INJURY MECHANISMS IN MOTORCYCLE ACCIDENTS

Peter M. Fuller, Ph.D.
Department of Anatomy
University of Louisville
School of Medicine
Louisville, Kentucky U.S.A.

John N. Snider, Ph.D.
Department of Industrial Engineering
University of Tennessee
Knoxville, Tennessee U.S.A.

ABSTRACT

The medical and scientific literature is replete with numerous case studies dealing with individual motorcycle accidents and the resulting injuries. The most noteworthy and extensive report to date has been the Hurt study that reported on over 900 individual motorcycle accidents. However, virtually none of the previous studies have looked carefully at the mechanism of the injuries resulting from motorcycle accidents. The present study has carefully analyzed over 125 motorcycle accidents in which there was an injury with an AIS of greater than 2. Of these 125 accidents, 58 were selected and a static reconstruction was performed, using exemplar vehicles and individuals to determine the exact vehicle and occupant kinematics that occurred during the accident sequence. It was determined from the static reconstructions, that while the predominate injury from the accidents is to the lower extremity, the injury is not by definition a crushing injury, but rather an impact injury. The leg is impacted by the opposing vehicle and then pushed out of the way. The true crushing injury is very seldom seen in motorcycle accidents. The soft tissue injury that occurs and that necessitates amputation in some cases, is the result of subsequent impacts of the body with the roadway.

INTRODUCTION

In reviewing the available data concerning injuries in motorcycle accidents, it is quite apparent that the leg region is the most frequently injured region of the body (1,2). While leg injuries seldom result in a fatality, they remain one of the most prevalent types of injuries seen in motorcycling. Injuries to the head region result in far more catastrophic injuries with

more devastating results and long term recovery and/or disability. However, the use of a protective helmet can and will significantly reduce head injuries. Other parts of the body can also be protected to a limited degree by the use of proper protective clothing.

To date there has been no well defined method to reduce or eliminate the types of leg injuries that are seen in motorcycle accidents. The motorcycle is an open machine that the rider sits astride with his/her legs along either side of the engine. In this type of posture the legs are vulnerable to injury from contact with another vehicle or obstacle. While there have been attempts by some and suggestions from others (3,4,5,6) that the use of some type of side protection device would eliminate or reduce leg injuries, to date research in this area has not supported the concept of a leg protection device that would eliminate or reduce leg injuries (7).

The work by Hurt at USC (1) remains the most extensive and exhaustive study done of motorcycle accidents and the injuries that resulted from those accidents. That study investigated and studied in depth over 900 motorcycle accidents in the Los Angeles area. Part of the study looked at the question of leg injuries and the possible role of crash bars to protect the leg region. They concluded that the use of a crash bar had no effect in reducing leg injuries. Their report showed that the use of crash bars may have some effect in reducing the injury to the lower leg, however it resulted in an increase of the injury to the knee, thigh and hip region of the body. More recently, the Hurt data has been reexamined with a view to the question of the effectiveness of crash bars, (8) and again the data shows no reduction in injuries with the use of crash bars.

The present study is an indepth review of over 125 motorcycle accidents in which there was an injury to the lower extremity. The injuries ranged from fracture of the metatarsals to hip dislocations. The major objective in this study was to look at the nature of the injury and the individual accident, to more clearly understand the mechanism of the injury. In most instances in which there is an injury to the lower extremity in a motorcycle accident, it appears to the attending physician that the injury is of a crushing nature. In fact, an examination of the hospital records, most notably the admitting report, will usually state something to the effect that this is a ".... crushing injury from a motorcycle accident." In reviewing each particular accident and the injuries that were sustained in the accident, it becomes quite apparent that few of the leg injuries are truly a crushing injury. It becomes evident that the vast majority of the injuries to the lower extremity are a high velocity impact to the leg region similar in many respects to the type of leg injury seen in pedestrian accidents.

METHODS

This study was aimed primarily at leg injuries, and therefore the type of accident cases we examined only addressed that area. The number of accident cases studied was 127 in which there was an injury to the lower extremity. The lower extremity was defined as any part of the body from the head of the femur, or hip joint, to the foot. The vast majority of the injuries were to the tibia/fibula region, which is often described as the lower leg. The next most often injured part of the lower extremity was the thigh region, in which the injury was a fracture of the femur. Injuries to the hip and foot were least often seen in this study, but again this was due to the type of accident studied.

The size of the motorcycle ranged from 90cc up to the largest touring motorcycles on the roadway today. The presence of crash bars on the accident vehicles in this sample size was notably low, with only five cases in which the presence of a crash bar was noted. The crash bars that were present were the standard off-the shelf type or the smaller version that are considered engine guards.

The speeds for the motorcycle in the accident scenario ranged from zero (stopped to make a turn) to a high of 45 mph. The most prevalent speed was in the range of 25-35 mph. Speeds of the adverse vehicle ranged from 10-45 mph, with the most often speed at the low end of that range.

The usual type of accident seen in this study was the situation in which the car makes a turn in front of the motorcyclist, and strikes the left side of the individual riding the motorcycle. Obviously this results in an injury to the left side of the body. There were a limited number of cases in which there was a stopped motorcycle that was struck by a moving car. Also, there were a limited number of cases in which the accident was a single vehicle accident. In this situation it is usually a matter of the motorcyclist leaving the roadway and striking an object off the roadway.

In studying these accidents, the police report was obtained and reviewed for data concerning the nature of the accident, including size of vehicles; speeds; direction of travel; point of impact; point of rest for the vehicles and occupants; and type of damage and location. Where possible, photographs of the accident vehicles were studied to determine the extent of the damage from the accident. A complete review of the medical records was done to determine the extent and nature of the injury. This included the admitting report, operative report, radiology report, and nursing notes. In most cases the x-rays were also reviewed. In many of the cases a complete examination of the motorcycle was done to determine and record the extent of the damage. This was

useful in assisting with the understanding of the accident scenario. The type of damage to particular parts of the motorcycle would often provide useful data in determining the type of accident and the direction of the forces in the collision. There were a limited number of cases in which the adverse vehicle was also available for study and examination. In these situations we were able to study and document the extent of the damage to the opposing vehicle. Again, this provided significant data as to the type of collision that was involved as well as helpful data as to the direction of force.

In cases in which one or both vehicles were available for inspection, they often provided valuable information concerning the points of contact of the body and thereby giving us data as to the mechanism by which the injury was produced. Frequently, it is possible to identify fabric transfer on one or both vehicles, location of material from clothing, and in some situations we were able to identify body imprints on one or both vehicles. These included dents in the fender and/or hood areas of the opposing vehicle, or a dent in the side of the gas tank.

All of the injuries sustained in the accident were recorded onto a data sheet and then given an AIS number (9). In addition to the AIS scaling system, we devised our own system for further defining the type of fractures that occurred in the different accidents (table 1). This system allowed us to classify each type of fracture as to bone, location of fracture and nature of fracture.

In total 127 accidents were studied in depth where there was an injury to the lower extremity. In addition to the lower extremity injuries, a record was also made of any other injuries that were sustained as well in the accident. For each of the accidents a determination was made as to the mechanism by which the injury occurred. Of particular interest was the nature of the fractures of the long bones and the mechanism by which the injury occurred.

Of the 127 cases studied, 58 were selected for a static reconstruction of the accident. In these situations we used exemplar vehicles which were of the same make, model and year as the accident vehicle. We also would use people who were of the same physical size as those involved in the accident that was being studied. Using the information regarding the damage to the vehicle, we could then align the vehicles to determine the angle of the collision. This would be based not only upon the damage that resulted from the accident, but in addition we also considered the injuries that resulted from the accident. The purpose here was to determine both the vehicle dynamics in the collision, and the rider/occupant kinematics.

RESULTS

TIBIA:

In Looking at the fractures of the long bones (i.e. tibia and femur) over half of the fractures were to the tibia, the number being 63% of the total fractures recorded. These ranged from simple non-displaced fractures to compound/comminuted fractures with significant soft tissue involvement. In studying the location of the fracture, the majority of the fractures were in the distal third of the tibia. Whenever there was a comminuted fracture of the middle and distal thirds of the tibia, there was an associated fracture of the fibula at the same location. Fractures of the tibial plateau were often associated with a fracture of the femoral condyles and significant involvement of the knee joint. Fractures at the tibial plateau that were displaced posteriorly often invaded the popliteal fossa, and the vessels and nerves with the fossa.

In examining the mechanism of injury through the use of exemplar vehicles and people, it is quite apparent that the injury to the middle and distal tibia is the result of the leg being impacted by the bumper of the adverse vehicle and then pushed in a rearward direction. This is typical of the situation where the automobile turns in front of the motorcyclist, and the latter then attempts an evasive maneuver to avoid the collision. The angle of collision between the two vehicle is usually less than 30 degrees. In this situation the leg is not pushed into the side of the motorcycle, but rather rearward along the side of the motorcycle.

In situations where fracture of the tibia occurs at the tibial plateau or the proximal one-third of the tibia, this is the result of the knee and upper tibia making contact with the fender region of the opposing vehicle. Again, the angle between the two vehicles is less than 30 degrees. When the impact to the leg is in this region of the body, there is often involvement of the peroneal nerve, which is just lateral and inferior to the knee. An injury to this nerve will affect the muscles of the anterior compartment of the lowrer leg and the result is foot drop and a numbness to the dorsum of the foot.

The type of fracture seen is usually a transverse or comminuted fracture in which there were many fragments of bone. A spiral or oblique fracture is seldom seen in accidents in which there are vehicle to vehicle collisions. We did observe a limited number of spiral fractures of the tibia, however, these were usually seen in situations of a single vehicle accident. In a single vehicle accident, the rider goes off the roadway and in an attempt to control himself and the vehicle puts his foot down and impacts the ground with sufficient force to cause a spiral fracture. The mechanism that results is this type of fracture is

a verticle or axial load as the foot impacts the ground. The force is transmitted through the foot and to the distal end of the tibia, often resulting in a tri-malleolar fracture and/or a spiral fracture of the tibial shaft.

Whenever there is a significant fracture involving the lower leg, with both the tibia and fibula involved, there is also soft tissue damage to the underlying tissue. This can be of particular concern when the blood vessels are damaged, and there is a loss of adequate blood supply. The main cause of the amputations is an inadequate blood supply to the tissue distal to the point of injury.

FEMUR:

The incidence of fractures to the femur were approximately half the number of tibial fractures. These usually occurred in the distal third of the femur, and were transverse fracture with little or no soft tissue involvement. The limited number of fractures at the head of the femur usually were associated with soft tissue injury, and dislocation of the head of the femur. Another problem seen with fractures of the head of the femur, was also a fracture of the acetabulum.

The fracture of the distal third of the femur is almost always the result of an indirect impact, rather than a direct impact as is seen in the tibial fractures. The static reconstruction showed that as the knee goes into the fender or grill of the adverse vehicle, the force is then transmitted along the long axis of the femur. While the distal portion of the femur is stronger than the shaft, the force is transmitted from the area of the femoral condyles to the shaft of the bone. The fracture then occurs at a point distal to the actual site of impact, and will usually be between the middle and distal third of the bone.

Fractures of the proximal third of the femur are usually the result of impact to the ground, and not from a direct impact with the opposing vehicle. In our study the limited number of cases where there was a fracture of the proximal third, it was determined for each of these that it was the result of an impact to the ground. When the neck of the femur is fractured, this is the result of the distal end of the femur being impacted, and then pushed rearward as the knee is held by the opposing vehicle. This is often seen in accidents where the knee goes into the compliant fender area of the car and is held there as the rider then slides forward.

Femoral fractures seldom have soft tissue involvement, and are usually transverse in nature. The lack of soft tissue injury is due to the anatomy of the thigh region. The femur is surrounded by large groups of muscles. The notable exception

is the accident where the neck is fracture and pushed rearward, and damages the muscles, nerves and vessels in the area.

ANKLE & FOOT:

Injuries to the ankle and foot region are the result of the foot being caught by the bumper and pushed rearward. We often see the situation where the foot is caught by the underside of the bumper, and results in fractures to the tarsal and metatarsals. These types of impacts can also have involvement of the blood vessels as they are close to the surface of the skin in this region, and thus are vulnerable to trauma in this area. Impacts to the foot/ankle can and will often result in dislocations of the ankle.

PATELLA:

The incidence of fracture to he patella is quite low. In the present study we recorded only 8 cases where there was a fracture of the patella. This fracture is usually see where there is a significant involvement the distal femur and the femoral condyles. When there is an explosive fracture of the distal portion of the femur, it is indicative of a high impact, and there will be an associated fracture of the patella. However, from the reconstructions performed that demonstrate a loading of the knee region, with a fracture of the distal femur, there is rarely a fracture of the patella at the same time.

DISCUSSION

In reviewing 125 motorcycle accidents in which there was a leg injury, it is quite apparent that the most frequently injured area of the leg is the region of the lower leg, with a fracture of the tibia and fibula. Whenever there was a comminution of the bone with soft tissue injury of the underlying tissue, the medical report would describe this as a crushing type of injury. While the injury may give this appearance to the attending physician, it becomes obvious when a careful analysis of the accident is made, that seldom is the injury mechanism a crushing injury. Using exemplar vehicles and people, and the information available concerning the speeds, and damage to the vehicles, we were able to reconstruct 63 of the accidents. In all but three of our cases this analysis showed the injury to be an impact type of injury, not unlike the situation where the pedestrian is impacted by an automobile. The leg is not crushed between the opposing vehicles, but rather is pushed rearward along the side of the vehicle.

Much of the soft tissue injury is the direct result of the sharp bone fragments causing lacerations of the muscles and vessels. Once the bones have been broken by the impact of the bumper or fender of the car, the structural integrity of the leg is then lost and as the leg i moved the sharp bone fragments cause additional injury. This type of injury comes from the inside out, rather from the outside in.

The mechanism of femoral fractures that occur in the motorcycle accident is different from that seen in the automobile accident. The work of Nahum (10) reports on the incidence and type of lower extremity injuries that occur in automobile accidents. The report of States (11) clearly shows the mechanism by which a posterior hip dislocation occurs in an automobile accident. However, in the motorcycle accident, rather than a hip dislocation, the more frequent fracture is a transverse fracture of the distal third of the femur. The reason for this can be attributed to the seated posture. In the automobile, the occupant usually sits with the knees forward and close together. However, the motorcycle rider sits with his legs astride of the gas tank and therefore are at approximately 45 degree angle. If there is a passenger behind the rider, there legs are at even a greater angle. In this position, the head of the femur is rotated deep into the acetabulum and is held firmly. In the normal sitting posture as seen in an automobile, the head is not as deep into the acetabulum, and upon impact, the head is driven posteriorly and can often result in a fracture to the rim of the acetabulum.

In reviewing 127 motorcycle accidents in which there was an injury to the lower extremity the mechanism by which these injuries occur is a high velocity impact, similar to that seen in pedestrian accidents. Static reconstruction of the accident clearly showed that the leg is not crushed between the two vehicles, but rather it impacted and then pushed rearward along the side of the motorcycle. In looking at the types of leg injuries that result from motorcycle accidents, the type of injury is very similar top that seen in pedestrian accidents.

REFERENCES

1. Hurt, H.H., Ouellet, J.V. & Thom, D.T. Motorcycle Accident Cause Factors and Identification of Countermeasures, Final Report, DOT-HS-5-00160, 1981.

2. Newman, J.A. & Webster, G.D. The Mechanics of Motorcycle Accidents, Proceedings, 18th Conference of the American Association for Automotive Medicine, 1974.

3. Chinn, B.P. Leg Protection for Motorcyclists. IRCOBI, 1986.

4. Hight, P.V., Langwieder, Mackay, M. An International Review of Motorcycle Crashworthiness. IRCOBI, 1986.

5. Jackson, R.D. A Characteristic Type of Motorcycle Fracture of the Tibia. Southern Medical Journal, v.63, pgs.222-225, 1970.

6. Ross, D.J. The Prevention of Leg Injuries in Motorcycle Accidents. Injury v. 15, pgs. 75-77,

7. Taguchi, M. & Fukuda, A. 1986 Yamaha/JARI Report on Motorcycle Collision Testing. Japan Automobile Research Institute. 1986.

8. Hurt, H.H., Ouellet, J.V., & Jennings, G. Motorcycle Crash Bar Effectiveness: A Re-Evaluation of Using AIS 80. 28th Proceedings American Association for Automotive Medicine, 1984.

9. American Association for Automotive Medicine Committee on Injury Scaling, The Abbreviated Injury Scale, 1980 Revision, AAAM, 1980.

10. Nahum, A.M., Siegel, A.W., Hight, P.V. & Brooks, S.H. Lower Extremity Injuries of Front Seat Occupants. Society of Automotive Engineers, 680483, 1968.

11. States, J.D. Adult Occupant Injuries of the Lower Limb., Biomechanical and Medical Aspects of Lower Limb Injuries, Society of Automotive Engineers, P-186, 1985.

TABLE - 1

UofL FRACTURE CLASSIFICATION

ARM	FOREARM	FEMUR	TIBIA	SPINE	PELVIS	HAND
1	2	3	4	5	6	7

PROXIMAL	MIDSHAFT	DISTAL
1	2	3

ANKLE	CLAVICLE	OTHER
91	92A	10

SCAPULA	PATELLA
92B	92C

SHAFT FRACTURES

A. SIMPLE FRACTURES

A1 SPIRAL	A2 OBLIQUE	A3 TRANSVERSE
	.1 PROXIMAL	
	.2 MIDSHAFT	
	.3 DISTAL	

B. WEDGE OR PIECE

B1 SPIRAL WEDGE	B2 BENDING PIECE	B3 2 0R 3 PIECES
	.1 PROXIMAL	
	.2 MIDSHAFT	
	.3 DISTAL	

C. BITS & BROKEN PIECES

C1 SEGMENTED FX.	C2 BROKEN PIECE	C3 FREE PIECES
	.1 PROXIMAL	
	.2 MIDSHAFT	
	.3 DISTAL	