehabilitation stay (183).

Concomitant head injuries and spinal cord injuries

Patients who have sustained a concomitant head injury as well as a traumatic spinal cord

injury have a further heightened level of morbidity, and need for complex rehabilitation (184).

The frequency of head injuries varies from 26 % to 74 % in various patient populations with traumatic spinal cord injuries (185, 186). A prospective study found that 34 % of those who had a traumatic spinal cord injury also had a mild head injury, and 26 % had a serious head injury (185). Those who are injured in traffic accidents and falls run a particular risk of sustaining a concomitant head injury. Concomitant head injuries were especially associated with cervical spinal cord injuries.

In our study from Western Norway, altogether 46.7 % of the patients who had a traumatic spinal cord injury also had a clinical concomitant head injury (147). The head injury was assessed as mild in 30.1 %, moderate in 11.0 % and serious in 5.7 % of the patients. Alcohol was the main risk factor for concomitant head injuries (OR = 3.69) (147).

Conclusion

There are wide geographical variations in the reported incidence, prevalence and lethality of traumatic spinal cord injuries. The variations are caused by differences in definition, inclusion, classification and procedures in identification of patients, geographical and cultural differences as well as variations in the available pre-hospital and hospital treatment.

We believe that the improved availability of pre-hospital treatment has helped ensure that a larger number of today's patients arrive at the hospital alive. This has led to an increase in prevalence, incidence and early survival. The differences between various countries in terms of mechanisms of injury, age and gender distribution reflect differences in culture and way of life, as well as differences in the composition of the respective populations.

In Norway, the incidence of traumatic spinal cord injuries has increased over the last fifty years. Falls and traffic accidents are the most frequent mechanisms of injury. There is a particular need for preventive efforts targeting traffic accidents among boys and men, and there is also a need for measures to prevent falls among elderly people. The healthcare system must face the challenge inherent in an increasing proportion of elderly patients with incomplete cervical injuries, not least since this group can benefit greatly from highly specialised rehabilitation.

Despite improved diagnostics and treatment, patients with traumatic spinal cord injuries still have a considerably higher mortality than the population as a whole. Increased knowledge among health professionals of the sequelae and complications after spinal cord injuries is important to reduce the complications, increase survival and improve the quality of life of these patients.

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