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IDENTIFICATION OF DRIVER AND FRONT PASSENGER IN TRAFFIC ACCIDENTS THROUGH SKELETAL INJURY PATTERN.

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ABSTRACT

This paper is a retrospective study examining 328 cadavers deceased from traffic accidents (252 drivers and 76 front seat passengers). Specifically, the skeletal injuries of the cranial, spine, chest, upper and lower limbs were examined. The purpose of the study is to ascertain whether it is possible to identify, through the skeletal injury patterns, who was driving at the time of the traffic accident. A statistical analysis was used to detect injuries that could differentiate between driver and front passenger. Drivers more frequently reported chest injuries, especially sternal injuries, due to the collision with the steering wheel. On the other hand, front passengers more frequently reported skull and spinal injuries. Furthermore, a greater incidence of pelvis fractures in front passengers was observed compared to drivers. The chest injury pattern resulted to be the most effective for distinguishing the driver from the front passenger.

1. Introduction

In Italy, mortality from car accidents in the general population is ranked third after cardiovascular and neoplastic diseases, and is ranked first in the 35-year-old population segment. Road accidents are the most frequent cause of traumatic death [1,2]. Based on the most recent data published in 2015, 173,892 car accidents causing personal injuries occurred in 2015, resulting in 3,419 deaths (within 30 days from the accident) and 246,050 injured people. 2015 was marked by a further increase in car accident deaths in Italy and in the European Union (1.3% more than in 2014, but much lower than in 2011). For every million people, 52 road accident deaths occurred in 2015 in the EU28 and 56.3 in Italy, which is 14th in the European ranking, behind UK, Spain, Germany and France [3,4]. Law No. 41 of March 23, 2016, published in the Gazzetta Ufficiale on March 24th, and enforced the following day, introduced a new road law in the Italian legislation. This is nothing more than a particular case of manslaughter that occurs whenever one of the behaviors specifically identified by art. 589 bis c.p. (criminal code), which are based on violations of certain rules governing road traffic, is verified. Stricter sentences for road homicide have frequently caused drivers involved in traffic accidents, resulting in the fatality of the passenger (seated in the front seat), to deliberately declare to have been the front passenger to avoid responsibility for the passenger's death. This results in the need for appropriate forensic medicine investigations to determine who was really driving the vehicle at the time of the accident. Hence, the reason for this study: verify, strictly from the forensic viewpoint and through the examination of skeletal injuries deriving from the car accident, whether it is possible to distinguish the driver from the front passenger.

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2. Materials and Methods

A total of 328 deceased subjects were examined between 2000 and 2016, 252 drivers and 76 front seat passengers, following car accidents in the territory of Rome and its province, taking into consideration all cars equipped with the same safety systems (seatbelts and air-bags). At the same time, the possible limiting factors (advanced patient age),which could have affected the outcome, were eliminated. The 328 cadavers underwent necroscopic examination. The skeletal injuries of the driver and the front passengerwere studied at the level of the skull (vault and cranial base), of the spine (cervical, dorsal, lumbar and sacral), of the chest (left hemithorax, right hemithorax and sternum) of the upper limbs (left arm and forearm, right arm and forearm) and lower limbs including the pelvis, given the close anatomical-functional correlation (pelvis, left thigh and leg, and right thigh and leg). For the two distributions (driver-passenger), classical statistical values were considered: 1) mean and 2) standard deviation, from which the following parameters derived: Pearson kurtosis (to check the overlapping distributions compared to the Gaussian), Asymmetry of Fischer (to identify possible asymmetric oscillations compared to the Gaussian) and Covariance (to confirm the correlation between the two distributions).

3. Results

The asymmetries present slight fluctuations, which are always concordant with both distributions. Driver and passenger data is homogeneous and always maintains the same trends for Kurtosis and Asymmetry. The positive Covariance values show a correlated and concordant behavior for the two distributions. Finally, Student's T and Chi square tests were performed to verify the validity of the available statistical sample. The Student's T-test, useful for the study of homogeneity of the distributions, in our case is valid for values lower than 5%. This value is maintained in all examined body regions, except for the chest. This result can be attributed to the presence of the steering wheel. Chi Square analysis (similarity of distributions) confirms the results obtained by Student's T-test (Table 1).

DRIVER	Mean ± SD	PASSENGER	Mean ± SD	T student	Chi Square
SKULL	**82** ± 31.43	SKULL	**29.33** ± 13.32	4.63	33.83
SPINE	28 ± 28.18	SPINE	12.8 ± 12.93	2.45	8.25
CHEST	**134** ± 49.56	CHEST	**35** ± 15.53		
UPPER LIMBS	24.4 ± 17.91	UPPER LIMBS	10.4 ± 7.54	3.60	8.03
LOWER LIMBS	**40** ± 32.22	UPPER LIMBS	**15.67** ± 10.91	4.29	14.80

Table 1 - Descriptive analysis of skeletal injury pattern asymmetry

Of the 328 cadavers examined, 282, i.e. 86%, had skeletal injuries. Overall, considering both the driver and the front passenger, the skull was affected by fracture injuries in 43.3% of the cases, the spine in 28.7%, the chest in 67.1%, upper limbs in 23.8% and lower limbs in 40.9% (Table 2).

Anatomical sites	Driver	Passenger	Total
Skull	**41.3%**	**50.0%**	**43.3%**
Spine	**25.4%**	**39.5%**	**28.7%**
Chest	**69.0%**	**60.5%**	**67.1%**
Upper limbs	**22.2%**	**28.9%**	**23.8%**
Lower limbs	**39.7%**	**44.7%**	**40.9%**

Table 2 - General distribution of fractures in drivers and passengers.

In the driver, the cranial area was affected by fracture injuries in 104 cases from a total of 252; in particular, cranial vault fractures were observed in 46 subjects (44.23%) and cranial base fractures in 96 (92.31%). In the passenger, the skull was affected in 38 cases out of a total of 76. 14 subjects presented fractures of the cranial vault (36.84%), and 36 subjects had fractures of the cranial base (94.74%) (Table 3 and 4).With regards to the spine, vertebral fractures were observed in 64 drivers and in 30 passengers. Fractures of the cervical spine were found in 52 drivers (81.25%), of the dorsal spine in 16 (25%), of the lumbar spine in 6 (9.38%) and of the sacral spine in 2 (3.13%). The vertebral fractures affected the cervical spine in 22 passengers (73.33%), the dorsal spine in 10(33.33%) and the lumbar spine in 2 passengers (6.67%) (Table 3 and 4). The thoracic region was affected in 174 drivers. Rib fractures were observed on the right thorax in 144 subjects (82.8%) and on the left thorax in 156(89.7%). Sternum fractures were present in 62 subjects (35.6%). Chest injuries were observed in 46 passengers. There were partial fractures on the right side of the chest in 40 subjects (87%), on the left side in 42(91.3%) and on the sternum in 12 (26.1%) (Table 3 and 4). In 56 drivers and 22 passengers, upper limb fractures were observed. The fractures involved the right arm in 12 drivers (21.43%), the right forearm in 20 (35.71%), left arm in 18 (32.14%) and left forearm in 16 (28.57%). Fractures of the right arm were observed in 14 passengers (63.64%), the right forearm in 4 (18.18%), left arm in 6 (27.27%) and left forearm in 6 (27, 27%) (Tables 3 and 4). Finally, the lower limbs were affected in 100 drivers and in 34 passengers. 32 drivers presented fractures of the pelvis (32%), 38 right thigh fractures (38%), 8 right leg fractures (8%), 44 left thigh fractures (44%) and 18 left leg fractures (18%). 18 passengers presented fractures of the pelvis (52.94%), 14 right thigh fractures (41.18%), 8 right leg fractures (23.53%), 18 left thigh fractures (52.94 %), and 2 left leg fractures (5.88%) (Tables 3 and 4).

	Anatomical Sites	Driver	Passenger	Total
SKULL	Vault	46	14	60
	Cranial base	96	36	132
	General skull	104	38	142
SPINE	Cervical	52	22	74
	Dorsal	16	10	26
	Lumbar	6	2	8
	Sacral	2	0	2
	General Spine	64	30	94
CHEST	Right Hemithorax	144	40	184
	Left Hemithorax	156	42	198
	Sternum	62	12	74
	General Chest	174	46	220
UPPER LIMBS	Right Arm	12	14	26
	Right Forearm	20	4	24
	Left Arm	18	6	24
	Left Forearm	16	6	22
	General Upper Limbs	56	22	78
LOWER LIMBS	Pelvis	32	18	50
	Right Thigh	38	14	52
	Right Leg	8	8	16
	Left Thigh	44	18	62
	Left Leg	18	2	20
	General Lower Limbs	100	34	134

Table 3 - Number of fractures anatomical sites among drivers and passengers.

	Driver	Passenger
Skull		
Vault	44.2%	36.8%
Cranial Base	92.3%	94.7%
Chest Fractures		
Right Hemithorax	82.8%	87%
Left Hemithorax	89.7%	91.3%
Sternum	35.6%	26.1%
Spine		
Cervical	81.2%	73.3%
Dorsal	25%	33.3%
Lumbar	9.4%	6.7%
Sacral	3.1%	0%
Upper Limbs		
Right Arm	21.4%	63.6%
Right Forearm	35.7%	18.2%
Left Arm	32.1%	27.3%
Left Forearm	28.6%	27.3%
Lower Limbs		
Pelvis	32%	52.9%
Right Thigh	38%	41.2%
Right Leg	8%	23.5%
Left Thigh	44%	52.9%
Left Leg	18%	5.9%

Table 4 - Distribution of fractures in the different anatomical sites between drivers and passengers.

Therefore, the driver's skull was affected by fracture lesions in 41.3% of the cases, the spine in 25.4%, the chest in 69%, the upper limbs in 22.2%of and the lower limbs in 39.7 %. The passenger's skull was affected in 50% of the cases, the spine in 39.5%,the chest in 60.5%, the upper limbs in 28.9% and the lower limbs in 44.7% (Graph 1).

Statistical data processing has taken into account the simultaneous presence in the examined subjects of multiple fractures within the same body region (for example presence of fractures of the vault and of the cranial base or of the right and left hemithorax etc.).

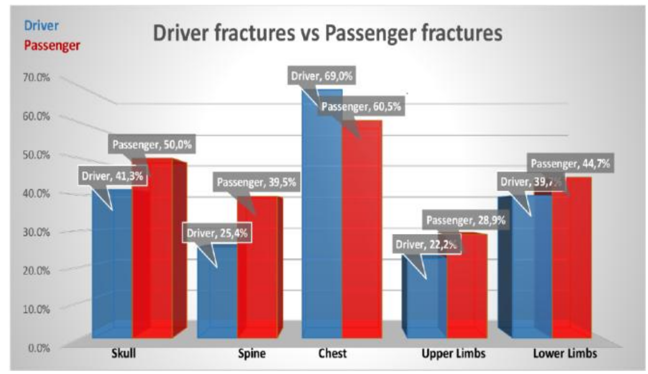

Figure 1 - Prevalence of fractures in driver and passengers

4. Discussion

The aim of this paper is to find out whether it is possible to distinguish the driver from the anterior passenger in case of fatal car accidents [5 – 9]. Indeed, more and more often, especially in Italy, with the introduction of road the homicide concept in the legislation, the driver survived from a fatal traffic accident, declares to be a passenger in order to avoid a criminal proceeding. Curtin et al. [10] have observed a different injury pattern between the driver and the passenger. Specifically, the most frequent lesions in drivers were in the brain, right femur fractures, fractures of the posterior arc of the right ribs, of the skull base, and right humerus and shoulder. While in the anterior passenger, the lesions were splenic, fractures of the anterior and posterior left rib cage, of the left shoulder, and left femur. Based on such observations, the authors have provided a predictive model for differential diagnosis, with an accuracy of 69.3%.Our study shows that the thoracic lesion pattern, and especially in the sternum, is the most relevant. The statistical data confirms that the most valid feature to differentiate the driver (69% of the cases) from the front passenger (60.5% of cases) is the chest lesion pattern. The explanation for this phenomenon can be attributed to the presence of the steering wheel [11], which is responsible for increased sternum injuries. The Student's T-test, helpful for the study of homogeneity of distributions, is valid for values lower than 5%. In our case the only parameter that exceeds such value is referred to the chest region and can be explained from an intrinsic difference in both study categories, i.e. the presence of the steering wheel only on the driver's side of the car. The presence of the steering wheel makes the two distributions asymmetric, and most likely explains the different lesions found at the chest level. This difference is of fundamental importance in the differential diagnosis between the driver and the passenger (higher incidence of chest injuries in the driver).With regards to the other analyzed anatomical areas, a greater incidence of skull and spinal injuries were observed in the front passenger compared to the driver (skull - 50% in the passenger vs. 41.3% in the driver, and spine - 39.5% in the passenger vs. 25.4 % in the driver).

This behavior can be explained as the consequence of chest trauma in the driver: most likely in the latter, the injurious energy will discharge more heavily on the chest following the collision against the steering wheel, thereby reducing the impact force exerted on the skull and spine [12]. Pigolkin YI et al. [13] report a percentage of substantially homogeneous injuries to cervical spine between the driver and front passenger. The difference resulting from the study is that in the driver the vertebrae from 2 to 4 are primarily concerned, while in the front passenger the vertebrae from 4 to 6.Lesions of the cervical, dorsal, and lumbar vertebrae resulting in death were more frequently found at the driver compared to front and rear right passengers [14].With regards to the skeletal lesions of the upper and lower extremities, the front passenger is more frequently affected than the driver. It should be noted, however, that in the upper and lower limb lesions the road accident dynamics assume a substantial role. In fact, it has been observed that if the impact occurs on the right side, the passenger is more likely affected on the right superior and inferior limb; vice versa if the impact occurs on the left side of the car, the injuries to the upper and lower limb is more frequent in the driver compared to the passenger. The data from the present study shows a greater frequency of forearm fractures in drivers than in the passenger. This result is consistent with what some authors have observed [15]. Another noteworthy result is the higher frequency of fractures on the right arm in the passenger compared to the driver, most likely in relation to the position inside the passenger compartment and the dynamics of the accident. With regards to the lower limbs, there is a greater incidence of pelvis fractures in the front passenger compared to the driver. This data can find the same etiopathogenetic explanation for the cranial and spinal lesions that are the most common in front passengers.

5. Conclusion

This study shows that examining skeletal lesions in car accident cases is a useful tool for identifying the driver and the front passenger. Specifically, the study states that chest, and specifically sternum, injuries are the most valuable element to differentiate the driver from the front passenger. At the same time, the front passenger is more frequently subject to skull and spine lesions, while upper and lower limb lesions occur at a similar frequency, depending mainly on the dynamics of the accident. With regards to the upper limbs, a greater incidence of forearm fractures was observed in the driver compared to the passenger, while right arm fractures were more frequent in the front passenger. Lastly, a greater incidence of pelvis fractures was observed in the front passenger compared to the driver.

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