Head Injury Causation and Characteristics in Motorcycle Riders

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Abstract – The objective of the study is to demonstrate causation and characteristics of head injuries sustained by helmeted motorcycle riders in traffic accidents. Even though motorcycle helmets are effective to prevent and reduce injuries to the head in crashes, still a majority of helmet wearers sustain significant and even fatal head injury. Therefore, enhancement and innovation of safety measures capable to diminish the incidence and severity of head injury remains important and inevitable as always. The results of the present study may contribute to achieve that objective of better controlling head injury in motorcycle crashes. Case by case analysis has been performed for 116 fatally injured motorcycle riders which were collected in part in the European COST 327 motorcycle project (63 cases) and, to have a more comprehensive sample, completed with 53 autopsy cases from the Munich University Institute for Legal Medicine. Type, location and intensity of the impact to the helmeted head was examined as well as corresponding specific lesions, i.e. haemorrhages, fractures, contusions, lacerations etc. The paper illustrates the distributions of that specific lesions correlated to their location and to the characteristics of the mechanical impact to helmeted head. Injuries to the cervical spine are reported as well. In conclusion, the analysis of head injury in motorcycle riders wearing helmets provides valuable insight which kind and location of specific lesions can be expected depending on particular head impact characteristics. The results can be of use to improve existing or design new safety measures better preventing or reducing these particular head injuries.

Key Words: Motorcycle accidents, Head injury of helmeted riders, Injury characteristics and causation.

1 Introduction

Many investigations [1-5] have confirmed that motorcycle helmets are effective to prevent and reduce injuries to the head in crashes. However, still a majority of helmet wearers sustain significant and even fatal head injury. Therefore, enhancement and innovation of safety measures capable to diminish the incidence and severity of head injury remains important and inevitable as always. The results of the present study may contribute to achieve that objective of better controlling head injury in motorcycle crashes.

2 Material and Method

Case by case analysis has been performed for 116 fatally injured motorcycle riders. Casualties have been collected in part during the European COST 327 motorcycle project (63 cases) [4] and, to have a more comprehensive sample, completed with 53 autopsy cases from the Munich University Institute for Legal Medicine.

86% of the cases are male, 14% of them female. Age distribution is the following: 13% 15 – 19 years of age, 23.6% 20 – 29 years of age, 26.1% 30 – 39 years of age, 15.2% 40- 49, and 13.1% over 50 years of age.

For each individual case type, location and intensity of the impact to the helmeted head was examined as well as corresponding specific head injuries, such as skull fractures, haemorrhages, contusions, lacerations etc. Lesions of brain stem and cervical spine were examined as well.

3 Results

3.1 Impact Characteristics

Impacts to the helmeted head of the motorcycle rider are classified **(1) frontal, (2) lateral (**left and right side), and **(3) occipital** according to the head coordinate system illustrated in Figure 1. Within the XY-plane **frontal** is defined for angles -45° to +45°, **lateral** ±46° to ±135°, and **occipital** ±136° to 180°. Furthermore, frontal exposure is subdivided into lower (**caudal**) head impact (ZX-angle -45° to +15°) and upper (**cranial**) head impact (ZX-angle +16° to +90°).

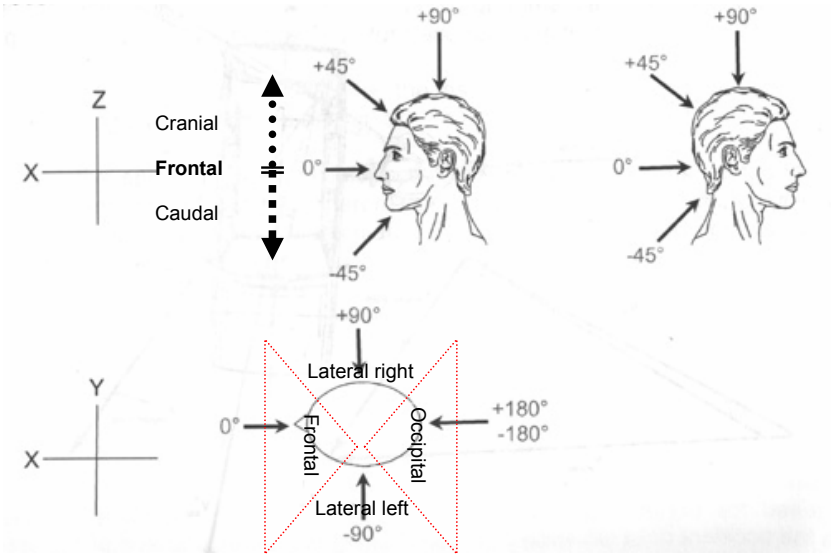

Fig. 1 Impact characteristics related to head coordinate system

The 116 casualties examined are distributed as follows:

(1 a)	Frontal Caudal	n = 35,
(1 b)	Frontal Cranial	n = 43,
(2 a)	Lateral left side	n = 19,
(2 b)	Lateral right side	n = 11,
(3)	Occipital	n = 8.

3.2 Injury Location

Impact characteristics defined above and head injury observed are correlated in each individual case. The location and relative incidence of specific lesions to the head (e.g. lacerations, fractures, brain contusions etc.) is documented in tables and bar diagrams. A selection of significant findings for frontal impacts to the helmeted head is presented in the following chapter.

3.3 Frontal Impact to the helmeted head

A majority of two thirds of the motorcyclists (n = 78) were exposed to frontal impacts against the helmeted head, 35 of them in the lower (caudal) region and 43 in upper (cranial) region of the head. Significant injuries associated are **facial fractures** (i.e. of orbita, nose, maxilla, teeth, mandibula)**, calvarium fractures, base fractures and brain contusions.** Injuries to the **brain stem, cerebellum** and **cervical spine** are demonstrated as well.

The following diagrams illustrate the relative incidence and location of these particular lesions related to frontal impacts against the lower head (caudal) and upper head (cranial). 100% represents the number of cases who sustained that particular injuries from frontal impacts to the head but are not all riders exposed to that impacts. The percentage of injured riders is indicated as well.

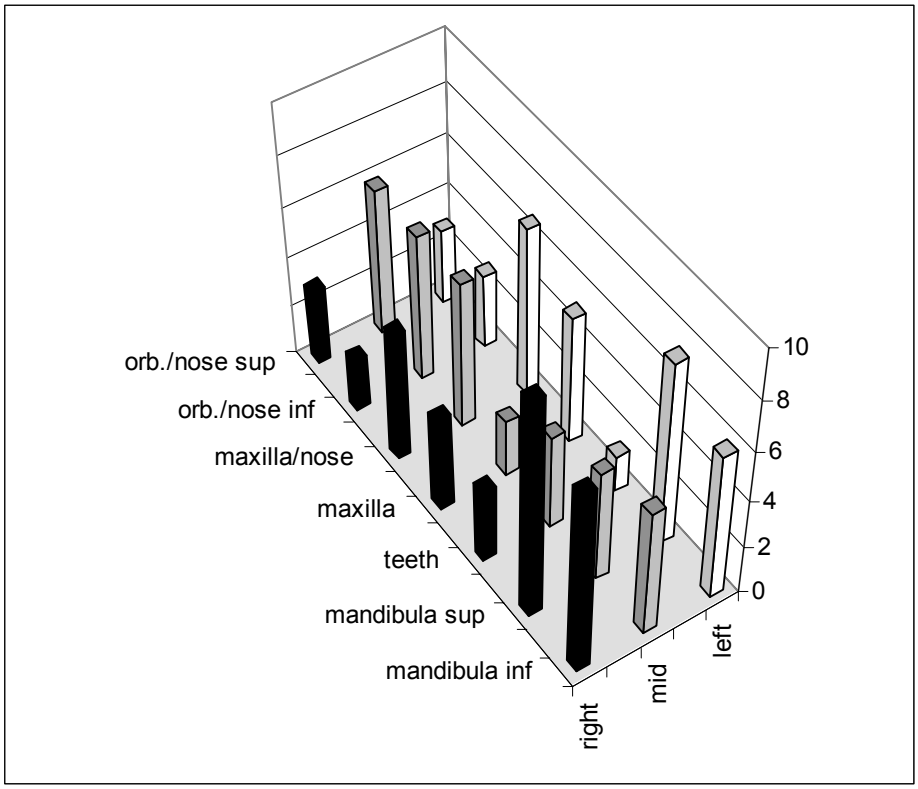

Fig. 2 Frontal impacts - Caudal: Percentage of facial fractures (25 of 35 = 71.4%)

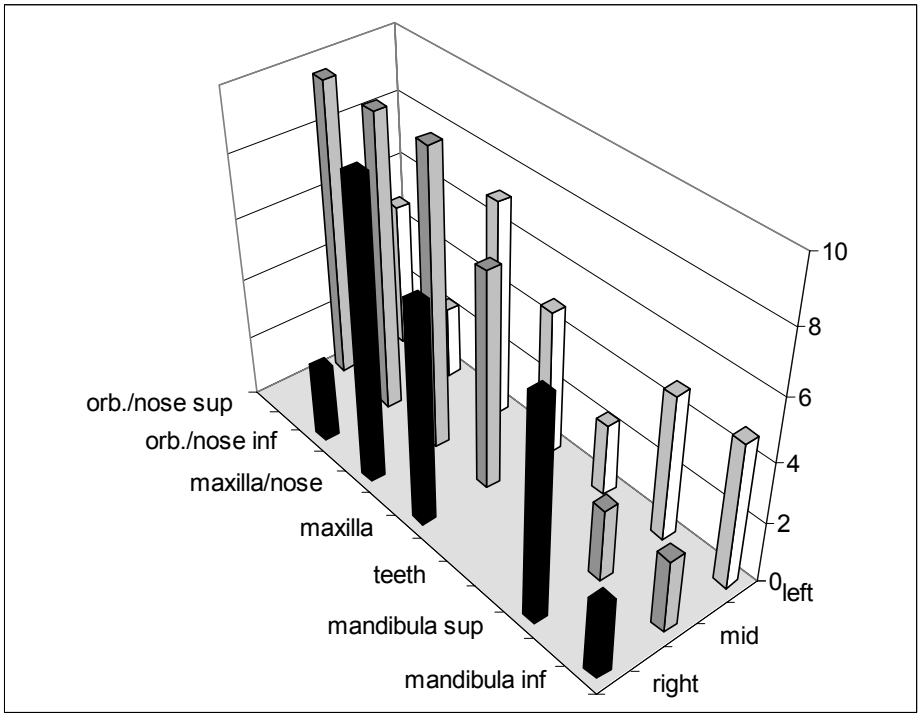

Fig. 3 Frontal impacts - Cranial: Percentage of facial fractures (10 of 43 = 23.3%)

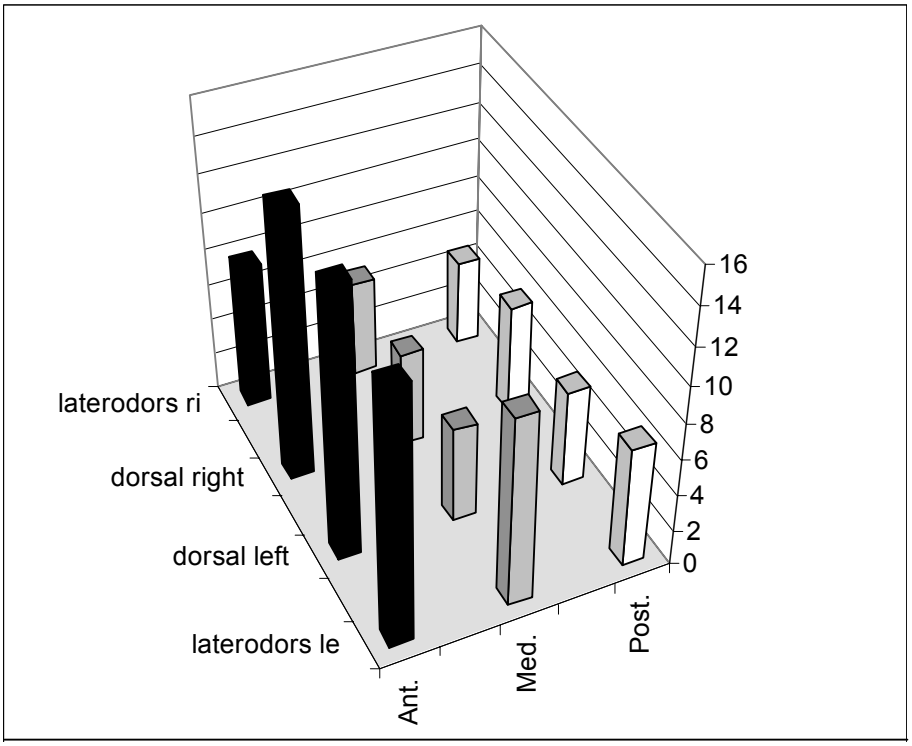

Fig. 4 Frontal impacts - Caudal: Percentage of calvarium fractures (dorsal = upper skull) (14 of 35 = 40%)

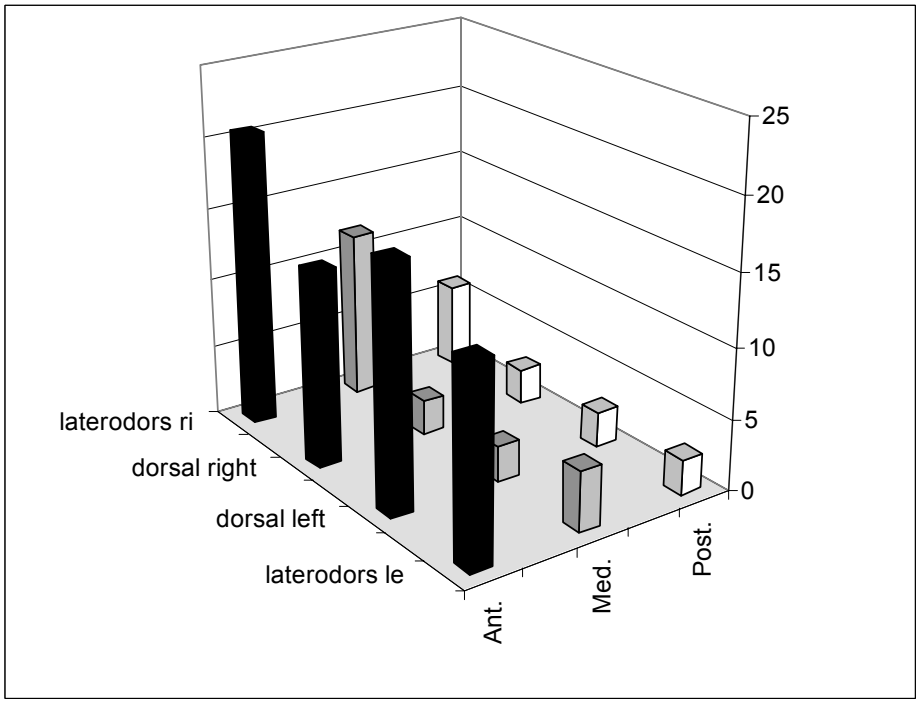

Fig. 5 Frontal impacts - Cranial: Percentage of calvarium fractures (dorsal = upper skull) (17 of 43 = 39,5%)

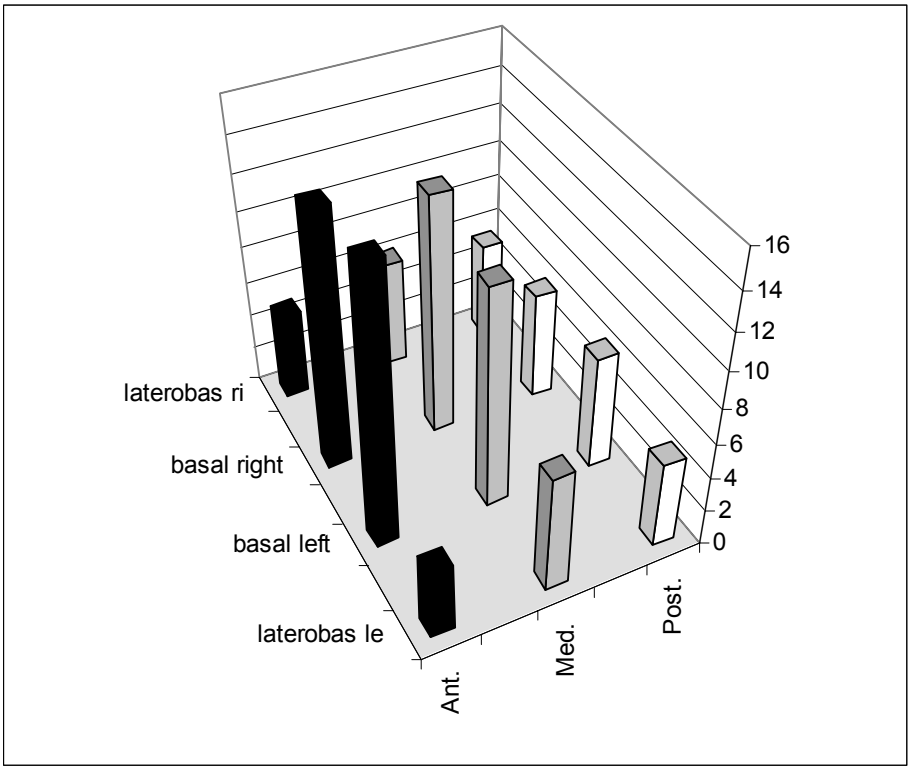

Fig. 6 Frontal impacts - Caudal: Percentage of base fractures (23 of 35 = 67,5%)

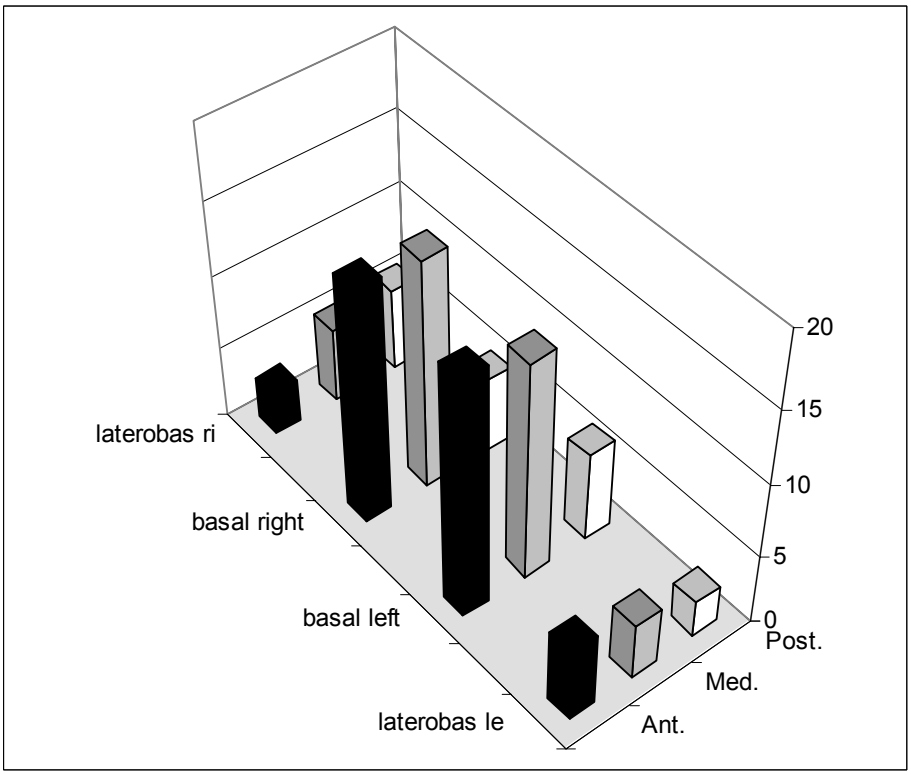

Fig. 7 Frontal impacts - Cranial: Percentage of base fractures (29 of 43 = 67,4%)

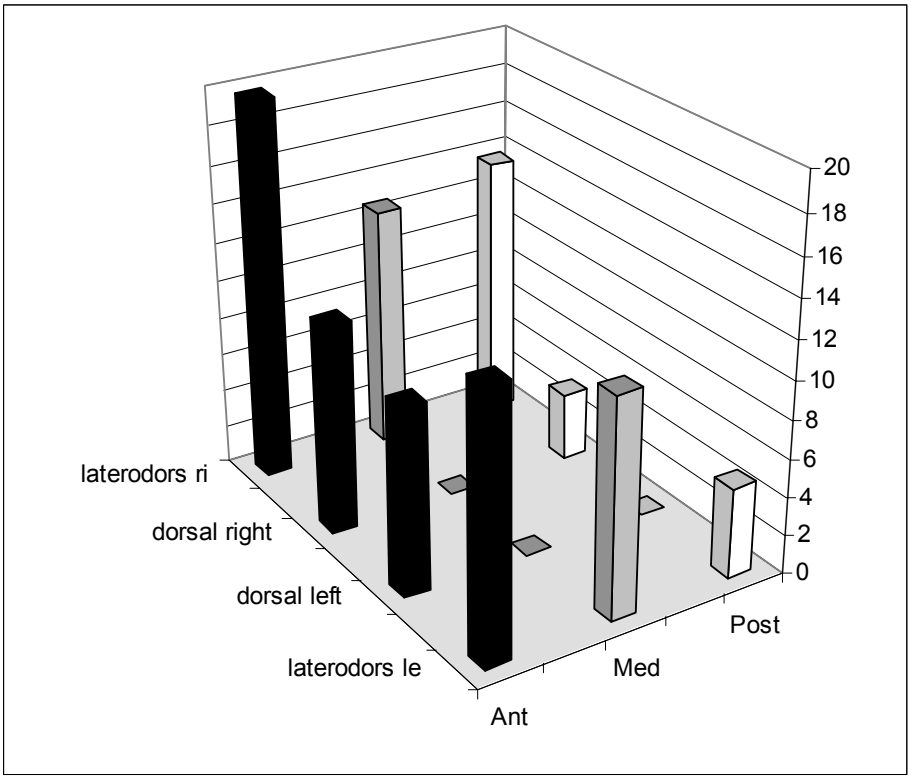

Fig. 8 Frontal impacts - Caudal: Percentage of dorsal (=upper) brain contusions (11 of 35 = 22,9%)

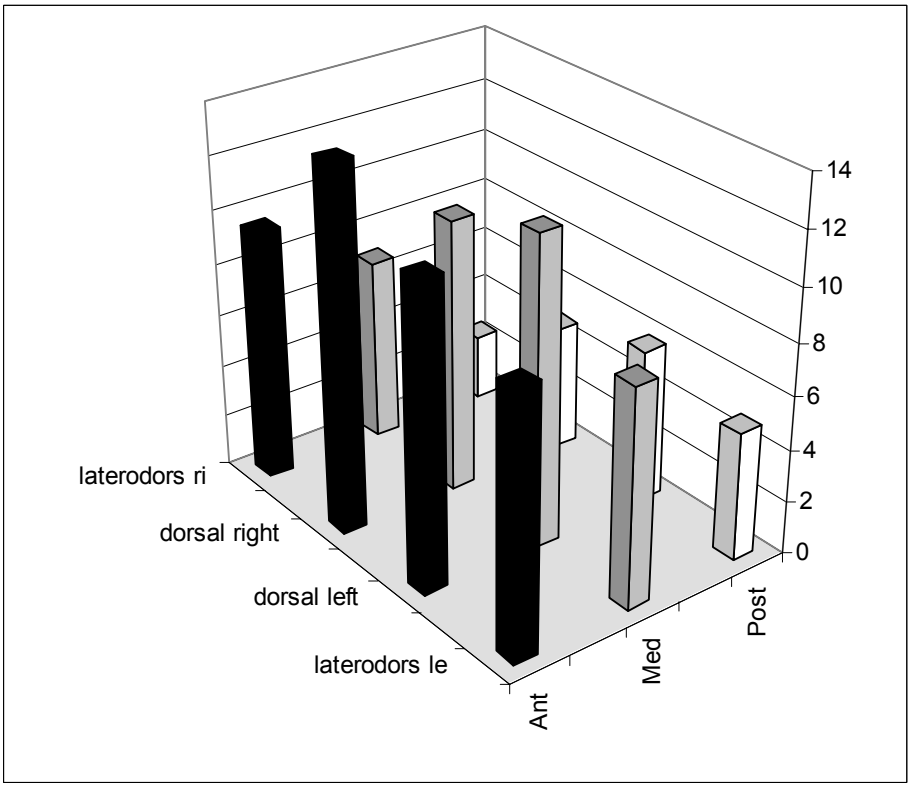

Fig. 9 Frontal impacts - Cranial: Percentage of dorsal (= upper) brain contusions (11 of 43 = 25,6%)

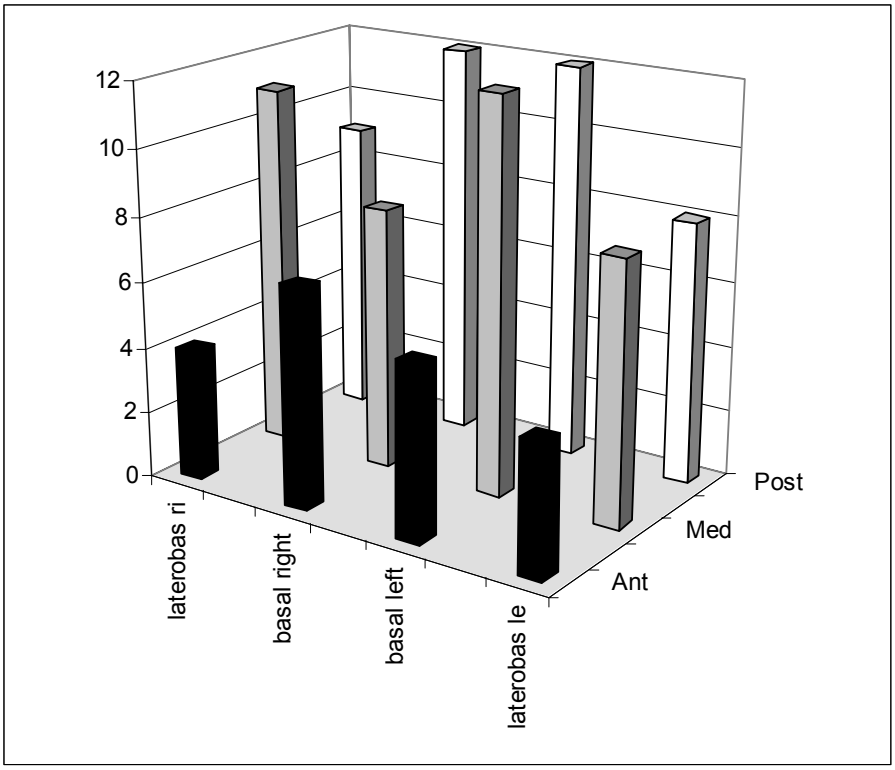

Fig. 10 Frontal impacts - Caudal: Percentage of basal brain contusions (17 of 35 = 48,6%)

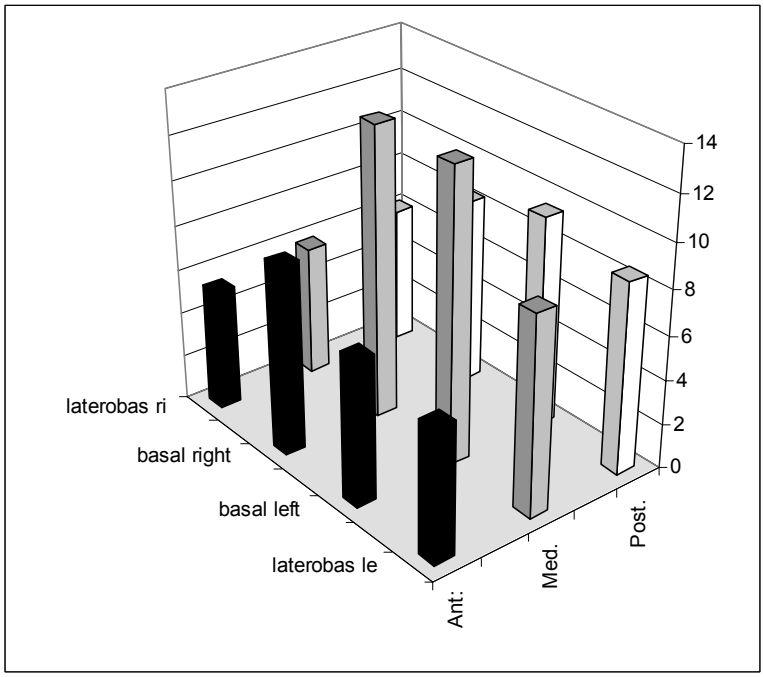

Fig. 11 Frontal impacts - Cranial: Percentage of basal brain contusions (10 of 43 = 23%)

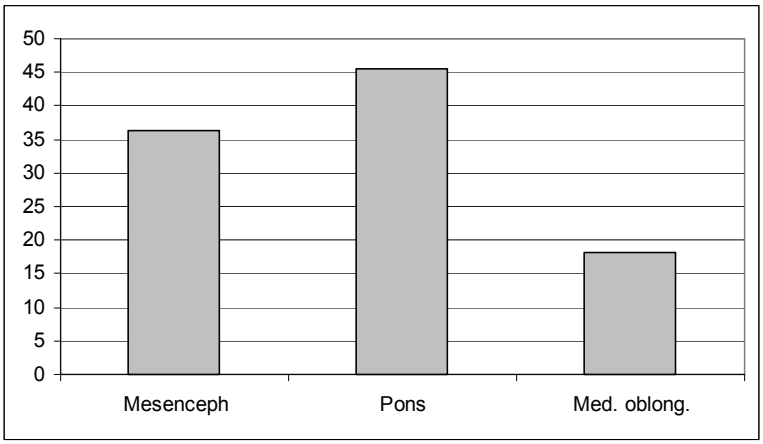

Fig. 12 Frontal impacts-Caudal: Percentage of brain stem lesions (6 of 35 = 17.1%)

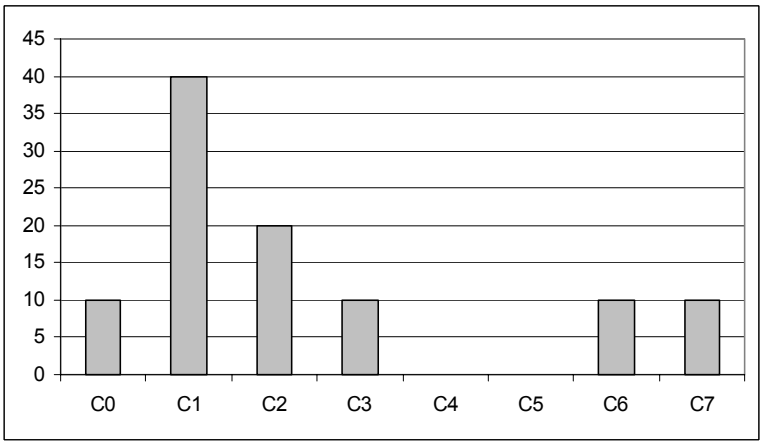

Fig. 13 Frontal impacts-Caudal: Percentage of cervical spine fractures (5 of 35 = 14.3%)

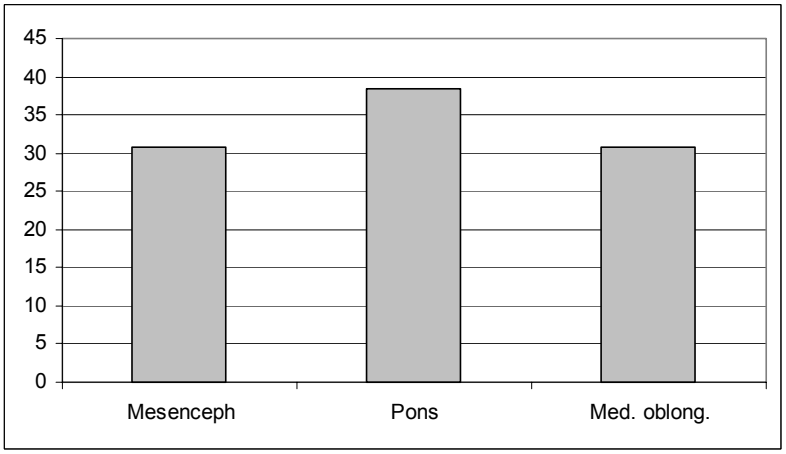

Fig. 14 Frontal impacts-Cranial: Percentage of brain stem lesions (7 of 43 = 16.3%)

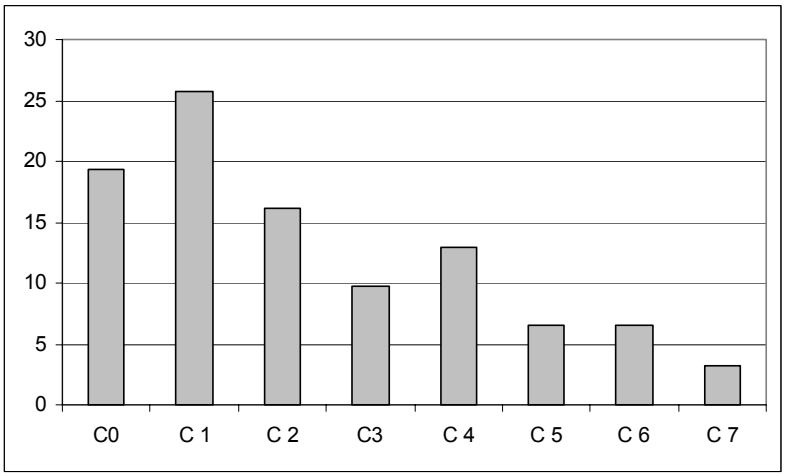

Fig.15 Frontal impacts-Cranial: Percentage of cervical spine fractures (11 of 43 = 25.6%)

The diagrams presented above suggest that skull fractures sustained from frontal impacts to the helmeted head predominantly are located close to the impact site. In particular, most facial fractures occur near to impact area, e.g. for caudal impacts in the mandibula region and for cranial impacts in the orbita and superior nose region. However, areas remote from the direct impact area are affected as well, so the superior nose and orbita region in case of an impact to the lower part of the helmet (caudal impact) and the mandibula region in case of cranial impacts (cf. Figure 2 and 3).

Calvarium and base fractures show similar distributions, i.e. a majority of fractures close to the impact site, but also, in particular the skull base, more and more remote fractures. This is evident for base fractures located medial and posterior as shown in Figure 7 and 8. Propagation of **shock waves** along the skull base could be an explanation for this.

Contusions in the upper cerebral region (= dorsal) are dominating near the impact site, but in the basal brain region there are more contusion opposite the direct impact indicating **Contre coup** lesions. This is in particular evident for caudal frontal impacts (c.f. Figure 9).

Brain stem lesions are associated to pons, midbrain (mesencephalon) and medulla oblongata.

Cervical spine fractures are predominantly located in the upper region C1 and C2.

To demonstrate other impact situations as well, as an example base fractures associated with **lateral left side impacts** are shown in Figure 16: Fractures are predominant not lateral but more in the medial skull base and occur as well on the opposite side.

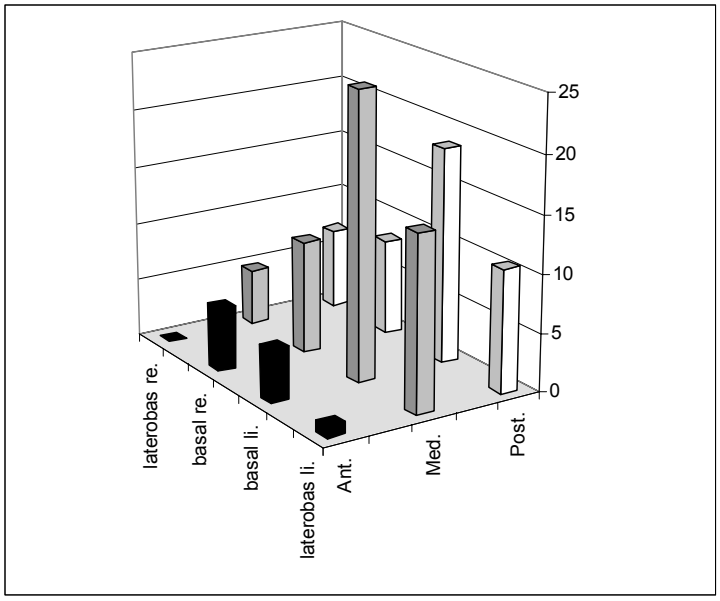

Fig. 16 Lateral left side impacts: Percentage of base fractures (12 of 19 = 63,2%)

4 Conclusion

The analysis of head injury in motorcycle riders wearing helmets provides valuable insight which kind and location of specific lesions can be expected depending on particular head impact characteristics. Because skull fractures occur predominately nearby the impact site direct force transmittance through helmets needs to be controlled in order to prevent or at least reduce this particular lesion. Improved helmet design including more effective damping materials could be the solution for better performance of motorcycle helmets in case of severe impacts. Controlling both direct force transmittance to the head and indirect acceleration loading of the brain must be by all means the major objective of helmet development.

5 References

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