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SURGICAL SYMPOSIUM CONTRIBUTION

The Burden of High-Energy Musculoskeletal Trauma in High-Income Countries

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Abstract

Introduction to the problem Though declining in the recent decades, high-energy musculoskeletal trauma remains a major contributor to the burden of disease in high-income countries (HICs). However, due to limitations in the available body of the literature, evaluation of this burden is challenging. The purpose of this review is to assess: (1) the current epidemiologic data on the surgical burden of high-energy musculoskeletal trauma in HICs; (2) the current data on the economic impact of high-energy musculoskeletal trauma; and (3) potential strategies for addressing gaps in musculoskeletal trauma care for the future.

Review of literature In 2016, mortality from road traffic injuries (RTIs) between the ages of 15–49 was reported to be 9.5% (9.0–9.9) in high-income countries, accounting for approximately 255 million DALYs. While RTIs do not fully capture the extent of high-energy musculoskeletal trauma, as the most common mechanism, they serve as a useful indicator of the impact on the surgical and economic burden. In 2009, the global losses related to RTIs were estimated to be 518 billion USD, costing governments between 1 and 3% of their gross domestic product (GDP). In the last decade, both the total direct per-person healthcare cost and the incremental direct per-person costs for those with a musculoskeletal injury in the USA rose 75 and 58%, respectively.

Future directions: addressing the gaps While its impact is large, research on musculoskeletal conditions, including high-energy trauma, is underfunded compared to other fields of medicine. An increased awareness among policy makers and healthcare professionals of the importance of care for the high-energy musculoskeletal trauma patient is critical. Full implementation of trauma systems is imperative, and metrics such as the ICD–DALY have the potential to allow for real-time evaluation of prevention and treatment programs aimed to reduce injury-related morbidity and mortality. The dearth in knowledge in optimal and cost-effective post-acute care for high-energy musculoskeletal trauma is a reason for concern, especially since almost half of the costs are attributed to this phase of care. Multidisciplinary rehabilitation teams as part of a musculoskeletal trauma system may be of interest to decrease further the long-term negative effects and the economic burden of high-energy musculoskeletal trauma.

Introduction to problem

Mortality caused by road traffic injuries (RTIs) as a surrogate for high-energy trauma has steadily declined in high-income countries (HICs) over the past decades [1]. However, it remains a major contributor to the overall burden of disease. In addition, trauma primarily affects the most productive age group, and as a result, it greatly

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impacts the work force and has a substantial economic burden. In the USA in 2013 alone, the combined medical and work-loss costs of fatal injuries exceeded $214 billion. Costs from fatal injuries represent approximately one third of the total $671 billion medical and work-loss costs associated with both fatal and non-fatal injuries [2].

Evaluation of the burden of high-energy musculoskeletal trauma is challenging. Fatal and non-fatal injuries reported by organizations such as the WHO and CDC are available in limited categories. These are restricted to cause or mechanism of injury (adverse effects, fire/heat, poisoning, or transport related) and intent (unintentional, violence related, undetermined). Since high-energy musculoskeletal trauma consists of a wide variety of pathologies, ranging from falls to motor vehicle collisions, motorcycle collisions and pedestrian trauma, and is present in several but not all of these categories, definitive numbers are difficult to obtain. Furthermore, there is a plethora of injury patterns, injury severities and sequela associated with high-energy musculoskeletal trauma.

The formulation and implementation of trauma systems by the WHO in the early 2000s has helped reduce mortality due to high-energy trauma globally [3–5]. These trauma systems are organized, coordinated efforts in a defined geographic area that deliver the full range of care to all injured patients [6]. This care includes education, prevention programs, implementation and optimization of the prehospital care phase, acute care resources and facilities, and post-hospital care. Having an established and optimized trauma system is essential to improve the outcomes of those who sustain high-energy extremity trauma. It has been demonstrated that those sustaining severe lower-limb and pelvic injuries benefit from treatment at a trauma center [7–9].

A major challenge is that it is difficult to separate musculoskeletal trauma care from the trauma care system as a whole in the first phases of the system. General and musculoskeletal trauma care shares the same root cause and initial management. Hence, prevention and many aspects of prehospital and acute care phases are identical, which is also true to a lesser degree during the post-resuscitation and post-hospital care phases. However, there is value in considering the unique aspects of a musculoskeletal trauma care system as its own entity in order to focus and optimize care, with the goal of reducing the clinical and economic burden of musculoskeletal injury.

The purpose of this review is to evaluate: (1) the current data on the surgical burden of high-energy musculoskeletal trauma in HICs by means of epidemiology, distribution, and trends; (2) existing reports on the economic impact of high-energy musculoskeletal trauma; and (3) gaps and strategies for musculoskeletal trauma care for the future.

Burden of musculoskeletal trauma in high-income countries: review of literature

A major obstacle in evaluating data concerning high-energy musculoskeletal trauma in HICs is the lack of adequate epidemiologic and economic data, specifically that describing high-energy musculoskeletal trauma. The Global Burden of Disease (GBD) project attempts to quantify and rank the morbidity and mortality of many disease conditions. Although data for both general musculoskeletal conditions and injury are known and continue to climb the rankings with each Global Burden of Disease report [10], these reports do not subclassify musculoskeletal injury within either the musculoskeletal disease or trauma categories. The impact of musculoskeletal injury must be conferred by considering its overall contribution to musculoskeletal disease, which includes both traumatic and non-traumatic conditions.

In the USA, the CDC conducts a survey called the National Health Interview Survey (NHIS), which monitors the health of the nation on a broad range of health topics through personal household interviews. According to the 2015 NHIS report, self-reported limitations in activities of daily living attributable to musculoskeletal injury (fractures or bone/joint injury) account for approximately 9% of all musculoskeletal conditions. In terms of prevalence, nearly 3% of Americans reported some impairment related to musculoskeletal injury. Unfortunately, these data do not differentiate high-energy from low-energy trauma. These data also do not account for the severity of impairment from high-energy musculoskeletal trauma, which is likely much greater than that from more common conditions, such as back or neck pain.

In the absence of population-level data on musculoskeletal injury in high-income countries (HICs), we can use injury mortality as a surrogate for high-energy trauma, with road traffic injuries (RTIs) being the most common mechanism. Globally, RTIs are considered to be the leading cause of death among people aged 15–29 and the third leading cause of mortality among those aged 15–44. [11] It is estimated that RTIs account for 9.5 (9.0–9.9) of deaths between the ages of 15 and 49 in high-income countries as a result of RTIs in 2016, which is a decrease of 4.7% since 1990 [1].

Falls are another common source of pelvic and extremity injury that could be classified as either high or low energy. One of the notable challenges in assessing the burden of high-energy trauma is that there is not a strict definition of high- versus low-energy trauma. In younger patients, a high-energy fall is commonly considered to be a fall from a significant height, but in older patients even a fall down a few steps can result in a complex pelvic or acetabular injury that would be better characterized as a high-energy injury, despite the lower kinetic energy. Thus, it is more difficult to draw conclusions from fall data, but one can extrapolate that the majority of fall-related mortality in younger patients is due to high-energy trauma, while falls in older adults result from low-energy trauma. Table 1 depicts the mortality rate due to falls and RTIs per 100,000 persons for the USA in 2016 adapted from the Centres for Disease Control and Prevention (CDC). The Global Burden of Disease (GBD) data report that between 1999 and 2006 there has been an increase in mortality caused by falls in the population over 70 years old [1].

A more direct method to estimate the burden of high-energy musculoskeletal trauma is to determine the incidence of fracture patterns commonly associated with high-energy mechanisms. Pelvic ring injuries have an estimated annual incidence of 20–37 per 100,000 persons [12–15]. Open RTI-related fractures are reported to occur at a rate of 5.8 per 100,000 person years, [16], and traumatic cervical spine fractures are reported to occur at a rate of 15–65 per 100,000 admissions [17]. Table 2 shows an overview of selected data on incidence of several fracture types caused by high-energy trauma.

Although these numbers are incomplete, it is clear that high-energy musculoskeletal trauma is not rare. One way of improving the knowledge on epidemiology of high-energy musculoskeletal trauma is by means of a regional or national registry system. Despite ample resources, the implementation of these registries in HICs remains sparse [29, 30].

The burden of high-energy musculoskeletal trauma is not only measured by mortality. The long-term disability and loss of productivity are a large contributor to the economic burden.

To adequately describe this, other parameters such as years of life lost (YLL), years lost to disability (YLD), and disability-adjusted life years (DALYs) are more appropriate. DALYs for a disease or health condition are calculated as the sum of the years of life lost (YLL) due to premature mortality in the population and the years lost due to disability (YLD) for people living with the health condition or its consequences [31]. In short, DALYs are the sum of both morbidity and mortality. Total DALYs from RTIs for all ages decreased by 1.6% (− 3.8 to 6.2) from 260 million (243–277 million) in 1990 to 255 million (236–281 million) in 2016 [32].

In spite of the decline, there remain a significant number of DALY’s per 100,000 persons in selected HICs for the productive age group (Table 3). A recent Australian study revealed that while DALYs declined for motor vehicle occupants, motorcyclists, and pedestrians, there was a 56% increase in DALYs for pedal cyclists [33]. Because the DALY has a very small number of categories for disability weights relative to the immense number of possible disease states related to injury, Kim et al. [34] developed the ICD–DALY, which aims to assign a disability weight for every International Classification of Disease (ICD) code related to injury. This has the potential to allow efficient and accurate assessment of disability weights and hence

Table 2 Incidence per different injury types

Injury type	Author	Incidence (per 100,000 persons per year)
Pelvic ring	Melton et al. [13]	37
	Ragnarsson et al. [14]	20
	Balogh et al. [15]	23
Acetabular fracture	Laird et al. [18]	3
	Rinne et al. [19]	8.1
Cervical spine	Hu et al. [20]	12
	Fredo et al. [21]	11.8
Femoral shaft	Weiss et al. [22]	10
	Enninghorst et al. [23]	10.1[a]
Tibial shaft	Weiss et al. [24]	4.8[a]
Ankle fracture	Thur et al. [25]	13.5[a]
Humerus	Ekholm et al. [26]	2.9[a]
	Robinson et al. [27]	1.6[a]
Distal radius	Diamantopoulos et al. [28]	6.1 Male[a] 4.0 Female[a]

[a]Represents the incidence caused specifically by falls from height, sports, and RTIs

Table 1 Mortality rates according to trauma mechanism and age group. Created from data on https://webappa.cdc.gov/sasweb/ncipc/mortrate.html

Mechanism	Age	Number of deaths	Crude rate	Age-adjusted rate
Fall	20–64	4891	2.55	2.2
Fall	>65	29,688	60.25	61.69
RTIs	20–64	29,634	15.45	15.33
RTIs	>65	8269	16.79	17.11

Table 3 DALY's per 100,000 persons 2016 ages 15–49 both sexes in selected HICs. (1) (Created from data on https://vizhub.healthdata.org/gbd-compare/)

Country	DALY	Range
Australia	560	489–641
Austria	473	388–559
Canada	607	543–691
France	617	492–713
Germany	456	372–546
Japan	315	273–370
The Netherlands	381	314–463
UK	381	336–442
USA	1046	974–1125

DALYs at both the individual and population levels using existing databases that currently use ICD–10. This also would greatly expand the pool of data available and could allow for real-time evaluation of efforts to reduce injury-related morbidity and mortality through prevention and treatment programs.

With respect to the economic burden, traumatic injuries in HICs such as the USA rank as the second most expensive condition in terms of healthcare spending, exceeded only by heart disease [35]. In 2009, the global losses related to RTIs are estimated to be 518 billion USD and cost governments the equivalent of 1 and 3% of their gross domestic product (GDP) [36]. In the last decade, both the total direct per-person healthcare cost and the incremental direct per-person costs for those with a musculoskeletal injury in the USA rose 75 and 58%, respectively.

An Australian study group reported the estimated costs of health loss associated with road traffic injuries over $14 billion during 2007–2015 in the state of Victoria [33]. One study reported a complication rate in high-energy trauma patients of 63%, with an attributable increase in median total hospital costs when adjusted for confounding variables which was approximately $40,000 for those with major complications [37].

When evaluating societal costs due to injury, 20% can be attributed to medical and related costs, another 35% are due to productivity losses due to death, and 45% are due to productivity losses due to disability [9]. Of those working before a traumatic injury from a moderate to high-energy force with a musculoskeletal injury with an Abbreviated Injury Scale (AIS) of 3 or more, only 58% have returned to work at 1 year [7]. Social deprivation is associated with a significant increase in the incidence of fractures, including both high- and low-energy injuries, in the most deprived 10% of the population [38]. Furthermore, some subgroups such as women, those with a lower socioeconomic level and those using illicit drugs, seem prone to prolonged disability [39].

It is evident that huge gains can be made by preventing mortality and long-term disability. Besides losses in terms of economic productivity and quality of life, RTIs strain healthcare services' financial resources, hospital bed occupancy, and demand placed on health professionals [3, 36].

Future directions: addressing gaps

Both the surgical burden and economic burden of high-energy musculoskeletal trauma are undeniably large in HICs. It is also clear that, to date, we are bound by sub-optimal data on this topic. Musculoskeletal conditions, including high-energy musculoskeletal trauma, are common, disabling, and costly, and still remain under-recognized, underappreciated, and under-resourced compared to other fields of medicine [10].

As a first step, it is important to continue to expand and optimize data collection to more accurately quantify the burden of high-energy musculoskeletal trauma. By having a better understanding of relative incidence and trends in high-energy musculoskeletal trauma, proper strategies to decrease their burden can be developed. There needs to be an increased awareness among policy makers and healthcare professionals of the importance of allocating funding resources in HICs toward this effort. Regional and national registries are one option to begin improving the knowledge of high-energy musculoskeletal trauma epidemiology, processes, and outcomes. These registries can help identify subgroups in the populations at risk of injury, adverse events, and prolonged disability, which can in turn inform primary and secondary prevention programs. Furthermore, it is worth evaluating the metrics to measure the burden of trauma, which at present is almost solely focused on mortality rates. DALYs are potentially useful as a composite metric that incorporate both mortality and long-term disability. This could be used more readily by linking disability weights to ICD-10 data, known as the ICD–DALY.

Ultimately, the most effective way of reducing the burden of high-energy trauma is the development of fully mature trauma systems, consisting of prevention programs, triage and transfer protocols, tiered and specialized hospital care, quality assurance systems, and post-hospital care. Prevention initiatives such as road safety measures and enforcement of speeding laws have proven effective. Still, measures aiming to reduce the number of pedestrian and pedal cyclist trauma can be effective and are not yet universally present in all HICs [40]. Other innovations, such as a tiered trauma activation, which include expedited evaluation by an emergency department physician and early trauma surgeon consultation, resulted in a reduced use of resources and lower hospital charges without increase in length of stay, time to disposition, or in-hospital mortality [41].

The dearth of knowledge on both effectiveness and cost-effectiveness of post-acute care for musculoskeletal trauma is problematic, particularly considering nearly half of total care costs are attributed to this phase. Inadequate and inconsistent pain management after high-energy musculoskeletal trauma is a predictor of physical disability. The effect of different pain management strategies and its effects on functional outcomes and costs is currently being studied in the PAIN study [42]. This initiative emphasizes the need for evidence-based and protocol-driven care with the goal of improving function and minimizing the economic burden of disability.

Only a few papers investigate different rehabilitation and follow-up strategies. One group reported early access to physical therapy and specialty care management to reduce the duration of care, cost of claims, and therapy visits, therefore alleviating some of the economic burden [43]. Another group described, contrary to their prior expectations, that intensive case management did not reduce work incapacity as compared to standard case management, but increased healthcare consumption and treatment costs [44].

Multidisciplinary rehabilitation teams, as part of a musculoskeletal trauma care system, may be of interest in the post-acute and long-term phases for patients sustaining high-energy musculoskeletal trauma. These teams could consist of representatives of orthopedic surgery, rehabilitation medicine, neurology, physical therapy, occupational therapy, orthotics and prosthetics, pain management, psychological counseling, and case management. Such an approach could be part of a trauma system aiming to reduce the negative impact of high-energy musculoskeletal trauma. The viability of such an approach in terms of functional outcomes and cost-effectiveness needs to be evaluated in the future.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest related to this work.

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