LOWER LEG INJURIES IN REAL-WORLD FRONTAL ACCIDENTS

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ABSTRACT

The magnitude and the type of lower leg injuries observed in real-world frontal accidents as well as the injury mechanisms in this body region have been examined. An investigation into the APR (Association Peugeot Renault) accident database has been carried out. From 2,022 front-seat occupants, restrained or not, involved in a frontal collision, 208 sustained either a strain, a laceration into joint, a dislocation or a fracture below the tibial plateaux. An in-depth analysis of the injury mechanisms has been performed using the X-rays of 42 occupants.

The most prominent injuries are metatarsal fractures (39 cases), malleolar fractures (39 cases) and ankle sprains (44 cases).

The brake pedal increases significantly the number of injuries on the right foot of the drivers. However no differences have been found between the right and the left legs as far as drivers' ankles are concerned. Passengers sustain more injuries on their left ankle, and seem to have more injuries on their right foot, directly exposed to wheel well intrusions.

The most significant parameters which influence the lower leg injuries appear to be the delta-V correlated with the footwell intrusion and the configuration of the impact especially the overlap. The seat-belt use and the occupant's age do not affect significantly lower leg injuries.

Two main mechanisms are identified. In the first one, forces acting under the metatarsal condyles coupled with the inertial effect of a dorsiflexing foot produce metatarsal fractures. Malleolar fractures and ankle sprains are attributed to eversion/inversion motions caused by forces acting under the ball of the foot.

This study represents a basis for tests involving cadavers and the Hybrid III dummy.

1. INTRODUCTION.

Although lower leg injuries are not life-threatening, they result in long-term disability and heavy cost to society (Pletschen [1990][10])*, which includes medical costs, productivity losses and administrative expenses.

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* Number in brackets designates the references at the end of the paper.

Lower limbs are one of the most common sites of injuries in car accidents together with head and thorax, especially in frontal impacts. Taking into account all AIS 2+ injuries occurring in frontal impacts and recorded in the APR accident database, lower extremities were found to be the second body region after the head for restrained drivers, and the fourth after the thorax, head and upper extremities for the restrained right-front passengers.

Most of the previous studies were focused on the upper leg since the mechanism of injury originating from the impact of the knee on the dashboard is quite simple and very frequent. For this reason, some comparisons will be made between the upper leg and the lower leg, throughout this paper.

The objective of this study is to evaluate the magnitude and the type of lower leg injuries as well as the main injury mechanisms, on which our attention must be focused, in order to face the legislation requirements, and improve the Hybrid III biofidelity. Some authors such as Ward [1991][13] have pointed out the deficiencies of the ECE regulations controlling the footwell intrusion. The capacity for the instrumented lower leg of the Hybrid III dummy to measure lower leg tolerances has not been well established and further research is necessary.

2. ANATOMY OF THE LOWER EXTREMITIES.

The talus hinges with the tibia and the fibula between the medial and the lateral malleolus, (figure 1). This makes up the ankle joint. The calcaneum underneath bears the talus. Metatarsals and phalanges are connected to the talus and the calcaneum through a juxtaposition of several bones: the navicular, the cuboid and the three cuneiforms. The ankle joint is respectively strengthened laterally and medially by the calcaneal fibular and the deltoid ligaments. Those ligaments are the site of so-called "ankle sprains".

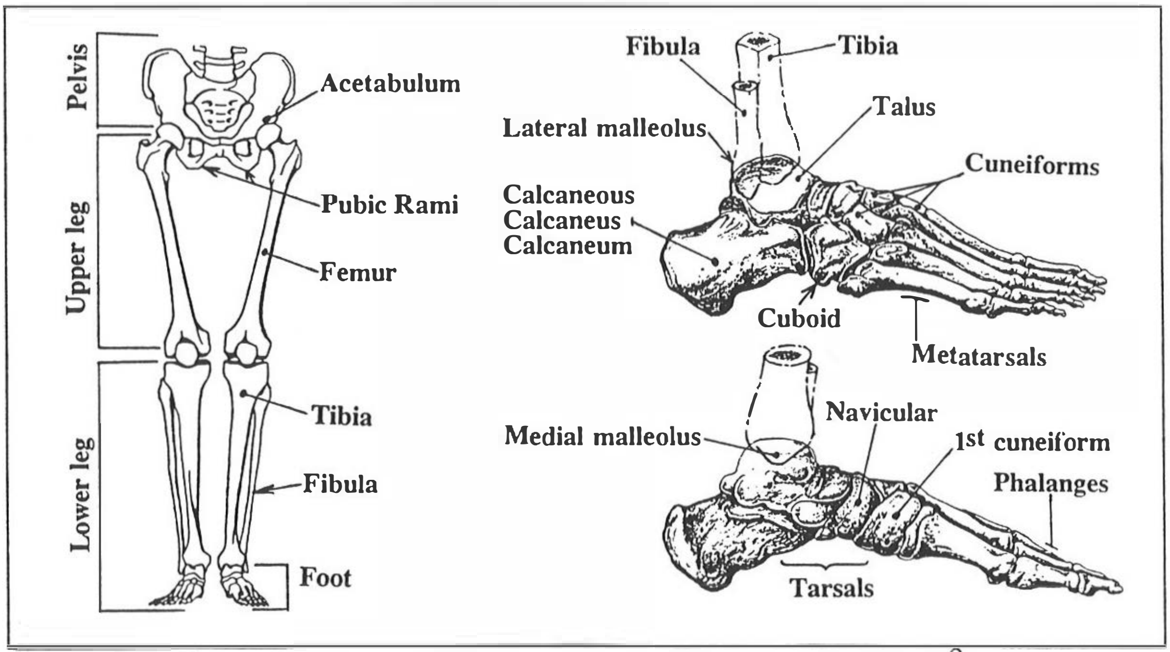


Figure 1: anatomy of the lower extremities, Huelke [1986][3].

3. BIBLIOGRAPHY.

Thorough investigations of lower leg injuries using accident databases, with a view to determining the injury mechanisms are quite recent. Some authors analyse the areas of contact between the occupant and the vehicle. Huelke [1991][4] distinguishes two main areas: the dashboard which causes fractures to the knee, femur and hip joint, and the footwell including the pedals which cause foot and ankle fractures. For the drivers, AIS 2+ injuries of the tibia/fibula are attributed to the dashboards (53% of the cases) and to the footwell/pedals (37% of the cases).

Pattimore [1991][9] and Ward [1991][13] used rough areas of contact coded in their computerized file, in conjunction with each lesion. According to Pattimore [1991][9], the footwell is the main source of injuries if drivers and passengers are considered together. However, the pedals intervene in 49 % of the foot and ankle fractures of drivers. Ward [1991][13] noticed that the footwell created more AIS 2+ lesions (39,5%) than the dashboard (24,6%). Indeed, the dashboard generates more AIS 1+ lesions (40,7%) than the footwell (8,2%). Those analyses make it difficult to study the mechanisms thoroughly.

Other authors have analysed more precisely a limited sample of cases, sometimes using X-rays. Morgan [1991][6] has attributed a mechanism for each of his 480 occupants involved in frontal collisions. Six different mechanisms were identified. The main mechanisms involve contact with the foot controls for the drivers and direct contact with the footwell for the passengers. Dorsiflexion together with an axial load along the tibia is assumed to be the right phenomena.

Lestina [1992][5] from 23 cases including X-rays only studied the ankle, the navicular and the calcaneal fractures. Inversion and eversion caused ankle fractures in 15 cases out of 23, mainly malleolar fractures.

Otte [1992][8] studies ankle and foot fractures from basic movements such as dorsiflexion, plantar flexion, compression, pronation and supination. By combining them, he defines complex mechanisms. The origins of lesions are:

- direct impacts, the body's inertial effect and compression between intruding structures,
- rotations, some of them being due to slipping off the pedals.

States [1971][11] describes a specific mechanism of fracture which consists of an entrapment of the lower leg between the dashboard and the floor. It could occur together with torque or flexion and create tibial diaphysis fractures, (States [1986][12]). Slipping off the pedals may explain ankle and foot fractures.

Backaitis [1987][1] also reports 2 cases of ankle fractures which are attributed to the pedals.

Nahum [1968][7] defines 2 kinds of mechanism: the direct impact as it happened in the case of tibial diaphysis fracture presented in his paper, and the forced motions such as those causing a malleolar fractures.

Zeidler [1981][14] focuses on the foot and ankle fractures of drivers involved in glance-off frontal car-to-car impacts. However this configuration, although rare (12/82 cases involved in car-to-car impacts on the driver near side with up to 2/3 overlap), highlights the damaging effect of direct impact on the foot and ankle.

In many papers, body regions are not precisely defined. Some of them only deal with ankle and foot injuries. So, it is often difficult to determine the main body regions and mechanisms on which our attention must be focused. Gloyns [1979][2] does describe precisely the injuries, but in slightly more violent accidents than the average.

In some publications, the influence of a parameter such as the belt, delta-V is evaluated without taking into account the number of occupants involved in each class defined by the parameter.

For those reasons, and also in order to help the synthesis and the criticism of the many figures found in the literature, an in-depth study has been performed using the APR accident database.

4. ACCIDENT ANALYSIS FROM THE APR FILE.

4.1. Introduction.

This investigation concerns **208** front-seat occupants (see Annexe) out of **2,022** who sustain at least either a sprain, a laceration into joint, a dislocation or a fracture to the lower leg. Sometimes, for comparison purposes, **396** occupants with similar injuries to the lower extremities and the pelvis have been considered. They include the 208 previous ones. The 2,022 occupants involved were selected as follows:

- single frontal collisions, with delta-V and acceleration known
- cars with first registration after 1972.
- non-ejected front-seat occupants tightly restrained or unrestrained, with age known.

The injury codes of the computerized files have been revised for the 396 occupants from the description recorded in the medical files.

The lower extremities were divided into 9 body areas:

The upper leg:
1- Hip joint, acetabulum, femoral head.
2- Pubic rami.
3- Other parts of the pelvis.
4- Femoral diaphysis.
5- Knee including femoral condyles and tibial plateaux.

The lower leg:
6- Tibial diaphysis.
7- Ankle: malleolus, talus, calcaneum, navicular and the cuneiforms.
8- Metatarsus.
9- Toes.

4.2. Relative proportion of the lesions.

Injured occupants (restrained or not) at the level of the foot and the ankle (162/396 = 40,9%), with severities as defined by the criteria specified earlier, are as numerous as those suffering knee injuries (160/396 = 40,4%), (figure 2). Hip joint, femoral diaphysis and even metatarsal fractures are also quite common, (77/396 = 19,4%, 74/396 = 18,6%, 42/396 = 10,6% respectively).

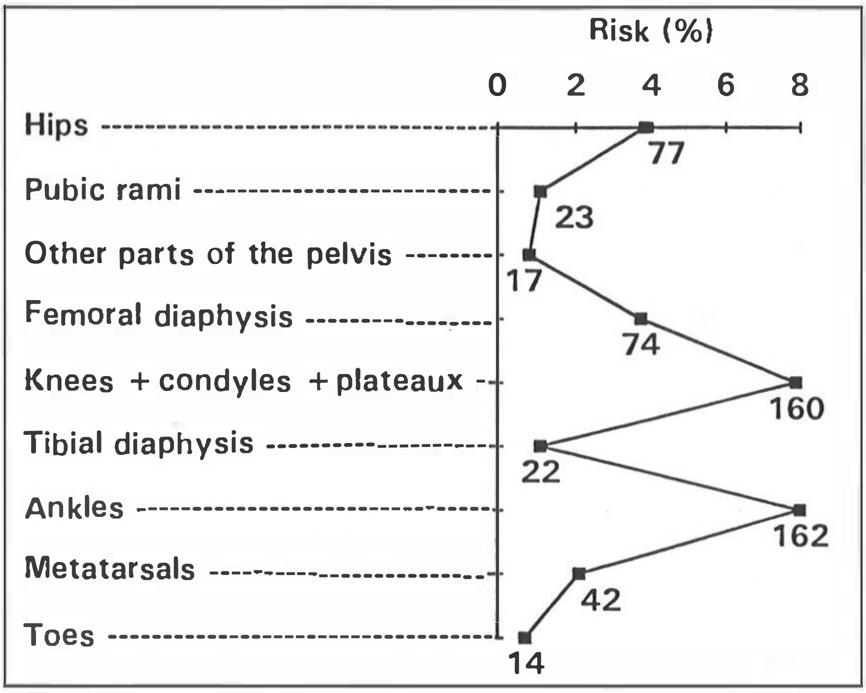


Figure 2: risk of injury (sprains, laceration into joint, dislocations, fractures) in the various leg areas, among restrained and unrestrained front occupants having sustained a frontal impact.

The main lesions occurring in each of the 9 body areas defined earlier are described in table 1. The number opposite each type of injury represents the number of occupants who have sustained that injury.

Region	Injury	Number of occupants	Frequency (% out of 396)
Hip	Acetabulum fractures	**49**	12,4
Pubic rami	Fractures of pubic rami	23	5,8
Femoral diaphysis	Fractures of the diaphysis	**74**	18,7
Knee	Kneecap fractures	**77**	19,4
Tibial diaphysis	Fractures of the diaphysis	21	5,3
Ankle	Fibula fractures	**48**	12,1
	Tibia fractures (distal part)	**36**	9,1
	Talar fractures	21	5,3
	Fractures of the calcaneum	12	3,0
	Ankle sprains	**44**	11,1
Metatarsus	Metatarsal fractures	**39**	9,8
Toes	Toe dislocations	7	1,8
	Toe fractures	6	1,5

Table 1: main injuries encountered in each body area for restrained and unrestrained front occupants having sustained a frontal impact.

Many minor wounds (contusions, abrasions, etc...) are also reported especially to the knee, but a very few to the ankle and the foot.

Of those occupants having distal tibial fractures, **39** sustained malleolar fractures and 8 others have "ankle fractures", which in principle concern malleoli too. Their frequency between the right and the left ankle remains the same, whether it concerns drivers or passengers. The medial malleolus seems to be slightly more fractured but the difference is not significant.

Ankle sprains are frequent too (**44** occupants). They are incorrectly described in 29 out of 44 cases. Out of the other 15 well documented cases, 12 have injuries to their lateral ligaments. Sprains seem to occur more frequently on the left ankle of the passengers, near the transmission tunnel, (right ankle: 3 passengers, left ankle: 10 passengers, 1 passenger whose the side was unknown; $\chi^2 = 7.04$ but some numbers are less than 5).

82 metatarsal fractures were recorded among the 39 occupants concerned. They occur 1 time on the 1st metatarsal,
23 times on the 2nd,
20 times on the 3rd,
21 times on the 4th,
12 times on the 5th,
(5 are not described any further), so mainly the 2nd, the 3rd and the 4th metatarsals. The greater mobility of the 1st and the 5th metatarsals, and the higher breaking strength of the 1st compared with the others, make them intervene less frequently.

From the 396 occupants with lower extremity injuries, 380 were precisely described in terms of location and side of the injury, (right or left leg). Those 380 occupants represent **452** injured lower extremities among which **339 (75%)** sustain isolated lesions in one of the nine body regions defined previously, mainly on the knee (104/452 = 23,0%) and on the ankle (105/452 = 23,2%). An examination of the combinations of injuries between the regions of the upper leg confirms the mechanism originated from the impact of the knee on the dashboard. But combinations between the knee and the ankle can't support the entrapment described by States [1971, 1986][11,12], insofar as there is a high probability of lesions occurring at both ankle and knee.

4.3. Influence of parameters concerning the occupant.

- **Comparison between the drivers and the passengers.**

The risk of lower leg injury is the same for all categories of occupants, except for unrestrained passengers, (figure 3). No reason has been found to explain this exception. On the contrary, the risk of sustaining upper leg injuries is higher for drivers than for passengers. Indeed, the footwell intrusion is higher on the driver side. Also, drivers may impact hard parts of the vehicle structure that are situated close to the knees such as the steering column.

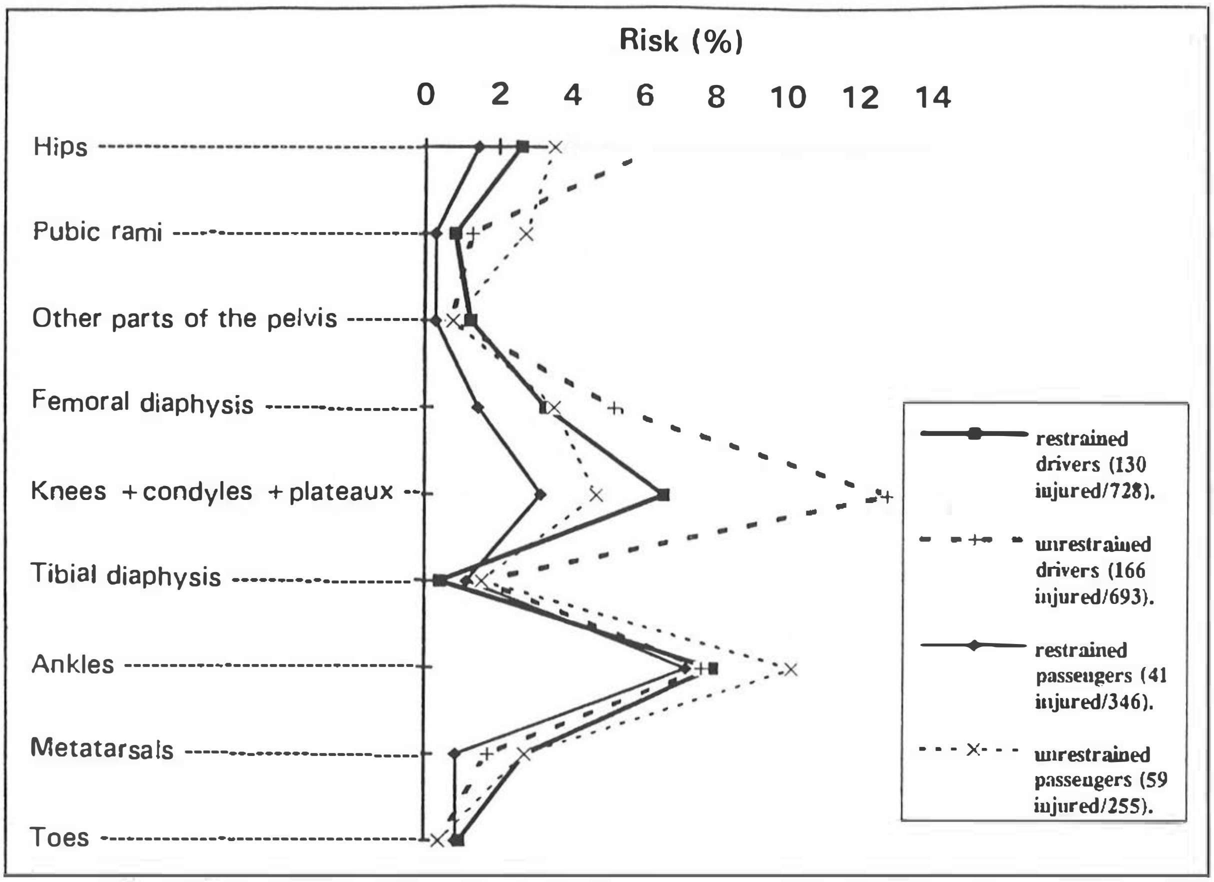


Figure 3: Comparison of the lesions to several body regions, between drivers and passengers involved in frontal collisions, with respect to their seat-belt use.

Moreover, as far as right-front passengers are concerned, the risk to the ankles is significantly greater than that posed to the knees. The risk to the knees, for unrestrained drivers is greater than the risk to the ankles. For restrained drivers, the difference is not significant, ($\chi^2 = 1.02 < 3.84$).

Seat-belt use does not reduce the number of lower leg injuries. The possible beneficial role of the seat belt for unrestrained passengers is not significant, ($\chi^2 = 2.91$ as far as lower leg injuries are concerned, and $\chi^2 = 1.67 < 3.84$ as far as ankle injuries are concerned).

- **Comparison between the left and the right leg.**

By distinguishing between injuries concerning the "foot" and those concerning the "ankle", the tibia and the fibula, the effect of the pedals can be highlighted (table 2).

208 occupants injured in the lower legs.	1421 drivers		601 passengers	
	Footwell intrusion		Footwell intrusion	
	< 150 mm 1102 drivers	> 150 mm 319 drivers	< 150 mm 464 pass.	> 150 mm 137 pass.
129 occupants with fractures of the tibia or malleoli + knee sprains and dislocations.	15 R, 16 L 0 B, 0 ? χ^2 = 0,03	26 R, 19 L 7 B, 1 ? χ^2 = 0,92	6 R, 14 L 0 B, 3 ? χ^2 = 3,27	6 R, 12 L 4 B, 0 ? χ^2 = 1,53
(**93** with malleolus fractures and ankle sprains, **42** witb tibial and fibula fractures).	41 R, 35 L 7 B, 1 ? χ^2 = 0,41		**12** R, **26** L **4** B, 3 ? χ^2 = **4,43**	
96 occupants with fractures of the metatarsals, cuneiform bones, navicular, talus, calcaneum + tibial pilon.	**22** R, **4** L **0** B, 1 ? χ^2 = **12,61**	21 R, 18 L 3 B, 1 ? χ^2 = 0,22	6 R, 4 L 0 B, 0 ? χ^2 = 0,40	10 R, 4 L 2 B, 0 ? χ^2 = 2,14
	43 R, **22** L 3 B, 2 ? χ^2 = **6,37**		16 R, 8 L 2 B, 0 ? χ^2 = 2,34	

Table 2: Difference between the right and left leg for restrained and unrestrained front occupants having sustained a frontal impact, depending on footwell intrusion and on whether the area affected is the "foot", or the "ankle", tibia or fibula (R = Right, L = Left, B = Both sides, ? unknown side, χ^2 significant if > 3,84 -threshold for 5%-).

In the case of slight intrusion (< 150 mm), the driver's right foot is injured significantly more often than the left foot. In particular, for the driver, seven calcaneum fractures out of nine occurred on the right foot (χ^2 = 5.56 significant, but some numbers are less than 5, 2 fractures on the left).

The ankle and tibia of passengers are injured more often on the left-hand side than on the right. This difference in fact concerns the ankle. Out of 14 restrained and unrestrained passengers, 10 suffered a sprain of the left ankle, near the transmission tunnel. Fractures of the malleoli seem to be evenly distributed. On the other hand, the right foot of passengers would tend to be more frequently injured, but the numbers are too small to demonstrate this. Indeed, extensive deformation of the wheel well, beneath the right foot of passengers (or the left foot of drivers), is often observed.

The effect of the brake pedal is confirmed in the case of right-hand drive vehicles (table 3).

Gloyns [1979] (UK)	47 restrained drivers		134 unrestrained drivers		19 restrained drivers		58 unrestrained drivers	
	Right	Left	Right	Left	Rigbt	Left	Right	Left
Hip	2	1	15	11	3	1	3	5
Femur	**6**	**0**	**22**	**7**	2	3	3	2
Knee	3	0	8	4	0	0	0	0
Tibia/fibula	3	3	8	5	0	0	2	3
Ankle/foot	**8**	**1**	**20**	**3**	3	0	1	1

Table 3: Comparison between the right and left side for the entire leg, for restrained and unrestrained front passengers sustaining at least one injury of AIS 2+ on any body area up to the head inclusive, involved in an 11 o'clock/1 o'clock frontal impact, GLOYNS [1979][2] (UK).

In the APR database, 12 occupants have a combination of foot and ankle injuries. 6 have metatarsal fractures associated with sprains or fractures of malleoli. 3 have a fracture of the calcaneum associated with a malleolus fracture. 3 have fractures of the tarsus associated with a malleolus fracture. There are accordingly few injuries affecting both the metatarsals and the ankle, even though they represent the most frequent case of foot/ankle combinations. Moreover, they occur generally in the event of extensive footwell intrusion (a single case with intrusion less than 150 mm). This shows that most of the fractures are due to impacts located on the body area concerned.

- **Influence of occupant's age.**

The risk of lower leg injury increases slightly with the age of the occupants, all of them considered together. But this result becomes less obvious when each category of occupants is considered separately, (figure 4). Yet, no significant bias due to the velocity change Delta-V (1,5 km/h between young and old occupants) has been observed.

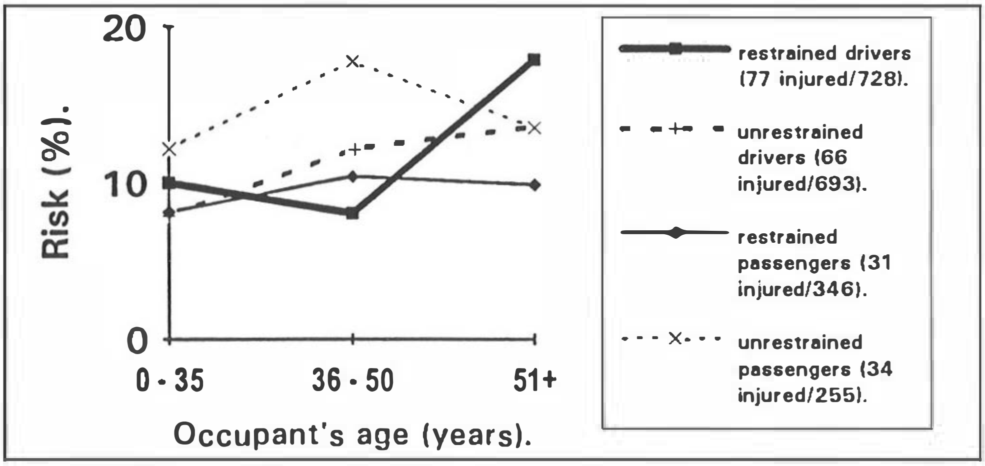


Figure 4: risk of lower leg injury with respect to the occupant's age, in frontal collisions.

So, based on the data, the occupant's age seems to have little influence on leg injury statistics.

4.4. Influence of the parameters concerning the collision.

- **The velocity change delta-V.**

50% of all occupants (injured or not) were involved in frontal collisions with delta-V below 35 km/h. Whereas 50% of the occupants sustaining lower leg injuries are involved in frontal collision with delta-V below **47 km/h**. This figure remains the same as far as the upper leg is concerned. So a high velocity change is necessary to produce lower leg injuries, (figure 5). Below 25 km/h, only 2,1 % of the occupants sustain lower leg injuries.

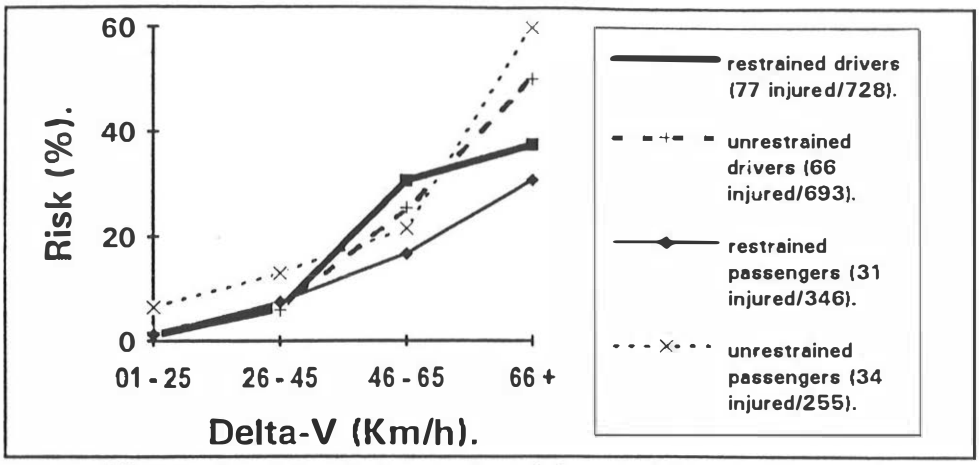


Figure 5: risk of lower leg injury with respect to the velocity change delta-V, in frontal collisions.

- **The footwell intrusion.**

The risk of lower leg injury increases with the extent of the footwell intrusion, (figure 6). 50% of all occupants (injured or not) are involved in collisions with footwell intrusions below 40 mm. But when they are injured in the lower leg region, the 50th percentile reaches **200 mm**. As far as upper leg is concerned, the 50th percentile for the footwell intrusion is 170 mm for unrestrained drivers and 330 mm for restrained drivers, because in that case, knee impacts occur less often.

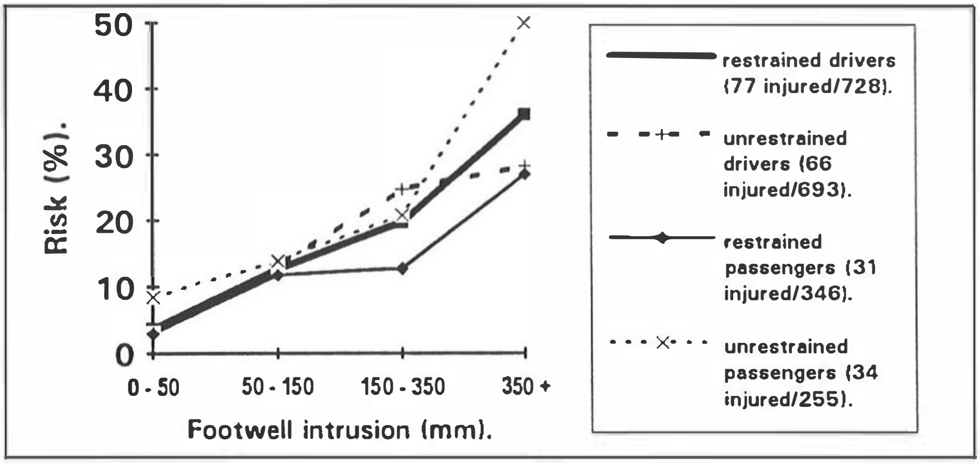


Figure 6: risk of lower leg injury with respect to the footwell intrusion, in frontal collisions.

At the lower end of the range of intrusion size (< 50 mm), 52 occupants have lower leg injuries. Yet, 7 cases of talus fratures, 9 with malleolus fractures and 8 with metatarsal fractures are encountered all the same. But the risk is low (52/1276 = 4,1 %) among the many occupants involved in those minor accidents.

Unfortunately, among violent impacts with velocity change between 46 and 65 km/h, which represents the realistic and reasonable field of conditions for future experimental studies, no difference was observed between impacts with the footwell intrusion below 150 mm and those with an intrusion of between 150 and 350 mm, in terms of risk to lower legs, (figure 7).

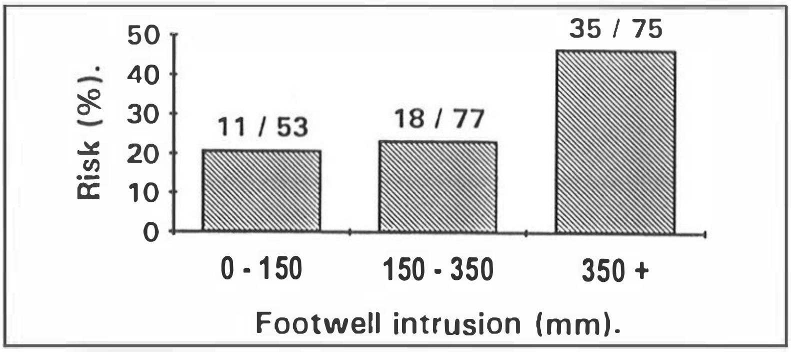


Figure 7: risk of lower leg injury for all front occupants restrained or not, involved in a frontal collision on their near side with delta-V between 46 and 65 km/h, with respect to the footwell intrusion.

- **The dashboard intrusion.**

For a given footwell intrusion, the risk of lower leg injury does not increase significantly with respect to the dashboard intrusion, (figure 8). This does not support the observations of leg entrapments described by States [1987, 1986][11,12], although the small number of occupants made it difficult to study this parameter.

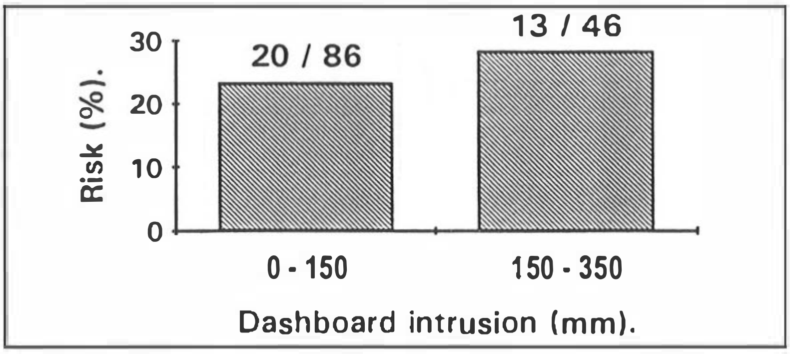


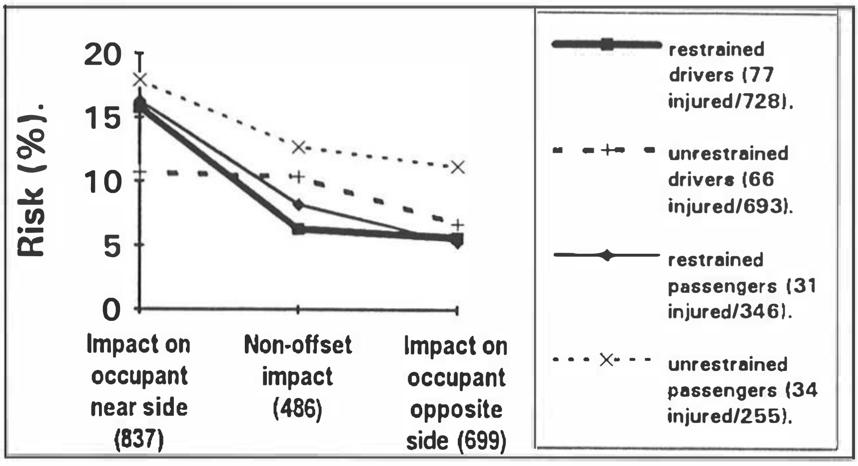
Figure 8: risk of lower leg injury for all front occupants restrained or not, involved in a frontal collision on their near side with delta-V between 26 and 65 km/h, and footwell intrusion between 150 and 350 mm, with respect to the dashboard intrusion.

- **The impact configuration.**

48.1 % of the occupants were involved in frontal impacts which cause intrusions into the driver side compartment (up to 2/3 overlap plus some non-symmetrical 100% overlap collisions), 27.9 % in collisions on the passenger side, and 24,0 % in non-offset collisions. One must notice the high proportion of collisions with high overlaps which induce effects similar to non-offset collisions: 52.2 % sustains overlaps over 2/3.

The risk of lower leg injury is twice as high when the impact is located on the occupant near side, (figure 9).

Figure 9: risk of lower leg injury with respect to the configuration of the frontal collision.



When the impact occurs on the occupant near side, the risk is particularly high when the overlap is around 1/2, (15,9%), (figure 10). 1/4 or 1/3 overlap impacts have generally a low mean acceleration level.

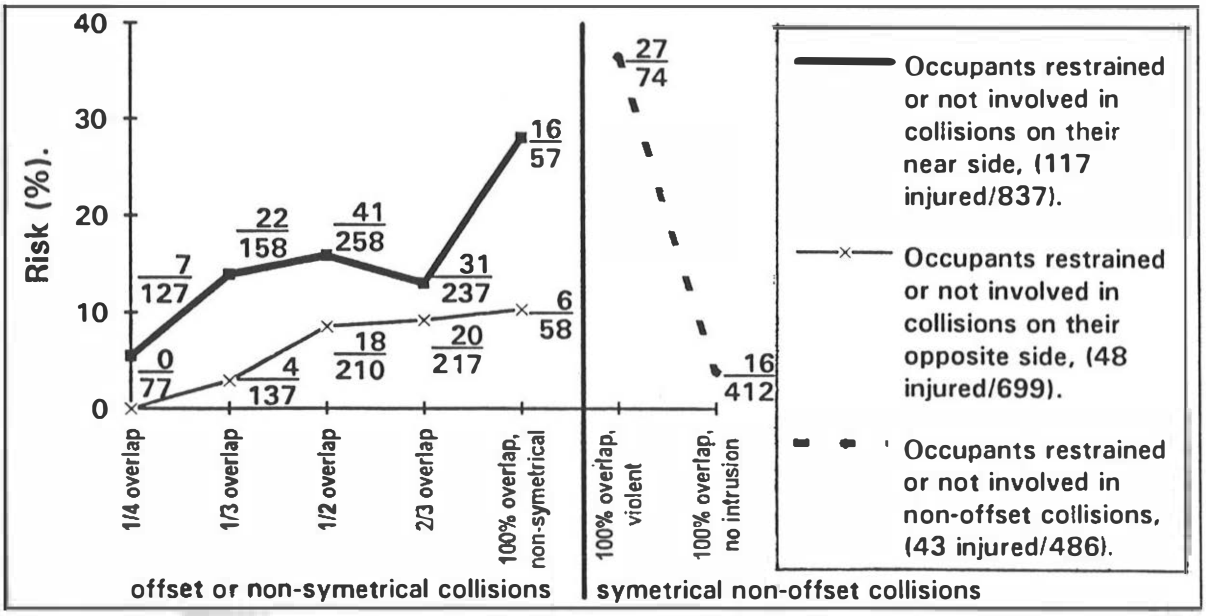


Figure 10: risk of lower leg injury for restrained and unrestrained front occupant with respect to the overlap of the frontal collision.

Non-offset collisions produce effects on lower legs, similar to those observed when the impact is located either on the occupant near side or on the opposite side, depending on the velocity change and the body areas concerned. The risk of ankle injury substantially increases when the impact is located on the occupant near side, (figure 11). A higher intrusion velocity is required in order to produce an ankle fracture than that required to fracture the knee. The foot is directly in contact with the footwell, and consequently submitted to its acceleration, whereas, the knee moves and comes into contact with the dashboard. Moreover, the crushable dashboard makes the knee less responsive to its acceleration.

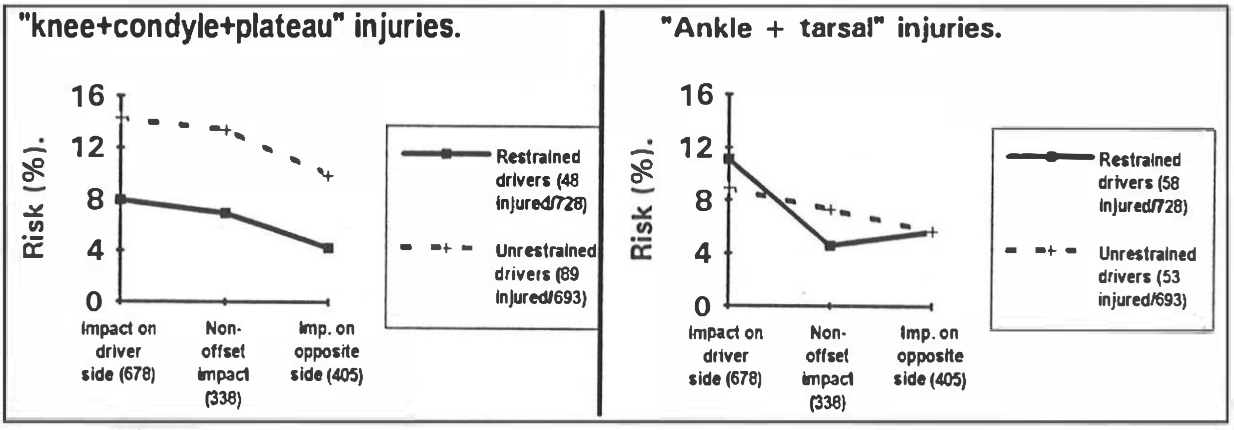


Figure 11: comparison between the risk of ankle injury and the risk of knee injury of the drivers with respect to the configuration of the frontal collision.

4.5. Radiographic analysis.

Of the 208 occupants with lower leg injuries, 64 were treated in Poissy hospital, the most frequently one mentioned in the accident files, 15 for ankle sprains and 49 for fractures below the tibial plateaux. Nearly all the medical files (42/49) for these occupants have been retrieved. Accordingly, the proportion of the various fractures considered in this sample, is theoretically still representative of the real-world accident.

X-rays are therefore available for 42 occupants involved in a frontal impact of known characteristics (photos of the vehicle, delta-V, intrusion, etc.), since this research was performed on part of the occupants selected in the previous statistical study.

The differences observed between the right and left legs of drivers are again found in this sample (table 4). Of 31 drivers, 19 have injuries to their right lower leg and 11 have injuries to their left lower leg, (χ^2 = 4,13 is significant). Contrary to the global sample (with the 208 occupants), most of this difference comes from the metatarsal fractures, (right foot: 10 drivers; left foot: 4 drivers).

	31 drivers			11 passengers		
	Right	Left	Both sides	Right	Left	Both sides
Lower leg	**19**	**11**	1	6	3	2
Foot in front of Chopart's line + tibial pilon	**14**	**5**	1	4	2	1
Metatarsals	**10**	**4**	0	3	2	0

Table 4: Comparison between the right and left legs, in the sample of 42 occupants fractured below the tibial plateaux, who have sustained a frontal impact restrained or unrestrained, and for which X-rays are available.

Each of the 42 occupants has been grouped according to his injury and the associated mechanism, (table 5).

Type of injury	Number of occupants	Possible mechanism
Fibula head fractures, often associated with tibial plateau fractures.	3	direct impact on the knee.
Tibial metaphysis fractures.	2	direct impact on the metaphysis.
Tibial diaphysis fractures.	4	direct impact on the tibia.
Tibial pilon and calcaneal fractures.	2	Forces along the tibia, acting under the heel.
Malleolus fractures, (one must keep in mind the **15** cases of ankle sprains discarded before).	**6**	Lateral motions: inversion and eversion motions due to forces acting under the ball of the foot.
Talar fractures	1	Dorsiflexion.
Metatarsal fractures (14 cases); toe, cuneiform, navicular and talus head fractures.	**19**	Forces acting under the metatarsal condyles, combined with the inertial effect of the foot in its dorsiflexing movement, and/or muscular contractions during a hard breaking.
Talo-navicular and talo-calcaneal dislocation, (2 without any fractures).	3	Unknown.
Complex fractures within several areas: ankle, foot.	2	No single mechanism.

Table 5: mechanisms for the 42 occupants fractured below the tibial plateaux, who have sustained a frontal impact restrained or unrestrained, and for which X-rays are available.

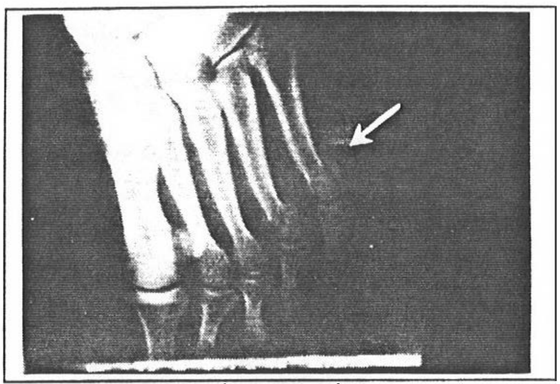
The main injury mechanisms for the 2 most frequent type of injury are as follows:

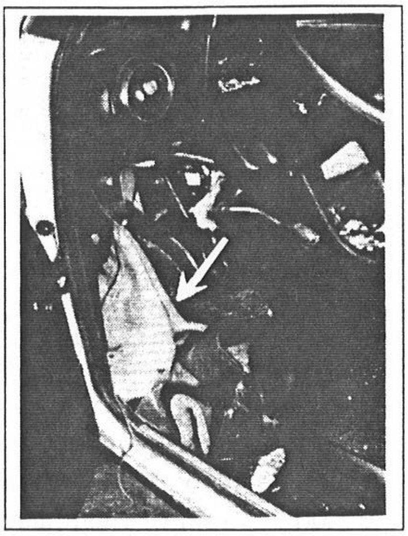
- **Fractures of the metatarsals (14 cases), plus, fractures of toes, cuneiform bones, navicular and talar head (5 cases): 19 cases.**

  Forces on the metatarsal extremities acting at the same time as the effect of inertia of the foot in its dorsiflexion movement.

Most of the metatarsal fractures occur at the condyles (9/15 occupants) and at the basis (6/5 occupants), but a very few at the diaphysis (2/15 occupants having sustained 61 and 78 km/h of delta-V).

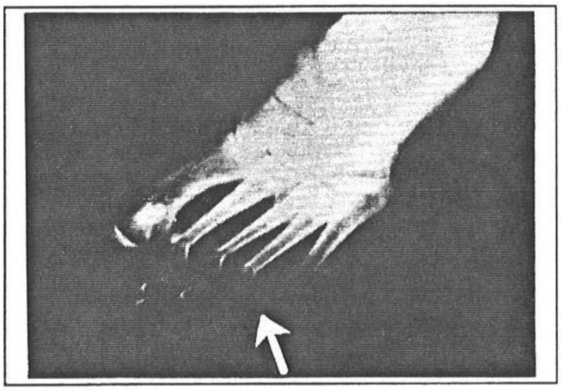
In two cases, the effect of forces under the ball of the foot is clear, (pictures 1, 2).

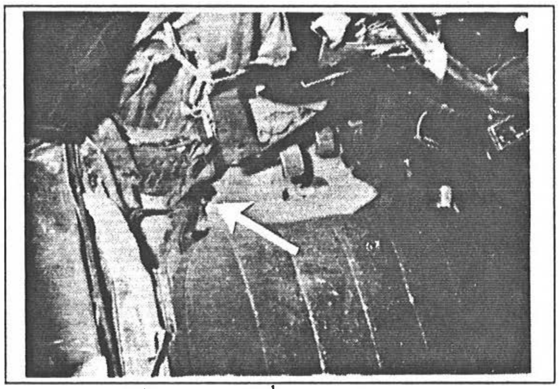




Picture 1: 4th and 5th left metatarsal condyle fractures. Restrained driver. Delta-V = 45 km/h. Footwell intrusion = 200 ± 50 mm. Mean acceleration = 10 g. 12 o'clock, 2/3 overlap impact on the driver side.

Mechanism: forces acting directly under the metatarsal condyles, due to the wheel well intrusion, associated with the inertial effect of the leg and/or muscular contractions.





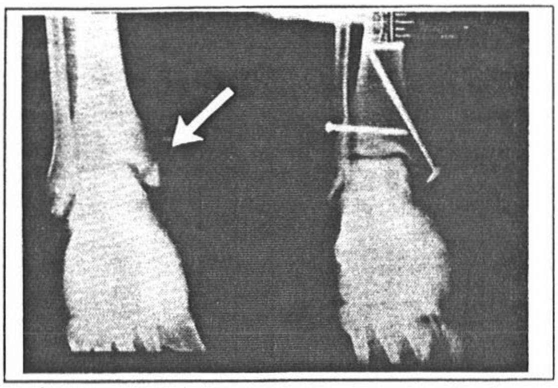
Picture 2: Several fractures of the left foot. 1st and 2nd metatarsal condyle fractures, plus 3rd and 4th metatarsal condyle and basis fractures. Cuboid fracture-dislocation. Scaphoid fracture and 1st and 2nd cuneiform fractures. Restrained driver. Delta-V = 49 km/h. Footwell intrusion = 400 ± 50 mm. Mean acceleration = 9 g. 12 o'clock, 1/2 overlap impact on the driver side.

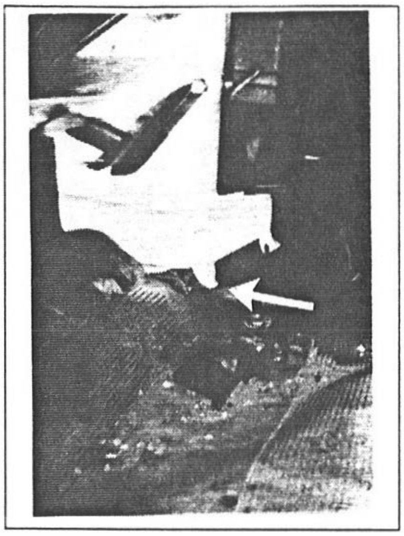
Mechanism: forces acting directly under the metatarsal condyles, due to the intrusion of the wheel into the compartment, associated with the inertial effect of the leg and/or muscular contractions.

- **Fractures of malleoli (after eliminating the 15 cases with sprains): 6 cases.**

Inversion and eversion motions due to forces acting on the ball of the foot.

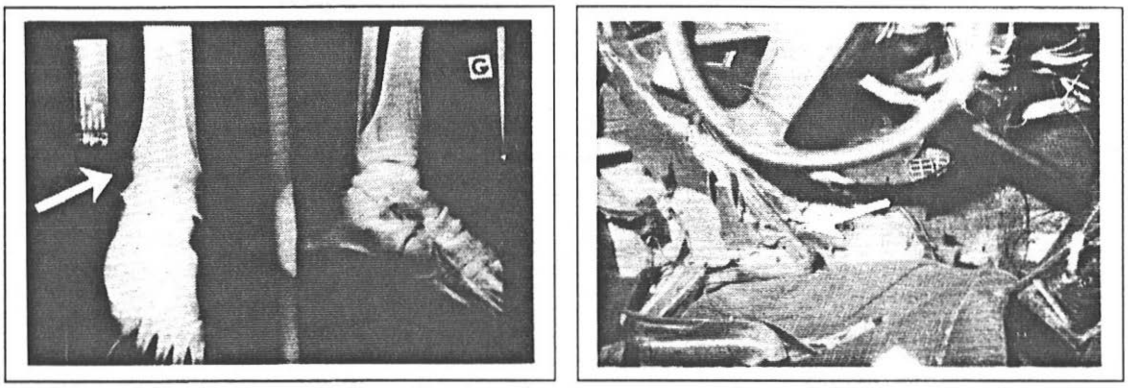
In two cases, fractures were caused by a lateral impact on the ankle. However, the associated footwell deformations are rather singular, (picture 3 and 4).





Picture 3: right medial malleolus fracture, tibial fibular ligament rupture. Unrestrained driver. Delta-V = 40 km/h. Footwell intrusion = 200 ± 50 mm. Mean acceleration = 12 g. 12 o'clock, 1/2 overlap impact on the passenger side.

Mechanism: lateral impact on the lateral side of the right ankle, due to the intrusion of the central structure of this car.



Picture 4: left medial malleolus fracture. Restrained driver. Delta-V = 47 km/h. Footwell intrusion = 500 ± 50 mm. Mean acceleration = 6 g. 11 o'clock, 1/3 overlap impact on the driver side.

Mechanism: lateral impact on the lateral side of the left ankle, due to the buckling of the left side sill.

Lestina [1992][5] confirms the mechanism of inversion and eversion by her study on 23 cases.

5. CONCLUSION.

The multiple mechanisms of lower leg injuries are slightly less important compared with the knee impacts on the dashboard which involved femur and pelvis fractures together with knee injuries, but they remain quite frequent. Metatarsal fractures, malleolus fractures and ankles sprains are the most frequent injuries found for the lower leg, according to this study.

The risk of lower leg injury remains the same for all categories of occupant, except unrestrained passengers.

- Seat belt use does **not** contribute to a reduction of these lesions.
- The occupant's age has little influence on leg injury statistics.
- The velocity change delta-V, the footwell intrusion and the impact configuration are the parameters having predominant influence on leg injuries. The 50th percentile for **delta-V** is **47 km/h** and **200 mm** for the footwell intrusion. The risk of injury doubles when the impact is located on the occupant near side.
- The effect of the pedals on foot injuries has been highlighted, even in the case of right-hand driving. The left ankle of passengers, near the transmission tunnel, is more frequently injured, especially as far as ankle sprains are concerned.

The main mechanisms consist of forces acting under the ball of the foot creating metatarsal fractures, and inversion and eversion motions of the foot producing malleolus fractures. This work represents a first step towards a global study involving PMHS experiments and Hybrid III dummy tests.

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ANNEXE
THE 208 OCCUPANTS WITH LOWER LEG INJURIES.

OCCUPANT NUMBER	FILE NUMBER	OCCUPANT'S SEAT	BELT (yes or no)	AGE (years)	Delta-V (km/h)	FOOTWELL INTRUSION (mm)	DASHBOARD INTRUSION (mm)	MEAN ACCELERATION (g)	DIRECTION OF IMPACT (o'clock)	OVERLAP	INJURIES (fractures, sprains, dislocations only)	AREA AND LEG AFFECTED
1	_1629_2	PAS	NO	27	20	0	0	6	12	1/2 Right	Talar fracture	Right
2	_1873_1	DRV	YES	44	39	0	0	10	12	2/3 Left	Malleolus fractures	Unknown Right
3	_2600_1	DRV	YES	21	62	100	0	13	11	2/3 Left	Metatarsal fractures	Right
4	_2688_2	PAS	YES	22	41	0	0	10	12	100% No intrusion	Toe fracture	Left
5	_2664_2	PAS	YES	17	66	600	300	10	12	1/3 Right	"Lower leg fracture"	Right
6	_2671_2	PAS	YES	26	41	300	300	6	11	1/3 Right	Lisfranc-line sprain	Left
7	_2676_2	PAS	NO	32	60	400	200	11	1	1/3 Right	"Lower leg fracture"	Right & Left
8	_2681_2	PAS	NO	24	33	0	0	7	12	1/2 Right	Metatarsal fractures	Right
9	_2761_1*	DRV	NO	47	66	300	100	12	12	1/2 Right	Deltoid ligament sprain	Left
	_2761_1*	DRV	NO	47	66	300	100	12	12	1/2 Right	Metatarsal fractures	Left
10	_2761_2	PAS	NO	71	66	300	100	12	12	1/2 Right	Malleolus fractures	Bilateral Left
11	_3068_1	DRV	NO	49	43	0	0	10	12	100% No intrusion	Metatarsal fractures	Right
12	_3269_1	DRV	NO	23	49	300	100	14	12	100% Left	Fibula head or upper fibula fracture	Right
13	_3270_1	DRV	NO	30	61	300	100	14	12	100% With intrusion	Metatarsal fractures	Right
14	_3270_2*	PAS	NO	28	61	300	100	14	12	100% With intrusion	Malleolus fractures	Lateral Left
	_3270_2*	PAS	NO	28	61	300	100	14	12	100% With intrusion	Malleolus fractures	Medial Right
15	_3329_1*	DRV	YES	28	49	400	200	9	12	1/2 Left	Cuboid fracture	Left
	_3329_1*	DRV	YES	28	49	400	200	9	12	1/2 Left	Cuneiform fracture	Left
	_3329_1*	DRV	YES	28	49	400	200	9	12	1/2 Left	Metatarsal fractures	Left
	_3329_1*	DRV	YES	28	49	400	200	9	12	1/2 Left	Scaphoid fracture	Left
16	_3342_1	DRV	YES	34	60	200	200	11	12	2/3 Left	"Lower leg fracture"	Right
17	_3376_1	DRV	YES	47	60	600	100	11	12	2/3 Left	"Ankle sprain"	Right
18	_3390_1	DRV	NO	43	68	300	100	13	12	100% With intrusion	Tibial diaphysis fracture	Right & Left
19	_3490_1	DRV	NO	33	48	300	300	9	12	1/3 Left	Fibula head or upper fibula fracture	Left
20	_3495_1	DRV	NO	30	40	0	0	10	12	1/2 Left	Tibial diaphysis fracture	Right
21	_3549_1	DRV	YES	45	45	200	0	10	12	2/3 Left	Metatarsal fractures	Left
22	_3613_1	DRV	NO	21	60	300	200	12	1	100% Left	"Ankle sprain"	Right
23	_3670_1	DRV	YES	41	69	800	400	11	12	100% Left	"Lower leg fracture" (distal part)	Right & Left
24	_3670_2*	PAS	NO	39	69	800	400	11	12	100% Left	Ankle fracture	Left
	_3670_2*	PAS	NO	39	69	800	400	11	12	100% Left	Tibia fracture, (distal part)	Left
25	_3770_2	PAS	NO	43	28	0	0	7	12	1/3 Right	Metatarsal fractures	Right
26	_3800_1	DRV	YES	29	64	400	400	8	12	1/2 Left	Malleolus fractures	Medial Right
27	_3877_1*	DRV	YES	34	63	200	100	14	12	100% Left	"Ankle sprain"	Right
	_3877_1*	DRV	YES	34	63	200	100	14	12	100% Left	"Foot fracture"	Left
28	_3888_2	PAS	NO	19	70	600	600	13	12	1/2 Left	"Lower leg fracture"	Left
29	_3890_1	DRV	NO	46	44	300	100	8	12	1/2 Left	Pilon tibial	Right
30	_3903_2*	PAS	NO	23	46	600	300	8	12	2/3 Right	Metatarsal fractures	Right
	_3803_2*	PAS	NO	23	46	600	300	8	12	2/3 Right	Toe dislocation	Right
31	_3967_1	DRV	NO	71	40	200	100	12	12	1/2 Right	Malleolus fractures	Bilateral Right
32	_3968_1	DRV	NO	30	30	0	0	5	12	2/3 Left	"Ankle sprain"	Left
33	_4044_1	DRV	NO	27	67	600	400	12	12	2/3 Right	"Ankle sprain"	Right & Left
34	_4162_1	DRV	NO	66	40	0	0	7	12	1/2 Left	Talo-calcaneal dislocation	Left
35	_4229_1	DRV	NO	49	64	100	0	17	12	100% With intrusion	Toe dislocation	Right
36	_4238_1	DRV	NO	32	36	200	100	8	12	2/3 Left	Calcaneal-fibular sprain	Right
37	_4256_2	PAS	NO	26	20	0	0	6	12	1/2 Left	"Ankle sprain"	Left
38	_4262_1	DRV	NO	22	43	300	100	9	11	2/3 Left	Metatarsal fractures	Right
39	_4433_1*	DRV	NO	26	60	300	200	13	12	2/3 Left	Deltoid ligament sprain	Left
	_4433_1*	DRV	NO	26	60	300	200	13	12	2/3 Left	Talar fracture	Right
40	_4607_1	DRV	YES	64	43	0	0	10	12	100% No intrusion	Talar fracture	Unknown
41	_4663_1	DRV	YES	21	38	0	0	8	12	1/2 Left	Toe fracture	Left
42	_4693_2	PAS	YES	36	62	600	200	7	12	1/3 Right	Talar fracture	Right
43	_4684_2*	PAS	NO	47	36	0	0	9	12	2/3 Right	"Ankle sprain"	Left
	_4684_2*	PAS	NO	47	36	0	0	9	12	2/3 Right	Metatarsal fractures	Left
44	_4737_1	DRV	YES	64	20	0	0	4	1	2/3 Left	Malleolus fractures	Bilateral Left
45	_4746_1	DRV	NO	48	38	0	0	7	11	1/2 Left	Malleolus fractures	Medial Left

46	_4766_2*	PAS	NO	46	33	100	0	6	12	1/4 Right	Malleolus fractures	Bilateral Right
	_4766_2*	PAS	NO	46	33	100	0	6	12	1/4 Right	Talo-calcaneal dislocation	Right
47	_4781_1*	DRV	NO	26	67	200	100	13	12	100% With intrusion	Calcaneal fracture	Right
	_4781_1*	DRV	NO	26	67	200	100	13	12	100% With intrusion	Malleolus fractures	Lateral Left
48	_4800_1	DRV	YES	60	48	600	400	8	11	1/2 Left	Calcaneal-fibular sprain	Right
49	_4800_2	PAS	YES	64	46	600	400	8	11	1/2 Left	Cuneiform fracture	Right
50	_4842_1	DRV	NO	26	63	600	300	8	11	1/4 Left	Tibial & fibula diaphysis fractures	Left
51	_4841_1	DRV	NO	66	20	0	0	6	12	2/3 Right	Tarsal bone dislocations	Right
52	_4867_1*	DRV	YES	66	28	100	0	7	11	2/3 Right	Cuboid fracture	Left
	_4867_1*	DRV	YES	66	28	100	0	7	11	2/3 Right	Metatarsal fractures	Left
53	_5084_1	DRV	NO	46	46	300	200	12	11	100% With intrusion	Tibial diaphysis fracture	Right
54	_5163_2	PAS	NO	18	68	200	0	16	12	100% With intrusion	Tibial & fibula diaphysis fractures	Right
55	_5164_1*	DRV	NO	44	62	100	0	14	12	2/3 Right	Metatarsal fractures	Right
	_5164_1*	DRV	NO	44	62	100	0	14	12	2/3 Right	Toe dislocation	Right
56	_5168_1	DRV	NO	30	48	100	200	11	12	100% With intrusion	"Ankle sprain"	Left
57	_5310_2	PAS	YES	17	46	100	100	14	12	100% With intrusion	Malleolus fractures	Bilateral Left
58	_5318_1	DRV	NO	30	42	0	0	8	12	100% No intrusion	"Lower leg fracture"	Right
59	_5328_2	PAS	YES	26	33	0	0	8	12	2/3 Left	"Foot sprain"	Left
60	_5378_2	PAS	NO	71	28	0	0	8	12	1/2 Left	Malleolus fractures	Lateral Right
61	_5407_2	PAS	NO	44	24	0	0	8	11	2/3 Left	Tarsal bone dislocations	Right
62	_5412_1*	DRV	NO	23	61	600	200	12	12	100% Left	"Ankle dislocation"	Right
	_5412_1*	DRV	NO	23	61	600	200	12	12	100% Left	Fibula fracture	Right
63	_5420_1	DRV	NO	32	36	100	0	8	12	2/3 Left	Calcaneal-fibular sprain	Left
64	_5431_1	DRV	YES	21	46	0	0	14	12	100% No intrusion	Metatarsal fractures	Right
65	_5432_1*	DRV	YES	61	43	0	0	13	12	2/3 Left	Scaphoid fracture	Right
	_5432_1*	DRV	YES	61	43	0	0	13	12	2/3 Left	Talar fracture	Right
66	_5514_1	DRV	NO	46	43	100	0	12	12	2/3 Left	Tibial & fibula diaphysis fractures	Right
67	_5518_1	DRV	NO	48	27	0	0	8	12	1/2 Left	Toe dislocation	Right
68	_5537_1	DRV	NO	41	36	100	0	6	11	1/4 Left	Calcaneal-fibular sprain	Left
69	_5604_1	DRV	YES	28	38	200	0	7	12	1/2 Left	"Ankle sprain"	Right
70	_5810_2	PAS	NO	61	37	0	0	10	12	100% No intrusion	Fibula head or upper fibula fracture	Left
71	_5675_1	DRV	YES	21	66	600	300	10	12	1/3 Left	Tibial & fibula diaphysis fractures	Left
72	_5688_1	DRV	NO	26	66	300	100	16	12	100% With intrusion	Malleolus fractures	Bilateral Right
73	_5728_2	PAS	NO	40	31	0	0	8	12	2/3 Left	Fibula head or upper fibula fracture	Right
74	_5758_1	DRV	YES	36	43	400	400	7	11	1/3 Left	Metatarsal fractures	Left
75	_5781_1	DRV	NO	37	61	100	0	14	12	100% Left	Pilon tibial	Right
76	_5787_2	PAS	NO	23	43	200	0	10	12	1/3 Right	Malleolus fractures	Lateral Left
77	_5791_2	PAS	NO	22	28	0	0	7	12	1/2 Left	"Ankle sprain"	Left
78	_5818_2	PAS	NO	23	68	600	300	12	12	1/3 Left	Malleolus fractures	Medial Left
79	_5875_2	PAS	YES	40	21	0	0	5	12	2/3 Right	Ankle fracture	Unknown
80	_5808_1	DRV	YES	66	61	300	300	8	12	1/3 Left	Deltoid ligament sprain	Left
81	_5844_2*	PAS	NO	18	66	600	300	11	12	1/2 Left	Malleolus fractures	Medial Right
	_5844_2*	PAS	NO	18	66	800	300	11	12	1/2 Left	Scaphoid fracture	Right
82	_5966_1	DRV	YES	23	60	600	500	8	12	1/2 Left	Metatarsal fractures	Left
83	_5988_1	DRV	NO	38	66	500	400	10	12	1/2 Left	Calcaneal fracture	Left
84	_6103_1	DRV	NO	66	26	0	0	6	12	100% No intrusion	Calcaneal-fibular sprain	Right
85	_6136_2*	PAS	NO	22	44	200	100	8	12	1/3 Right	Calcaneal fracture	Right
	_6136_2*	PAS	NO	22	44	200	100	8	12	1/3 Right	Malleolus fractures	Lateral Right
86	_6182_2*	PAS	YES	46	61	300	200	17	12	100% With intrusion	Cuboid fracture	Right
	_6182_2*	PAS	YES	48	61	300	200	17	12	100% With intrusion	Metatarsal fractures	Right & Left
87	_6266_1	DRV	YES	30	30	200	100	6	11	1/4 Left	Calcaneal-fibular sprain	Left
88	_6306_2	PAS	NO	32	41	0	0	8	11	2/3 Left	"Ankle sprain"	Left
89	_6312_1	DRV	NO	36	37	0	0	8	12	1/2 Left	Tarsal bone dislocations	Right
90	_6346_2	PAS	NO	48	28	0	0	7	1	100% No intrusion	Metatarsal fractures	Left
91	_6362_1	DRV	NO	24	62	400	200	8	11	1/2 Left	Tibial diaphysis fracture	Unknown
92	_6403_1	DRV	YES	38	47	0	0	13	12	100% No intrusion	Metatarsal fractures	Right
93	_6412_1	DRV	YES	21	56	600	600	10	11	1/2 Left	Fibula fracture	Right
94	_6474_1	DRV	NO	28	48	0	0	14	12	100% No intrusion	Talar fracture	Right
95	_6476_2	PAS	YES	18	61	700	600	8	12	2/3 Left	"Ankle sprain"	Left
96	_6662_1	DRV	NO	33	38	100	100	8	1	1/2 Right	"Foot fracture"	Left
97	_6668_1	DRV	YES	18	78	700	600	16	12	100% With intrusion	Metatarsal fractures	Right
98	_6668_2*	PAS	NO	14	78	700	600	16	12	100% With intrusion	Cuboid fracture	Left
	_6668_2*	PAS	NO	14	78	700	600	16	12	100% With intrusion	Malleolus fractures	Bilateral Right
	_6688_2*	PAS	NO	14	78	700	600	16	12	100% With intrusion	Malleolus fractures	Bilateral Left
	_6668_2*	PAS	NO	14	78	700	600	16	12	100% With intrusion	Talo-calcaneal dislocation	Right
99	_6706_1	DRV	YES	28	61	0	100	12	1	100% Left	Pilon tibial	Right
100	_6738_2	PAS	YES	17	62	400	100	8	11	1/2 Right	Tibia fracture, (distal part)	Left
101	_6766_2*	PAS	YES	36	32	100	0	8	12	100% Right	"Ankle sprain"	Right
	_6766_2*	PAS	YES	36	32	100	0	8	12	100% Right	Scaphoid fracture	Left
102	_6772_1*	DRV	NO	34	67	300	100	16	12	100% Right	Tibial & fibula diaphysis fractures	Right & Left
	_6772_1*	DRV	NO	34	67	300	100	16	12	100% Right	Toe dislocation	Right
103	_6778_1	DRV	NO	60	48	100	0	8	11	2/3 Left	Tibial & fibula diaphysis fractures	Left

104	_6789_2*	PAS	YES	63	72	400	300	16	12	100% Right	Ankle fracture	Left
	_6789_2*	PAS	YES	63	72	400	300	16	12	100% Right	Fibula fracture	Right
105	_6803_1	DRV	NO	26	53	400	200	9	12	1/2 Left	Tibial & fibula diaphysis fractures	Left
106	_6805_2	PAS	YES	55	63	400	100	15	12	100% With intrusion	Tibial & fibula diaphysis fractures	Right
107	_6812_1	DRV	YES	30	59	1000	800	13	12	2/3 Right	Malleolus fractures	Bilateral Right
108	_6896_1	DRV	YES	32	24	0	0	5	12	2/3 Left	"Ankle sprain"	Right
109	_6897_2	PAS	NO	70	23	0	0	5	11	1/2 Left	"Ankle sprain"	Left
110	_6917_1	DRV	YES	42	43	100	0	10	1	2/3 Right	"Ankle sprain"	Right
111	_6948_2	PAS	NO	28	18	0	0	4	12	2/3 Left	"Ankle sprain"	Left
112	_7076_1	DRV	YES	24	27	0	0	6	1	2/3 Left	"Ankle sprain"	Right
113	_7105_1*	DRV	YES	43	60	500	100	16	12	2/3 Right	Talar fracture	Left
	_7105_1*	DRV	YES	43	60	500	100	16	12	2/3 Right	Tarsal bone dislocations	Right
114	_7195_1*	DRV	YES	26	74	700	600	12	1	2/3 Right	Cuneiform fracture	Right
	_7195_1*	DRV	YES	26	74	700	600	12	1	2/3 Right	Metatarsal fractures	Right
115	_7205_1	DRV	NO	23	71	600	200	20	12	100% With intrusion	Malleolus fractures	Bilateral Left
116	_7206_1*	DRV	NO	70	50	300	100	9	12	1/2 Left	Calcaneal fracture	Left
	_7206_1*	DRV	NO	70	50	300	100	9	12	1/2 Left	Talar fracture	Left
117	_7233_1	DRV	YES	28	65	600	500	10	11	1/2 Left	Calcaneal fracture	Right
118	_7234_1	DRV	NO	44	53	300	200	8	1	2/3 Left	Cuneiform fracture	Right
119	_7236_1	DRV	YES	38	52	500	500	9	11	1/2 Left	Toe fracture	Left
120	_7252_1*	DRV	NO	25	46	200	100	11	12	2/3 Right	Malleolus fractures	Lateral Left
	_7252_1*	DRV	NO	25	46	200	100	11	12	2/3 Right	Talar fracture	Left
121	_7303_1	DRV	NO	34	20	0	0	3	1	1/3 Right	"Ankle sprain"	Right
122	_7323_1	DRV	YES	65	60	400	300	12	1	2/3 Left	Metatarsal dislocations	Left
123	_7418_1	DRV	YES	20	56	600	500	9	12	1/2 Left	Fibula fracture	Left
124	_7448_1*	DRV	NO	58	48	400	200	8	12	1/3 Left	Malleolus fractures	Lateral Right
	_7448_1*	DRV	NO	58	48	400	200	8	12	1/3 Left	Metatarsal fractures	Left
	_7448_1*	DRV	NO	58	48	400	200	8	12	1/3 Left	Tibial & fibula diaphysis fractures	Left
125	_7449_1*	DRV	NO	25	57	100	100	12	12	1/2 Left	Deltoid ligament sprain	Right
	_7449_1*	DRV	NO	25	57	100	100	12	12	1/2 Left	Malleolus fractures	Lateral Right
	_7449_1*	DRV	NO	25	57	100	100	12	12	1/2 Left	Metatarsal fractures	Right
	_7449_1*	DRV	NO	25	57	100	100	12	12	1/2 Left	Talar fracture	Right
126	_7455_1	DRV	YES	60	54	200	200	12	12	1/2 Left	Fibula fracture	Right
127	_7464_1	DRV	YES	67	46	200	100	11	12	1/2 Left	"Ankle sprain"	Right
128	_7464_2	PAS	YES	62	46	200	100	11	12	1/2 Left	Calcaneal fracture	Right
129	_7483_1	DRV	YES	67	57	500	200	9	11	1/3 Left	Cuboid fracture	Left
130	_7485_1*	DRV	NO	34	28	0	0	9	12	100% No intrusion	Scaphoid fracture	Right
	_7485_1*	DRV	NO	34	28	0	0	9	12	100% No intrusion	Talar fracture	Right
131	_7485_2	PAS	NO	34	28	0	0	9	12	100% No intrusion	Metatarsal fractures	Right
132	_7500_1	DRV	YES	75	60	400	200	15	12	100% Right	Tibia & fibula fracture, (distal part)	Right
133	_7500_2	PAS	YES	72	60	400	200	15	12	100% Right	Metatarsal fractures	Right
134	_7503_1	DRV	YES	58	32	0	0	8	12	2/3 Left	Toe dislocation	Right
135	_7507_1	DRV	YES	32	50	100	100	11	12	1/3 Left	Toe sprain	Left
136	_7508_1	DRV	YES	57	61	100	200	10	12	1/2 Left	Cuboid fracture	Right
137	_7509_1	DRV	YES	40	57	400	200	11	12	1/2 Left	Toe dislocation	Right
138	_7517_2	PAS	NO	39	80	100	100	16	12	100% Left	"Lower leg fracture"	Left
139	_7518_1	DRV	YES	54	47	500	300	9	12	1/2 Left	Malleolus fractures	Medial Right
140	_7522_1	DRV	YES	63	42	0	0	10	12	2/3 Left	Tibia & fibula fracture, (distal part)	Left
141	_7523_2	PAS	YES	50	42	100	100	10	11	1/2 Left	"Ankle sprain"	Unknown
142	_7524_1	DRV	NO	68	56	300	400	9	12	1/3 Right	Malleolus fractures	Bilateral Right
143	_7533_1	DRV	NO	73	54	400	200	13	1	2/3 Right	Metatarsal fractures	Right
144	_7534_1	DRV	YES	29	58	100	100	14	12	100% Left	"Ankle sprain"	Right
145	_7539_1	DRV	NO	34	52	0	100	11	1	2/3 Left	Cuneiform fracture	Left
146	_7594_1*	DRV	NO	23	65	600	500	10	12	1/2 Left	"Ankle dislocation"	Left
	_7594_1*	DRV	NO	23	65	600	500	10	12	1/2 Left	Tibia & fibula fracture, (distal part)	Left
147	_7701_1	DRV	NO	55	56	300	300	11	12	2/3 Left	Fibula fracture (distal part)	Left
148	_7722_1	DRV	NO	44	37	100	0	10	1	1/2 Right	Talar fracture	Right
149	_7742_1*	DRV	YES	19	43	200	100	10	11	1/2 Left	Metatarsal fractures	Right
	_7742_1*	DRV	YES	18	43	200	100	10	11	1/2 Left	Toe dislocation	Right
150	_7765_1*	DRV	YES	38	43	400	400	8	11	1/4 Left	Malleolus fractures	Bilateral Right
	_7765_1*	DRV	YES	38	43	400	400	8	11	1/4 Left	Toe fracture	Left
151	_7776_2	PAS	YES	37	60	500	400	12	12	2/3 Right	Ankle fracture	Left
152	_7786_1*	DRV	NO	44	73	300	100	16	12	100% With intrusion	Cuboid fracture	Right
	_7786_1*	DRV	NO	44	73	300	100	16	12	100% With intrusion	Cuneiform fracture	Right
153	_7792_1	DRV	NO	55	42	200	100	8	12	1/2 Left	Malleolus fractures	Medial Left
154	_7818_1	DRV	YES	44	48	200	100	10	11	1/2 Left	Metatarsal fractures	Left
155	_7843_1	DRV	YES	29	56	100	0	18	12	100% With intrusion	Calcaneal-fibular sprain	Right
156	_7843_2	PAS	YES	30	56	100	0	18	12	100% With intrusion	"Ankle sprain"	Left
157	_7927_1	DRV	NO	64	37	100	100	6	12	1/4 Left	Calcaneal-fibular sprain	Right
158	_7935_2	PAS	NO	18	52	100	100	9	12	2/3 Left	"Ankle sprain"	Left
159	_7948_2	PAS	YES	61	37	100	100	10	1	2/3 Left	Talar fracture	Right
160	_7999_1	DRV	NO	22	55	500	200	10	12	1/3 Left	"Lower leg fracture"	Right & Left

161	_8001_2	PAS	YES	46	40	0	0	8	11	2/3 Right	"Foot fracture"	Left
162	_8020_1	DRV	YES	39	52	500	500	10	12	1/2 Left	Calcaneal fracture	Right
163	_8024_1*	DRV	NO	40	51	300	200	11	12	100% Left	Malleolus fractures	Medial Right
	_8024_1*	DRV	NO	40	51	300	200	11	12	100% Left	Metatarsal fractures	Right
	_8024_1*	DRV	NO	40	51	300	200	11	12	100% Left	Toe fracture	Left
164	_8057_1	DRV	NO	23	58	200	100	15	12	100% Left	Metatarsal fractures	Left
165	_8067_1	DRV	YES	36	49	100	0	15	12	100% Left	Calcaneal fracture	Right
166	_8077_1	DRV	YES	32	45	100	100	10	11	1/2 Left	"Ankle sprain"	Left
167	_8114_1	DRV	YES	26	55	400	300	12	12	100% With intrusion	Malleolus fractures	Medial Left
168	_8117_1	DRV	YES	23	50	100	200	12	12	100% Left	Calcaneal-fibular sprain	Left
169	_8169_1*	DRV	NO	19	75	700	0	13	12	100% With intrusion	Cuboid fracture	Right
	_8169_1*	DRV	NO	19	75	700	0	13	12	100% With intrusion	Fibula fracture	Right & Left
	_8169_1*	DRV	NO	19	75	700	0	13	12	100% With intrusion	Metatarsal fractures	Right
	_8169_1*	DRV	NO	19	75	700	0	13	12	100% With intrusion	Scaphoid fracture	Right
	_8169_1*	DRV	NO	19	75	700	0	13	12	100% With intrusion	Talar fracture	Left
170	_8180_2	PAS	YES	33	58	0	600	10	11	2/3 Left	Fibula head or upper fibula fracture	Left
171	_8188_1*	DRV	NO	42	72	700	600	13	10	100% With intrusion	Calcaneal fracture	Right
	_8188_1*	DRV	NO	42	72	700	600	13	10	100% With intrusion	Cuboid fracture	Right
	_8188_1*	DRV	NO	42	72	700	600	13	10	100% With intrusion	Cuneiform fracture	Right
	_8188_1*	DRV	NO	42	72	700	600	13	10	100% With intrusion	Metatarsal fractures	Right
172	_8273_2	PAS	YES	28	37	200	100	6	12	2/3 Right	"Foot fracture"	Left
173	_8274_1*	DRV	YES	36	68	700	700	11	12	2/3 Right	Malleolus fractures	Bilateral Left
	_8274_1*	DRV	YES	36	68	700	700	11	12	2/3 Right	Metatarsal fractures	Left
174	_8274_2*	PAS	YES	14	68	700	700	11	12	2/3 Right	Calcaneal fracture	Left
	_8274_2*	PAS	YES	14	68	700	700	11	12	2/3 Right	Malleolus fractures	Medial Left
175	**_8503_1**	**DRV**	**YES**	**49**	**47**	**500**	**300**	**6**	**11**	**1/3 Left**	**Malleolus fractures**	**Medial Left**
176	_8538_2	PAS	YES	13	50	400	300	8	12	1/3 Right	Toe dislocation	Left
177	_8544_1	DRV	NO	32	43	100	200	8	12	1/2 Right	Calcaneal-fibular sprain	Right
178	_8580_2	PAS	NO	19	43	700	0	10	12	100% With intrusion	"Foot fracture"	Left
179	_8608_1*	DRV	YES	56	47	300	200	9	12	1/2 Left	Metatarsal fractures	Left
	_8608_1*	DRV	YES	56	47	300	200	9	12	1/2 Left	Toe dislocation	Left
180	_8616_2*	PAS	YES	18	74	500	500	15	11	100% With intrusion	Tibial diaphysis fracture	Left
	_8616_2*	PAS	YES	18	74	500	500	15	11	100% With intrusion	Toe fracture	Left
181	_8638_1	DRV	YES	28	58	300	300	8	12	1/2 Left	Metatarsal fractures	Right
182	_8704_1*	DRV	NO	41	63	600	300	15	1	100% With intrusion	Metatarsal dislocations	Right
	_8704_1*	DRV	NO	41	63	600	300	15	1	100% With intrusion	Scaphoid fracture	Right
183	_8704_2*	PAS	NO	22	63	600	300	15	1	100% With intrusion	Metatarsal fractures	Right
	_8704_2*	PAS	NO	22	63	600	300	15	1	100% With intrusion	Toe dislocation	Right
184	_8714_2	PAS	YES	18	45	300	100	7	12	1/3 Right	Metatarsal fractures	Right
185	_8722_1	DRV	YES	55	50	0	0	1	12	100% No intrusion	Pilon tibial	Right
186	_8723_1*	DRV	YES	22	75	500	500	17	11	100% Left	Talar fracture	Left
	_8723_1*	DRV	YES	22	75	500	500	17	11	100% Left	Tarsal bone dislocations	Left
187	_8723_2	PAS	YES	18	75	500	500	17	11	100% Left	Malleolus fractures	Lateral Right
188	_8728_1*	DRV	YES	60	40	300	200	6	12	1/2 Left	Malleolus fractures	Medial Right
	_8728_1*	DRV	YES	60	40	300	200	6	12	1/2 Left	Metatarsal fractures	Right
	_8728_1*	DRV	YES	60	40	300	200	6	12	1/2 Left	Scaphoid fracture	Right
	_8728_1*	DRV	YES	60	40	300	200	6	12	1/2 Left	Talo-calcaneal dislocation	Right
189	_8728_2	PAS	YES	58	40	300	200	6	12	1/2 Left	Talar fracture	Right
190	_8742_1	DRV	YES	68	48	400	200	6	12	1/3 Left	Metatarsal fractures	Left
191	_8834_2	PAS	YES	40	28	100	100	9	1	1/3 Right	Calcaneal-fibular sprain	Right
192	_8868_1	DRV	YES	21	32	0	0	8	1	1/2 Right	Malleolus fractures	Lateral Left
193	_8878_1	DRV	NO	27	38	500	300	5	11	1/4 Left	Malleolus fractures	Medial Left
194	_8881_2	PAS	NO	18	38	100	0	6	12	1/3 Right	Calcaneal-fibular sprain	Right
195	_8893_1	DRV	YES	29	53	400	100	8	12	1/2 Left	Fibula fracture	Right
196	_9002_1	DRV	YES	45	40	0	0	10	12	2/3 Left	Malleolus fractures	Medial Left
197	_9003_1*	DRV	YES	66	40	200	100	10	12	2/3 Left	Calcaneal fracture	Right
	_9003_1*	DRV	YES	66	40	200	100	10	12	2/3 Left	Malleolus fractures	Lateral Right
198	_9026_1	DRV	YES	22	74	300	400	15	12	100% Right	"Ankle sprain"	Left
199	_9037_2	PAS	NO	53	41	100	100	11	12	1/2 Right	Ankle fracture	Left
200	_9042_1	DRV	YES	30	47	500	600	8	11	1/3 Left	Malleolus fractures	Unknown Right
201	_9043_1	DRV	YES	28	51	0	0	8	2	100% No intrusion	Talar fracture	Right
202	_9059_1	DRV	YES	31	35	200	0	10	1	1/3 Right	"Ankle sprain"	Right
203	_9062_1	DRV	YES	22	48	100	0	11	12	1/2 Right	Malleolus fractures	Lateral Right
204	_9069_1	DRV	YES	60	43	0	0	13	12	100% No intrusion	Calcaneal fracture	Right
205	_9074_1	DRV	YES	30	55	100	100	11	12	1/2 Right	Tibial & fibula diaphysis fractures	Left
206	_9082_1	DRV	YES	21	45	100	100	13	12	100% With intrusion	"Ankle sprain"	Left
207	_9083_2	PAS	YES	50	33	0	0	11	12	100% No intrusion	Ankle fracture	Unknown
208	_9116_1*	DRV	YES	37	70	200	300	20	12	100% With intrusion	Metatarsal fractures	Right
	_9116_1*	DRV	YES	37	70	200	300	20	12	100% With intrusion	Tarsal bone dislocations	Right
	_9116_1*	DRV	YES	37	70	200	300	20	12	100% With intrusion	Toe dislocation	Right

Rq: Bold-faced cases represent the 4 ones illustrated in the article.