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ORIGINAL ARTICLE

Cost of trauma in Europe

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Introduction

Approximately 1 600 000 head injured patients are admitted to hospital care in Europe (population 683 million), producing a brain injury rate of 235/100 000 and causing as many as 66 000 deaths per year (Kraus *et al.,* 2005). Costs of hospitalization vary by injury type, averaging according to US studies at $20 084 for gunshot wounds, $20 522 for motor vehicle crashes, $15 860 for falls, and $19 949 for blows to the head (McGarry *et al.,* 2002). Unfortunately, only scattered reports have been published on traumatic brain injury (TBI) epidemiology across Europe and very few include prevalence or cost data.

TBI is defined as an insult to the brain that leads to temporary or permanent impairments of cognitive abilities and physical functioning. Head injury results from an interaction between an individual and an external agent such as a mechanical force and contributes significantly to the outcomes in one half of all deaths from trauma (Kraus, 1987). This mechanical force may be related to road traffic accidents, falls (with or without alcohol consumption) and work/sport accidents. Trauma injures neural tissue by primary (direct brain tissue injury) or secondary mechanisms (increased intracranial pressure, ischemia related to general hypoxia and hypotension). The consciousness level is a valuable index of injury severity. Impairment of consciousness is stratified according to the Glasgow Coma Scale Scores (GCS) in terms of the responses to external stimuli. The lower the level of GCS on admission, the worse the outcome. Those patients with moderate or severe TBI who survive are often unable to return to full employment and require some degree of rehabilitation. This means that TBI is related to significant direct medical and non-medical costs in terms of hospitalization, outpatient care and rehabilitation, indirect costs due to lost productivity, and intangible costs due to reduced quality of life. This review provides an overview of existing epidemiological and economic evidence in TBI, and discusses the possibility of estimating the total costs of TBI in Europe. The results presented in this summary are described in more detail in previous publications (Kraus, 1987; Tagliaferri 2005).

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Methodology

We searched Medline for epidemiological articles published between 1980 and 2004. The search was undertaken using the terms 'epidemiology', 'head injury', 'trauma', 'brain injury' and 'Europe'. These terms were linked using the following combinations: 'epidemiology' plus 'head injury' or 'brain injury' and 'trauma' and 'Europe'. References from the retrieved reports were checked to identify other possible reports. The reports selected for review were limited to studies of European populations, without restrictions on age, gender or severity of TBI. While the search language was English, articles in French, German, Italian, Spanish and Portuguese were also included in the review if relevant. We studied the abstract in English of those papers in other languages. Data extracted (when available) included: country, number of patients, severity of trauma, incidence, male/female incidence ratio, hospital days, mortality, prevalence, cost of care and other relevant factors.

We identified 21 articles focusing on epidemiological descriptions of TBI. Nine reports were national population studies (Denmark, Spain, UK, Sweden, Finland, Portugal and Germany) and 12 studies focused on countries, provinces, or regions in Norway, Sweden, Italy, Switzerland, Spain, France, The Netherlands and the UK.

The review methodology and results of relevant health economic studies have been described in detail previously (Berg, 2004). Based on a literature search for studies containing cost data on TBI, three studies were identified containing some selected costs of TBI in European countries. Two of these studies focused on inpatient costs per treatment episode for TBI and mild TBI in Germany (Firsching and Woischneck, 2001) and Spain (Brell and Ibanez, 2001), respectively, while the third study contained a rough estimate for the costs of care and rehabilitation following severe TBI in the UK (Wood *et al.,* 1999). None of the studies were truly population based, but instead used secondary data, surveys or cohort information for their analysis. To complement the literature studies, data from the Swedish Hospital Discharge and Causes of Death registers were used to obtain comprehensive estimates for the costs of hospitalization and an estimate of the indirect costs due to early mortality. The ICD-10 codes most related to brain injuries were used for the register ana-

lysis: S02.1, S02.9, S06.0-S06.9 (intracranial injury) and S07.1. Cost data were inflated to the year 2004 with consumer price index, and converted to Euros adjusted for purchasing power (Eurostat, 2004a, b; European Central Bank, 2004).

Results

The incidence, gender ratio, age groups and the highest incidence by age are given in Table 1 for regional and national studies. A range of incidence rates for hospitalized patients has been reported from a high of 365/10^5/year in western Sweden (Andersson *et al.,* 2003) to a low of 83/10^5/year in Glasgow in the UK (Kay *et al.,* 2001). The overall average rate for hospitalized patients was about 235/10^5/year. Five out of 21 articles reported the incidence of TBI by age (Andersson *et al.,* 2003; Engberg Aa and Teasdale, 2001; Peloso *et al.,* 2004; Steudel *et al.,* 2004; Santos *et al.,* 2003). Peaks of incidence were reported in the second/third decades and over 70 years of age. There were no published reports on TBI prevalence rates in Europe and no data on the duration of sequalae from TBI at any level of severity or in different age groups.

Of the 21 studies included in this report, nine provided data on mortality rates directly or gave the basic elements of the rate to make a best guess. A range of in-hospital mortality rates has been reported from a high of 11.5/10^5/year in a German national study (Firsching *et al.,* 2001) to a low of 2/10^5/year in north Staffordshire, UK (Hawley *et al.,* 2003). In Table 1 the mortality rates for different studies are given. An average mortality rate of about 9.7/10^5/year of in-patients is derived from the available reports. Mortality rates vary in different groups of age. Peaks of mortality rates were reported in the third decade and over 70 years of age (Steudel *et al.,* 2004; Santos *et al.,* 2003; Masson *et al.,* 2001; Nardi *et al.,* 1999; Servadei *et al.,* 2002a, b).

Road traffic accidents and falls were the two main causes of TBI. While in southern Europe road traffic crashes constitute the vast majority of cases, falls (with or without alcohol consumption) are the leading cause of trauma in northern Europe. Only two studies, both in the UK, report assaults as a second cause of TBI after falls.

Based on the limited existing cost estimates, the average cost per inpatient with TBI in 2004 ranges from €2500 in Germany to €2800 in Spain and around €3000 in Sweden (cf. Table 2). Using conservative assumptions, the incidence-based inpatient costs derived from the Swedish Hospital Discharge register for patients admitted for TBI in 2001 were €4562 for the first year following admission. If all readmissions, regardless of diagnosis, were included, the corresponding 1-year cost would amount to €7120 per TBI patient. The costs for men were 16% higher than for women. Inpatient costs also increased with age, with relative peaks seen for the age groups 15–24, 50–59 and 70–84 years.

Based on analysis of the Swedish Causes of Death register, the average number of life years lost per person dying of TBI as a multiple cause of death is 20 years, of which almost 10 years still could be productive working years. Men accounted for 71% of all deaths due to TBI, with an average age of death of 58 years, compared with 68 years for women. This results in considerable lifetime costs due to TBI mortality, on average €375 000 per death in Sweden.

Discussion

While the incidence describes the occurrence of new cases in the population over a period of time, the prevalence describes all cases in the population at a particular time and is a measure of both new and established cases. Therefore, the prevalence rate is better for an accurate cost calculation. As mentioned before, there are no published reports on TBI prevalence rates in Europe and no data on the duration of sequalae from TBI, which makes even best guesses impossible.

The rate of hospital admissions for TBI across Europe is high (235/10^5/year) when compared with a recent 98/10^5/year published by Thurman for the USA (Thurman *et al.,* 1999). This difference is entirely due to broader admission criteria for mild head injured patients (GCS 14–15) in Europe compared with the USA. The main problem in comparing different European incidence results is that some studies in this review present different case definitions and patient inclusion rules. Most rates include hospitalized patients (regardless of outcome) plus deaths identified from local authorities (Firsching, 2001; Andersson *et al.,* 2003; Engberg Aa and Teasdale, 2001; Santos *et al.,* 2003; Tiret *et al.,* 1990). Some include only hospitalized patients (Ingebrigtsen *et al.,* 1998; Vazquez-Barquero *et al.,* 1992), others include patients only if treated neurosurgically (Annoni *et al.,* 1992) and some others include patients from national registers (Kleiven *et al.,* 2003; Alaranta *et al.,* 2000). These features obviously contribute to the large range of incidence and mortality rates of TBI across Europe.

A somewhat surprising finding of our study is the systematic difference concerning the causes of trauma observed between northern Europe (UK and Scandinavia) on the one hand and continental and southern Europe on the other hand. The prevalence of falls as the main cause of trauma in the north and of road traffic accidents in the south is also confirmed by a recent multicentre study (Hukkelhoven *et al.,* 2002). This may

Table 1 Incidence, mortality rate, severity of trauma, gender ratio and highest incidence by age[a]

Country	Year of study	Incidence	Mortality/10^5/ year	Severity of trauma	Highest incidence by age (years)	Male/female	First cause of TBI	Second cause of TBI
France (Aquitaine) (Masson *et al.*, 2001)	1996	17.3	5.2	severe TBI	> 70	2.4	RTA (48%)	fall (42%)
Italy (Friuli,Venezia,Giulia) (Nardi *et al.*, 1999)	1998	176[BG]	N/A	H.P.	N/A	N/A	N/A	N/A
Italy (Romagna) (Servadei *et al.*, 2002a)	1998	250	N/A	H.P.	1–4	1.6	RTA (48%)	fall (33%)
Italy (Romagna & Trentino) (Servadei *et al.*, (2002b)	1998	314	7.7	H.P.	20 to 30 & > 70	1.6	fall (33%)	RTA (48%)
Netherlands (Maastricht) (Meerhoff *et al.*, 2000)	1997	88	N/A	H.P.	[a]	2	fall (43%)	RTA (22%)
Norway (Troms) (Ingebrigtsen *et al.*, 1998)	1993	169	N/A	H.P.	10–24 & > 80	1.7	fall (62%)	RTA (21%)
Sweden (Western) (Andersson *et al.*, 2003)	1992	365[BG]	4	H.P.	0–9	1.46	fall (58%)	RTA (16%)
UK (Glasgow) (Kay *et al.*, 2001)	1995	83[BG]	N/A	H.P.	N/A	N/A	fall (43%)	assault (34%)
UK (North Staffordshire) (Hawley *et al.*, 2003)	1992	280	2[BG]	H.P.*	< 2 (18%)	1.9	fall (60% under 2)	RTA (37% from 10 to 15)
Spain (Cantabria) (Vazquez-Barquero *et al.*, 1992)	1992	91	N/A	[a]	[a]	2.7	RTA (60%)	fall (24%)
Switzerland (St. Gallen) (Annoni *et al.*, 1992)	1992	20	N/A	NS treated^	N/A	3.1	N/A	N/A
France (Aquitaine) (Tiret *et al.*, 1990)	1986	282	22	H.P.	< 5 & 15–24 & > 75	2.1	RTA (60%)	fall (33%)
Denmark (Engberg Aa and Teasdale, 2001)	1991–1993	157	10.7	H.P.	> 60	1.7	N/A	N/A
Germany (Firsching and Woischneck 2001)	1996	341[BG]	11.5	H.P.°	N/A	2.4	RTA (56%)	RTA (56%)
Germany (Steudel *et al.*, 2004)	1998	337	9.7	H.P.	N/A	N/A	N/A	N/A
United Kingdom (Kay, 2001)	2001	322[BG]	10	H.P.	N/A	N/A	fall (40%)	assault (20%)
Sweden (Peloso *et al.*, 2004)	1987–2000	175	N/A	mild TBI	0–25 & > 65	1.4	N/A	N/A
Sweden (Kleiven *et al.*, 2003)	1987–2000	259	N/A	all TBI	15–19 & > 75	2.1	fall (54%)	RTA (26%)
Spain (Brell and Ibanez 2001)	1999	227[BG]	N/A	mild TBI	N/A	N/A	N/A	N/A
Finland (Alaranta *et al.*, 2000)	1991–1995	100	N/A	H.P.	[a]	[a]	fall (61%)	RTA (26%)
Portugal (Santos *et al.*, 2003)	1996	137	N/A	H.P.	20–29	1.8	N/A	N/A

[a][BG] best guess; N/A not available; [a] data from the abstract, * children only, ^ neurosurgically treated, ° moderate and severe H.P; H.P: hospitalised patients; RTA road traffic accident.

Table 2 Average cost (€ 2004) per inpatient with traumatic brain injury in three European countries[a]

Country	Average inpatient with TBI (€)	Inpatient with concussion (€)	Inpatient with severe brain injury (€)
Germany	2529	1071	6647[b]
Sweden[d]	3024	927[b]	6045
Spain[c]	2833	987	6362

[a]Costs were inflated with consumer price index, and converted to Euros adjusted for purchasing power (Eurostat, 2004a, b; European Central Bank, 2004).

[b]Average of several relevant costs in each country.

[c]For Spain, ratios between costs in Sweden and estimated costs for minor head injury (concussion) using German data on length of hospital stay were used to estimate average cost per inpatient with TBI and with severe brain injury.

[d]Estimate used in the model estimation for cost of trauma in Europe.

cause differences in the admitted population since TBI related to falls are milder than road traffic related accidents. Except for the UK, assault- and violence-related injuries do not constitute a problem in Europe yet, differently from the USA (Adekoya, 2004). European data on mortality are lower than published data for the US ($30/10^5$/year) (Kraus *et al.,* 1984) and much lower than data from South Africa ($81/10^5$/year) (Nell and Brown 1991) and Colombia ($120/10^5$/year) (Gutierrez *et al.,* 2000).

It is at this stage not possible to provide any sound estimate for the total costs of TBI in Europe due to the lack of essential data on medical outpatient care, direct non-medical services and indirect costs. The little existing data mainly focuses on hospital care, and often only applies to selected TBI patients. In this respect, the Swedish register analysis is likely to provide the most up-to-date and comprehensive assessment of inpatient costs. The differences in healthcare systems between the USA and Europe make the Swedish inpatient statistics more suitable for a conservative estimate of the cost of TBI as part of the European cost of brain disorders. While these costs are probably not representative of either common care patterns or of TBI patients overall, they suggest that costs due to acute hospitalization are only a small part of the direct and total costs of TBI.

To obtain a ballpark figure for total costs, it is of interest to consider evidence from the USA, where more research has been conducted in this area. According to a US study (Max *et al.,* 1991) using 1984–86 data, the average lifetime cost per TBI case was $197 163 (scaled to 2004 price levels). Total lifetime costs associated with all head injuries resulting in death or hospitalization in 1985 were thus estimated to $64.6bn (2004 prices), with 65% of costs being attributable to survivors and 35% to fatalities. The study also showed that the lifetime economic costs of TBI are dominated by indirect costs, which account for 88% of the total burden, and most of the direct costs are incurred in the acute hospital setting. However, only the cost of brain injuries resulting in hospitalization were included and the results did not cover direct medical and non-medical costs such as cognitive rehabilitation, neuropsychological services, or different types of living and support services, nor did they consider the costs of informal care. Therefore, it is likely that that direct costs actually account for a larger proportion of total costs; overall, the above figures are likely to be conservative estimates. Thompson and colleagues (Thompson *et al.,* 2001) also highlighted the difficulties of obtaining comprehensive and consistent data on resource use related to TBI, such as the identification of all relevant patients, the inclusion of injuries that do not result in hospitalization, and the tracking of long-term outcomes.

In the case of TBI, the incidence and care patterns can vary substantially across countries. Therefore, it is extremely difficult to generate any European-wide estimate of the total costs of TBI on the basis of the scarce existing data. Furthermore, the little existing evidence refers to different timeframes, which makes combination of the data impossible. Any estimate can only constitute speculation at this point. There are two ways in which the limited existing evidence could be used for two types of best guess:

- Using the 1-year cost of inpatient care for Sweden (€4562 per admitted patient) as a basis for extrapolation to other countries, adjusting for relative and absolute differences in price levels, combined with an average incidence rate for Europe. While there is not a well-defined pattern for the incidence of TBI across Europe, the incidence rate of $235/10^5$/year for hospitalized patients can be considered a best guess for a European average at this stage.
- Applying the conservative US estimate of total lifetime costs per TBI case of $197 163 (€168 100, not adjusted for price level index), adjusting for differences in price levels between the USA and Europe, as well as between European countries. This can again be combined with the assumed incidence rate of $235/10^5$/year for hospitalized patients across Europe. Since the distribution of direct and indirect costs for TBI is likely to vary across countries and is not necessarily similar to the one found in the USA, the assumption that indirect costs account for 88% of total lifetime costs in Europe would have to be used bearing this important caveat in mind.

The first estimate has the benefit of being based on inpatient data for one European country, whereas the second estimate is a rough application of total lifetime costs from the USA to the whole of Europe. Both approaches are based on the assumption that epidemi-

ological and treatment patterns do not vary across countries or regions. Although this is likely not to be the case, particularly considering the heterogeneity within Europe, it is the best estimate that can be derived on the basis of currently existing information. The differences in healthcare systems between the US and Europe make the Swedish inpatient statistics more suitable for a conservative estimate of the cost of TBI as part of the European burden of brain disorders.

Conclusions

Twelve countries in Europe have reported their epidemiological data regarding TBI. These reports contain incidence of TBI on a national or regional level, main causes of trauma and gender features. There are few data about incidence by age, mortality rates and practically no data about prevalence of TBI and the costs of the condition. European data (mainly for incidence and trauma causes) differ from US-based studies and therefore a straightforward application of US studies to Europe is not feasible. Future study directions will include prevalence data that are now unavailable in Europe.

Overall, economic evidence on TBI is presently scarce in Europe. Available information is mostly related to hospital treatment, which probably only constitutes a relatively small component of overall costs resulting from TBI. In light of this, there is a strong need for comprehensive cost-of-illness studies in this area that address both direct and indirect costs. The lifetime costs of TBI should be assessed through long-term population and register studies. Since mild TBI cases may not always be captured in national databases, it is also important to stratify the costs by severity, using a standard measurement scale. As a longer term goal, a relevant measurement tool to assess quality of life in patients should be developed, as the intangible costs of TBI are likely to be substantial.

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