Goniewicz Krzysztof, Goniewicz Mariusz, Pawłowski Witold, Lasota Dorota. Epidemiology of road traffic accidents in adults. A systematic review. Journal of Education, Health and Sport. 2017;7(7):92-100. eISSN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.823475
http://ojs.ukw.edu.pl/index.php/johs/article/view/4591

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part B item 1223 (26.01.2017).
1223 Journal of Education, Health and Sport eISSN 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 25.06.2017. Revised: 02.07.2017. Accepted: 05.07.2017.

Epidemiology of road traffic accidents in adults. A systematic review

Epidemiologia wypadków drogowych z udziałem dorosłych

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Key words: road traffic accidents (RTA); injuries; road safety.

Słowa kluczowe: wypadki drogowe (RTA); obrażenia; bezpieczeństwo na drodze.

Abstract

Road accidents are a serious problem of the modern world. They are one of the main causes of injuries and are the third most numerous cause of death. Every year, about one million people, adults and children, die on the roads and several millions are injured. Mortality rate due to injuries from road accidents amounts to 2,2% of all deaths in the world. The research presents a mechanism of traffic accidents, pathophysiology of injury, partition of car accidents and characterized the insults of victims in various types of automobile accidents.

Injuries resulting from road accidents have numerous substantial consequences as they are related with releasing large amounts of kinetic energy which must be absorbed. Kinetic energy absorbing is the basic mechanism of injury arising during road accidents.

In apprising an automobile accident should take into consideration the type of the car accident and the extent of damage to the vehicle People participating in road accidents of high energy are especially endangered with substantial injuries. There is a close relationship between the rate of vehicle damages and seriousness of casualties' injuries.

Streszczenie

Wypadki drogowe stanowią poważny problem współczesnego świata. Są jedną z głównych przyczyn wszystkich urazów, które to stanowią trzecią przyczynę zgonów na świecie. Każdego roku na drogach świata ginie około miliona osób dorosłych i dzieci, a kilkanaście milionów zostaje rannych. Umieralność z powodu obrażeń poniesionych w wyniku wypadków drogowych stanowi 2,2% wszystkich zgonów na świecie.
W pracy przedstawiono mechanizm wypadków drogowych, patofizjologię obrażeń, podział wypadków samochodowych oraz scharakteryzowano obrażenia poszkodowanych w różnych typach wypadków samochodowych.

Obrażenia powstałe w wyniku wypadków drogowych pociągają za sobą bardzo poważne skutki, gdyż związane są one z uwalnianiem dużej energii kinetycznej, która musi zostać pochłonięta. Pochłanianie energii kinetycznej jest podstawowym mechanizmem powstawania obrażeń w wyniku wypadków drogowych.
Oceniając wypadek samochodowy należy zwrócić uwagę na typ wypadku samochodowego oraz stopień uszkodzenia pojazdu. Poszkodowani z wypadków o dużej energii są szczególnie narażeni na ciężkie obrażenia. Istnieje ścisły związek między stopniem uszkodzenia pojazdu a ciężkością obrażeń u uczestników wypadku.

Introduction

Problems of road accidents occurred at the beginning of motorization development. In 1769, Nicolas-Joseph Cugnot designed and built the first vehicle steam driven and caused the first accident when he hit a wall when driving it. The first collision of two cars was registered in 1893. In the USA, in 1895, only 4 vehicles were used in the whole country but two of them took part in a collision in Saint Louis. As a result, one of drivers had serious body injuries [13]. In the course of tens of years since that accident, the issue of road accidents grew to an epidemic amount. At present it is the most important problem in the field of medical and social service all over the world. Injuries and damages resulting from road accidents involve substantial costs and losses that Brongel called "the most serious and the most expensive war of the modern world" [1].

Constant motorization development, especially within past few years, is related with very serious growth in road accidents number. Not only drivers and passengers are casualties but also pedestrians (most often children and elders). Nowadays, a fatal road accidents occurs

every 50 seconds and every 2 seconds there is an accident resulting in people injuries. Every year, about one million people, adults and children, die on the roads and several millions are injured. Mortality rate due to injuries from road accidents amounts to 2,2% of all deaths in the world [2,3]. According to estimations of the World Health Organization, in 2020, the number of deaths in road accidents can increase to even 2 millions a year [4].

The level of traffic security is assessed by the number of accidents and amount of their results. According to this, Poland holds one of the last positions in such informal ranking. During past decade, about 19 died and about 200 persons was injured in road accidents every day. At present, over 5 thousand people dies in road accidents every year in Poland and over 60000 are injured [5].

According to Pierre-Jean Vaillard, road accidents happen because "… drivers of the present days drive vehicles of tomorrow on roads of the past…" [6]. Causes of road accidents are various and often very complex. The most frequent causes of road accidents include: lack of speed adjusting for present road conditions (especially exceeding speed limit), drivers bravado together with lack of proper driving skills (especially in case of young drivers), disrespecting road traffic rules, bad condition of vehicles and roads and problem of intoxicated drivers [7,8].

The analysis of road traffic prevention in Poland highlight that leading factor responsible for the high number of fatalities on the roads is disrespect of the rights of most vulnerable road users – pedestrians and cyclists. Fatality rate among pedestrians in absence of obvious wrongdoing on their part reaches almost 60% in urban areas. The second key risk factor is violation of the speed limits regarding to 75 and 54% of drivers within urban and rural areas. Next serious imminence of road traffic safety in Poland creates the young drivers. Data routinely collected by Police indicate that 18% of road traffic collisions in Poland are caused by drivers between 18 – 25 years of age. Furthermore, the fatality rate of road traffic injuries caused by them constitutes 18% of all road traffic deaths. Population of young drivers composes 10% of Polish inhabitants. According to the report, the major risk factors that leads to increasing number of fatalities affecting young drivers are lack of driving experience, the drink-driving, inclination to hazard behaviors on the roads and lack of adaptation of certain driving behaviors to respective road traffic conditions [9,10].

Road accidents mechanism

Injuries of adult people that result from road accidents involve various serious consequences. According to the first Newton's law of motion, "in the absence of a net force, a body either is at rest or moves in a straight line with constant speed". Vehicle's kinetic energy is absorbed when it suddenly stops due to a hit. Bodies of a driver and passengers are also moving at particular speed till the moment of an accident which stops in the moment of hitting any part in this vehicle's interior. Kinetic energy absorbing is the basic mechanism of injury arising during road accidents [3]. The main role in this mechanism is played by acceleration which is the quotient of the difference between initial and final speed and time. The higher acceleration and smaller amount of time of its value change, the larger injury force. The injury force is directly proportional to the product of mass and speed difference and inversely proportional to the time during which speed value is changed [11].
Kinetic energy of a moving body is proportional to mass and its speed square. In road accidents kinetic energy at the speed of 45 km/h is nine times larger than in case of a hit at 15 km/h [12].

Knowledge about injury mechanism enables predicting possible injuries of a road accident casualty. Overlook of injuries at the accident place may result in serious health harm of a casualty, lifelong disability or even death. People participating in road accidents of high

energy are especially endangered with substantial injuries. There is a close relationship between the rate of vehicle damages and seriousness of casualties' injuries [13].

Most often, people got injured because of hits against vehicle interior elements, impact of such elements (e.g. not secured objects, other passengers), violation of passengers site integrity by various elements or objects (e.g. other vehicle, a lamp post, a tree), falling out of a vehicle (partly or completely) and high temperature (fire) [14].

Injuries pathophysiology

The highest risk of death of casualties, both pedestrians and people inside vehicles, is related with multiple body injuries, of which 15-30% ends with death and 30-50% results in disabilities [15].

The extent of injuries is evaluated on the basis of pathophysiological parameters (pulse, arterial blood pressure, breath rate, level of consciousness, body temperature etc.), spread of injuries or by scales of injuries level. Pathology of multiple injuries is not a sum of all injuries and causes various diagnostic, therapeutic and organizational problems for medical service. Injuries may result in life threatening state, caused mainly by: substantial blood loss (hypovolemic shock), respiratory insufficiency, primary or secondary central nervous system impairments and loss of consciousness [16].

Hypovolemia at road accidents casualties most often results from massive bleeding (external or internal or both), with losses amounting to several liters. If the lost blood amount exceeds 1/3 of circulating blood (in case of an adult weighing 70kg it is about 1500 ml), hypovolemic shock is developed and further loss, to about 50% of circulating blood, leads to loss of consciousness. Due to a loss of large amounts of blood, circulating is centralized, flow of blood through organs (kidneys, liver and alimentary tract) is impaired and cells suffer from anoxia what results in start of various defensive mechanisms, which may be also fatal [17].

Respiratory insufficiencies after an injury may be caused by obstruction of the upper respiratory tract. Most often it occurs due to tongue root collapsing of unconscious persons. Obstructions can occur due to direct injuries of a larynx or a trachea.

Impairments of a thoracic cavity wall, like fractures of several ribs, may lead to so called slack chest and paradoxical breathing what significantly limits air access to lungs. Breathing disorders can be also caused by open and pressure edema, which occurs due to e.g. bronchi or bronchioles crack. Lungs bruising and/or aspiration can directly impair gas interchange at the alveolus-capillary level [18].

Brain impairments are the most common cause of consciousness disorders. Direct mechanical brain impairments can cause specific anatomical changes, that express themselves by various consciousness disturbances and in the most serious cases, this disorders are accompanied by circulatory and respiratory disorders due to brain stem lesions. As a result of injuries, intracranial compartment syndrome (extradural and intradural hematomas or intracerebral hematoma, subarachnoid hemorrhage, cerebral edema) can develop. Consciousness disorders can occur due to secondary causes like ischemia and hypoxia of brain in the course of bleeding or respiratory obstruction [19]

Hypothermia causes acidosis intensity and coagulation disorders what is another problem as it limits operational possibilities, forces shortening of procedures performed during the preacute period [19].

Injuries directly cause tissues impairments, which directly and indirectly (through bleeding and anoxia) case complications in all organs. The more serious injury was, the more serious complications are. This phenomenon is called the systemic inflammatory response syndrome (SIRS – *systemic inflammatory response syndrome*) [15].

Mechanisms leading to car accidents are one of the criteria on the basis of which their classification is made. Due to arising mechanisms, car accidents can be divided into:head-on collisions, side collisions, back collisions, rollovers, collisions with vehicle's turn on horizontal plane.

Every one of the above mentioned types is characterized by specific injury types. The extent of injuries depends on the size and type of a vehicle. Smaller vehicles are able to absorb less amount of kinetic energy so there are more injuries and deaths in case of accidents with smaller vehicles. Service vehicles and small trucks have more firm construction so their drivers and passengers have more chance to survive an accident. In case of lorries and sports cars, there are more accidents with one participant only. Rollovers often occur in case of sports car accidents [18].

"Head-on collisions are most often simply called a road accident". During a head-on collision of two vehicles or a vehicle with stationary object, drivers and passengers continue moving forward despite having safety belts fastened and a vehicle is stopped (fast toward deceleration). Injuries of casualties mostly depend on the part of body they hit a vehicle's interior (a windscreen, a driving wheel, a distribution board) [19].

In case when a driver has seat belts not fastened, his or her knees hit a board, chest hit a driving wheel and a head hits on a windscreen, a sun visor or upper windscreen border. When kinetic energy is large, a driver may fall out of a vehicle. Similar injuries regard to a passenger having seatbelts not fastened (mostly injuries resulting from hitting a windscreen and a board, rarely on a driving wheel). If a driver and a passenger had their seatbelts fastened and a car was not equipped with airbags, then they would hit their knees on a distribution board. A head in such case is bent towards what causes a chin hits a sternum and sometimes a driving wheel. People sitting in back seats who have seatbelts not fastened hit front seats or may even fall out of a vehicle. They act as "secondary missiles" what means that their impact may cause injuries of a driver and passengers. In case of people who do not have seatbelts fastened at the accident moment, the order of injuries occurring is as below: knees – thighs – a hip – a chest – a head. In case of people with seatbelts fastened, injuries character depends on the impact force [20].

A hit on a windscreen most often causes head and face injuries. These are abrasions, bruising and superficial cut wounds of a forehead, a nose and a face. Strong impacts may result in serious injuries of soft tissues or lacerated wounds. Head injuries is often related with heavy bleeding what creates an impression of death hazard. However, head injuries are not the main hazard for a driver and/or passengers, but injuries of a respiratory tract, a chest, an abdomen and the cervical part of a spinal cord which can even be fatal. Due to a hit on the upper border of a windscreen, a cranial basis can be fractured, closed cranial lesions and cervical fractures [21].

A hit on a driving wheel may cause injuries of a face, a neck, a chest or an abdomen. The most frequent injuries resulting from a chest hit on a driving wheel include:
transverse fractures of a sternum (usually at the 3rd intercostal space), both sided ribs fracture, lungs perforation (caused by fractured ribs), hematomas and breakages of lungs parenchyma, heart breakage, lungs bruising, aerothorax edema, aortas tear, tearing of a liver and a spleen [21].

Depending on the type of hit, also the following injuries may occur: kidneys impairment, bladder lesion, intestines impairments, diaphragm injuries (diaphragmatic hernia). All of the above injuries may cause respiratory disorders, internal bleeding and bleeding shock.

Serious injuries occur more rarely since modern cars have steering columns absorbing energy. Percentage of fatal casualties decreased to 12% and in case of serious injuries leading to death – to 38% [22].

Hitting a distribution board most often results in facial and knees injuries. Cervical fractures and chest injuries may also occur. Knees hitting a distribution board is related with such injuries as kneecap bruises, kneecap breakage and knee dislocation. If the energy is transferred further, thigh bone fractures, dislocations in a hip joint or neck of femur fractures and occur [22].

Drivers and passengers having seatbelts fastened are more probable to survive an accident as seatbelts protect them from hitting internal vehicle elements and from falling out. Properly put seatbelts stabilize a pelvis and a chest what makes that life threatening injuries are less frequently occurring. Fastening seatbelts in case of people sitting in front seats, decreases the risk of fatal injuries by 45% and serious injuries by 50%. However, they can suffer from impairments of cervical vertebras and spinal cord, clavicle fractures (at the area where a seatbelt adheres) and injuries of internal organs [23,24].

Similarly as seatbelts, also airbags have positive influence on decreased death rate and frequency of serious injuries. Airbags' role is to amortize an impact and to diffuse at least some part of energy released during an accident. Airbags prevent only from one impact. They protect whole body and head from injuries only in case when seatbelts are fastened and sitting in a proper position. When a seat bolster is in a back position, or a seat is drew up too close to a driving wheel, the efficiency of airbags is lower and it can even result in more serious injuries. Death risk is 50% lower only when airbags function together with seatbelts during an accident [23,24].

Side collisions most often occur in road crossings (a vehicle is hit on a side by other vehicle) and due to a side skidding (a vehicle hits a stationary object, e.g. a tree or a post). During this type of collision, energy goes laterally from the shoulder level and downwards, what results in injuries in one or both sides of casualty's body, depending on the side of impact. A head can be bent to the side and hit a window or a impacting vehicle if a window is broken. A head may also hit a door post.

Injuries occurring mechanism during a side accident is the same as in case of a head-on collision. Injuries mostly depend on the side of body hitting a vehicle element and impact energy. The most common injuries include: facial abrasions, limbs fractures, ribs fractures, shoulder girdles impairments, aortas and heart breakage. There may also occur breakages of a liver, a spleen or kidneys. Other injuries include cranial basis fractures, coup/countercoup brain impairments (resulting from side encephalon dislocation), cervical vertebras fractures, lungs bruising, pneumothorax, pelvis fractures.

In case of side collisions, more death regard to people from hit cars as the engine in a hitting vehicle is additional protection for its passengers. In case of a side collision with stationary objects and a driver or passengers have seatbelts not fastened, they may fall out of a vehicle, hit an object and fall back to vehicle's interior [23,24].

The least number of deaths is among casualties of back collisions. It results from the fact that people in a hit vehicle are protected by a trunk and back part of passengers area. People sitting in a hitting car are protected by the engine area. The most common situation is when a vehicle at a standstill is hit in the back by other vehicle. This type of collision can also happen when a vehicle going faster hits a vehicle in front of it. One of the most serious hazards related with such collisions is the risk of tank damage and its firing.

As a result of sudden acceleration of a hit vehicle, seat rests might bent. As a result, bodies of passengers or a driver will be drew back what causes hyperextension of their cervical

vertebras. It is especially dangerous when headrests are improperly set. This mechanism may also cause serious head and neck injuries, sometimes resulting in death. If a seat rest is broken, there is a hazard of lumbar vertebra impairments. Apart from acceleration mechanism, also toward deceleration may occur when a hit vehicle hits other object or when a driver suddenly brakes. In such situation, there is a higher risk of cervical vertebras injury and of internal organs lesions [25].

The mortality rate in case of rollovers (accidents when a vehicle is turned over) is lower thank during head-on or side collisions, providing that people of such vehicle do not fall out and a vehicle does not hit a solid object. The most common cause of these collisions is falling out of a road. When passengers have their seatbelts fastened, it is more probable they will survive. Seatbelts protect people from falling out of a vehicle. "The risk of death is 25 times higher in case of people who fall out of a vehicle" [26].

Injuries of turnovers casualties are various as the damaging force may act on any side of a vehicle. It is impossible to characterize specific distribution and type of injuries. However, it is more probable that spinal cord injuries occur as acting force is axial [27].

Collisions of this type happen most often when a vehicle is hit on its front or back side. As a result, one part of a vehicle is at a standstill while the other is moving rotationally. Injuries resulting from such collisions are similar as in case of head-on and side collisions [26].

Summary

Road accidents are a serious problem of the modern world. They are one of the main causes of injuries and are the third most numerous cause of death. Injuries resulting from road accidents have numerous substantial consequences as they are related with releasing large amounts of kinetic energy which must be absorbed. Kinetic energy absorbing is the basic mechanism of injury arising during road accidents. Most often, road accidents result in multiple and multi-organs injuries. They may be located in various parts of body. The extent and placement of injuries depends mainly on the type of an accident (head-on collisions, back collisions, side collisions, turnovers, collisions with vehicle's turn on horizontal plane), body area hit and the amount of energy absorbed by a casualty. The most common are the injuries of head and limbs. [22,23,24,25].

In order to improve traffic safety, the society should be properly educated about changes of road behavior, inevitability of penalties for rules breaking. Specialists of various branches related with traffic safety should be continuously trained [27]. Apart from the above, road conditions should be improved, dangerous areas must be protected, vehicles in bad technical condition should not be allowed to move on the roads and first aid trainings have to be organized in larger scale. Such activities may substantially improve road safety what will result in less number of accidents and fatal casualties.

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