CLINICAL STUDY OF HEAD INJURIES IN PATIENTS WITH TRAUMATIC UNCONSCIOUSNESS

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Within the frame of traumatic pathology, head injuries prevail due to their frequency and their severity. While a lot of them have a moderate severity only, some are life threatening or result in very important sequelae. Head injuries are therefore the first cause of mortality and of severe disabilities mainly.

This paper analyzes 176 cases of severe head injuries with a traumatic unconsciousness exceeding 24 hours. All the patients were admitted to the Intensive Care Unit of the Neurological Hospital "Pierre Wertheimer" in Lyon.

POPULATION CHARACTERISTICS

1) Selection criteria

* the first criterion is the admission to the Neurological Intensive Care Unit, which determines the severity of head injuries (AIS 5).

* the second criterion is that patients must not have severe injuries to other body segments. In fact, 85 out of the 176 patients had no associated injury except superficial abrasions or contusions. Table 1 shows associated injuries in the 91 other patients. Only 1 had an AIS 4 level injury (spleen rupture). All the other injuries were ≤ AIS 3. This criterion leads to consider that associated injuries only have a minimum aggravating effect on head injuries.

2) Types of accidents

The sample of this study includes traffic accidents mainly (152 cases) and 24 cases of non-traffic accidents. The distribution between the various road users' categories is given in Table 2.

3) Age and sex

Figure 1 indicates the distribution of patients in 5 age groups. It can be seen that the two younger age groups are overrepresented : 67 % of patients are under 30 years. The mean age is 26.4 years. However, the distribution as per age varies with the type of accident : 50 % of non-traffic accidents occurred in patients of 40 years and over, while 50 % of accidents involving pedestrians and unhelmeted two-wheel riders occurred in patients less than 20 years old. Fifty-four per cent of helmeted two-wheel riders of this population are between 20 and 29 years old.

Seventy-seven per cent of patients are male and 23 % are female.

	AIS 1	AIS 2	AIS 3	AIS 4
RIB FRACTURES	10	4	–	–
CLAVICULAR OR SCAPULAR FRACTURES	–	14	–	–
FRACTURE AND/OR DISLOCATION OF THE UPPER LIMBS	–	18	6	–
FRACTURE AND/OR DISLOCATION OF THE LOWER LIMBS	–	12	33	–
PELVIC FRACTURES	–	8	2	–
SPINAL FRACTURES OR DISLOCATIONS	–	8	6	–
ARTERIAL LACERATIONS	–	–	3	–
LUNG CONTUSIONS - PNEUMOTHORAX -	–	–	–	–
HEMOTHORAX	–	–	14	–
SPLEEN RUPTURE	–	–	–	1

Table 1 : Associated injuries

CAR OCCUPANTS	46	(26%)	
HELMETED TWO-WHEEL RIDERS	28	(16%)	**Traffic accidents**
UNHELMETED TWO-WHEEL RIDERS	34	(19%)	**152**
PEDESTRIANS	44	(25%)	(86%)
			Non-traffic accidents
			24
			(14%)
			TOTAL 176

Table 2 : Distribution of accident types

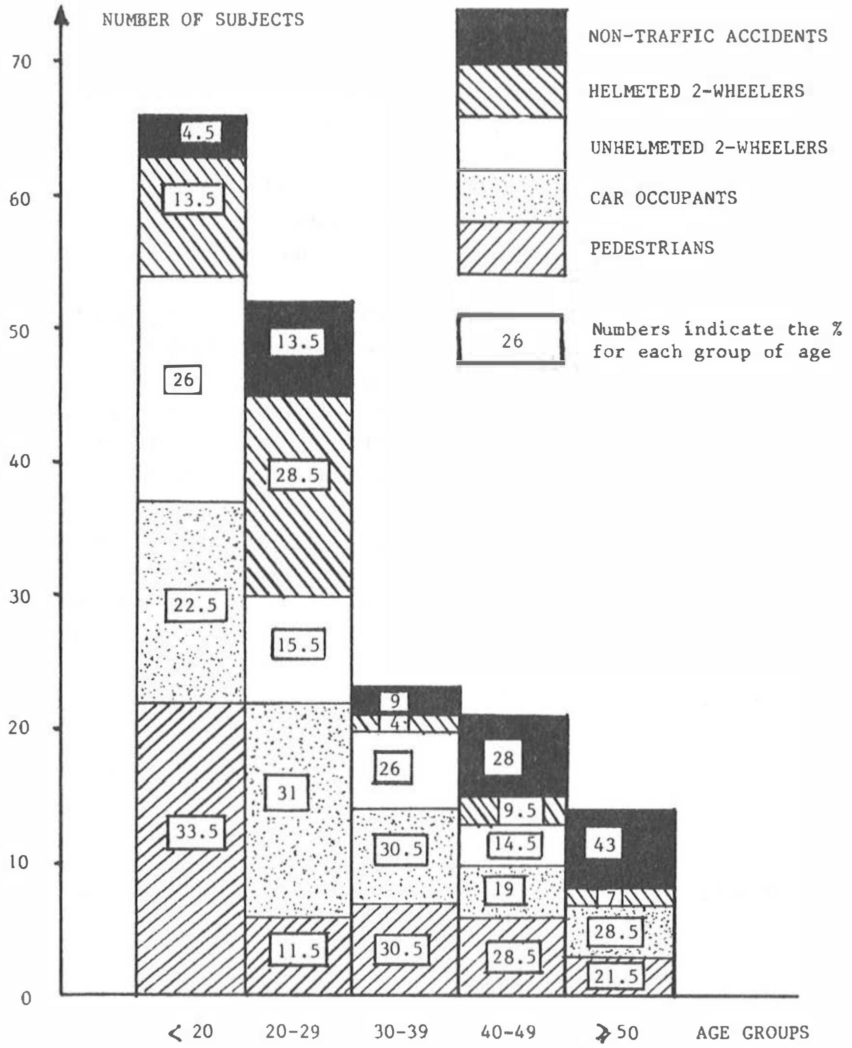

Figure 1 : Distribution of victims in age groups

METHODOLOGY

All the patients were examined by the physicians of the Mobile Emergency Unit on the accident site and during their transportation to hospital. Once admitted, in addition to frequent clinical examinations, various means of investigation were used to establish the diagnosis : skull radiography, CT scan, EEG, brain evoked potentials, intra-cranial pressure,...

The outcome has been studied up to 6 months after the accident. It can be arranged into the following 4 grades of decreasing severity :

* **fatality**
* **severe outcome** including vegetative state and all important sequelae making the patient not autonomous

* **moderate outcome** including sequelae resulting in a significant disability but without loss of autonomy

* **recovery** either full or only with very slight sequelae not able to disturb the patient's life in a significan way.

This classification is not based on the exact nature of sequelae but rather on the patient's ability to take care of himself and to have the same activity again as before the accident.

For each subject, all the available means have been used to establish the best diagnosis, which is not always the most obvious at the CT scan. It is considered as the most likely to explain the clinical symptoms of Central Nervous System disfunctioning.

The dynamic aspect of performed investigations is of prime importance and any modification of symptoms must be taken into account. The following case constitutes a demonstrative example :

> A girl of 15 was impacted by a bus when crossing the street. She was immediately in a deep coma with a Glasgow Coma Score of 3. CT scan did not show anything except a very small prefrontal contusion ; there was neither hematoma nor mass effect. Both pupils were in mydriasis. The day after, the left pupil became more dilated than the right one, the EEG showed an asymetry between the two hemispheres. Another CT scan was made showing an extradural hematoma (EDH) under the impact zone. After surgery, she died at the end of the third day. No necropsic examination was performed.
>
> It is difficult to determine what the exact cause of death was. It seems obvious that a diffuse injury existed before the occurrence of the EDH ; on the other hand, the fatality rate is very high with a GCS of 3. We concluded that the EDH did not change the prognosis significantly and we gave "Diffuse Injury" as best diagnosis.

One of our assumptions is that the prognosis of focal injuries is very dependent on the presence of an associated (and often undiagnosed) diffuse injury. We think that the importance of diffuse injuries is underestimated. This results from the fact that focal injury is diagnosed much more easily than diffuse injury from C.T. scan as well as from post-mortem examination in the absence of microscopy. Therefore in this study we give an important weight to clinical symptoms in the diagnosis determination. This is in agreement with Gennarelli's definition (1). Besides, we do not keep the distinction between diffuse injury and diffuse white matter shearing injury (DWSI) that Gennarelli makes, because this distinction, while useful in view of a prognosis, is based only on the severity of consequences of an injury mechanism identical in the 2 cases and is not very useful to define ways of protection.

All our patients sustained a brain concussion which was more or less deep and long lasting. We kept it as best diagnosis only when there was a beginning of improvement within the first day, when a full recovery, except an amnesia (see OMMAYA's definition (2)) occurred and when there was no associated mass lesion.

RESULTS

Table 3 shows the outcome for each type of best diagnosis. It appears that diffuse injury is the most severe when considering the number of fatalities and of severe outcomes as well. Intra-cranial hematomas give an large number of fatalities but have a low index of severe outcomes. Contusions seem to be the less severe injuries. In fact, diffuse injuries are prevailing by their number essentially ; their fatality rate (39 %) is low as compared with that of hematomas (54 to 76 %). This is due to the fact that benign cases of hematomas are not able to result in an immediate unconsciousness lasting 24 hours at least ; therefore when they were present in this sample, they were associated with more severe injuries and were not considered as the best diagnosis. Furthermore other benign cases of hematomas were not present in this sample since one of the selection criteria was an immediate unconsciousness.

This table shows that the rate of skull fractures associated with intra-cranial injuries is not the same for all types of injuries. This point will be discussed later on.

Table 4 indicates the outcome for each type of accident victims. As a whole, the distributions are not significantly different. The recovery rate is about the same in the five sub-populations (varying from 23 % to 32 %). However larger differences exist concerning the fatality rate (35 % to 58 %).

The categories of patients for which a head protection has been designed (car occupants and two-wheel riders) have a lower fatality rate than the others. At the same time they have a high rate of severe outcome. This suggests that some cases which would have been fatal without protection are turned into non fatal cases but with a severe outcome (a significant difference exists between distribution of fatalities and severe outcomes in the five categories of patients). The rate of skull fracture is significantly different between the five categories.

Figure 2 shows the variation of the average rate of injury according to the kind of accident. For contusions (coup and contre-coup) and for Intra-Cranial Hematomas (ICH), the variation is not very large. On the contrary, for diffuse injuries, Sub-Dural Hematomas (SDH) and EDH there are large scatters : for EDH the highest rate is up to 9 times the lowest one. It must be noted that non-traffic accidents have the lowest rate of diffuse injuries and the highest rate of both SDH and EDH. It is almost the opposite for helmeted two-wheel riders. In this population, for all traffic accidents, diffuse injuries are frequent and SDH occur very seldom. At last, EDH are 5 times as frequent in unhelmeted two-wheel riders as in helmeted ones.

	Skull fracture number (rate)	Fatality	Severe outcome	Moderate outcome	Recovery	Total	Mortality index *	Index of severe outcome *
DIFFUSE INJURY	16 (26)	24 (39)	12 (20)	9 (15)	16 (26)	61 (100)	1364	682
S D H	7 (41)	13 (76)	2 (12)	0	2 (12)	17 (100)	739	114
I C H	7 (47)	11 (73)	1 (7)	2 (13)	1 (7)	15 (100)	625	57
CONTRE-COUP CONTUSIONS	13 (48)	9 (33)	4 (15)	4 (15)	10 (37)	27 (100)	511	227
COUP CONTUSIONS	14 (61)	7 (30)	5 (22)	4 (18)	7 (30)	23 (100)	398	284
E D H	16 (62)	14 (54)	2 (8)	3 (11)	7 (27)	26 (100)	795	114
OTHERS	1 (14)	2 (29)	1 (14)	0	4 (57)	7 (100)	114	57
TOTAL	74 (42)	80 (45)	27 (15)	22 (13)	47 (27)	176 (100)	4546	1535

* Mortality index and index of severe outcome indicate the number of fatalities and of patients with a severe outcome respectively for a population of 10000 cases.

Table 3 : Distribution of skull fractures and outcomes for each injury type

	Skull Fractures Number (Rate)	Fatality	Severe Outcome	Moderate Outcome	Recovery	Total
CAR OCCUPANTS	16 (35)	16 (35)	13 (28)	6 (13)	11 (24)	46 (100)
HELMETED TWO-WHEEL RIDERS	7 (25)	10 (36)	5 (18)	4 (14)	9 (32)	28 (100)
UNHELMETED TWO-WHEEL RIDERS	20 (59)	16 (47)	5 (15)	5 (15)	8 (23)	34 (100)
PEDESTRIANS	17 (39)	24 (55)	2 (5)	5 (11)	13 (29)	44 (100)
NON-TRAFFIC ACCIDENTS	14 (58)	14 (58)	2 (8.5)	2 (8.5)	6 (25)	24 (100)
TOTAL	74 (42)	80 (45)	27 (15)	22 (13)	47 (27)	176 (100)

Table 4 : Distribution of skull fractures and outcomes in the five types of accidents

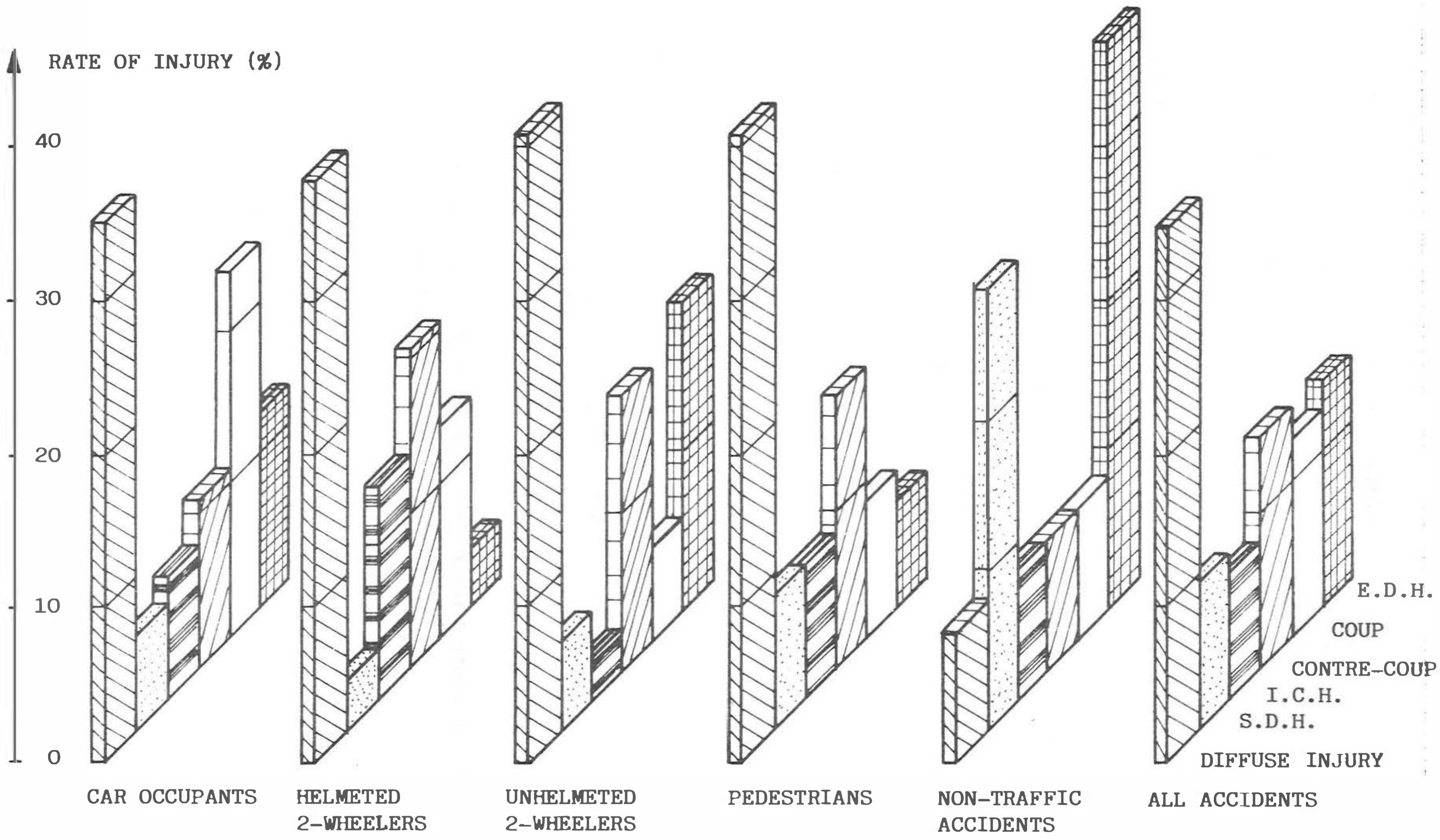

Figure 2 : Rate of each best diagnosis depending on the type of accident

DISCUSSION

The above results give an idea of relationships between types of injury, grades of outcome and types of accident. Some of these results need a comment. Besides, in spite of an attempt to have an homogeneous population, some factors may have effects intricated or different depending on the type of accident and/or the type of injury.

1) Effect of injuries to other body segments

When comparing the group of subjects without associated injuries of a level ≤ AIS 2 with that of patients sustaining injuries to other body segments of AIS 3 or 4 levels (see Table 5), the outcome distributions are seen to be about identical. It can be said that, in our population, associated injuries are not of such a severity that they are able to result in a noticeable aggravation of head injuries.

	AIS 0 - 1 - 2		AIS 3 - 4		TOTAL	
Fatality	59	(46%)	21	(45%)	80	(45%)
Severe outcome	19	(15%)	8	(17%)	27	(15%)
Moderate outcome	16	(12%)	6	(13%)	22	(13%)
Recovery	35	(27%)	12	(25%)	47	(27%)
TOTAL	**129**	**(100%)**	**47**	**(100%)**	**176**	**(100%)**

Table 5 : Effect of associated injuries on outcome

2) Effect of age

When dividing subjects in only 2 outcome categories, i.e. favourable (recovery and moderate outcome) and unfavourable (fatality and severe outcome), the mean age of the former is lower than that of the latter (22.3 years vs 28.7).

Besides, Figure 3 gives the cumulative distribution of age groups in the whole population and in the sub-groups of favourable and unfavourable outcome.

This figure shows that under 30 years of age, there are 67 % of the population, 81 % of the favourable outocmes, and only 58 % of the unfavourable ones.

When dividing the whole population into 2 age groups ($<$ 30 years and $\geq$ 30 years), there is a significant difference in outcome ($X2 = 10.93$ $P < 0.02$) (see Figure 4).

We can then come to the conclusion that age is a significant factor. However, its effect is not the same for the various types of accident : while it is obvious for traffic accidents, it is not so for non-traffic ones.

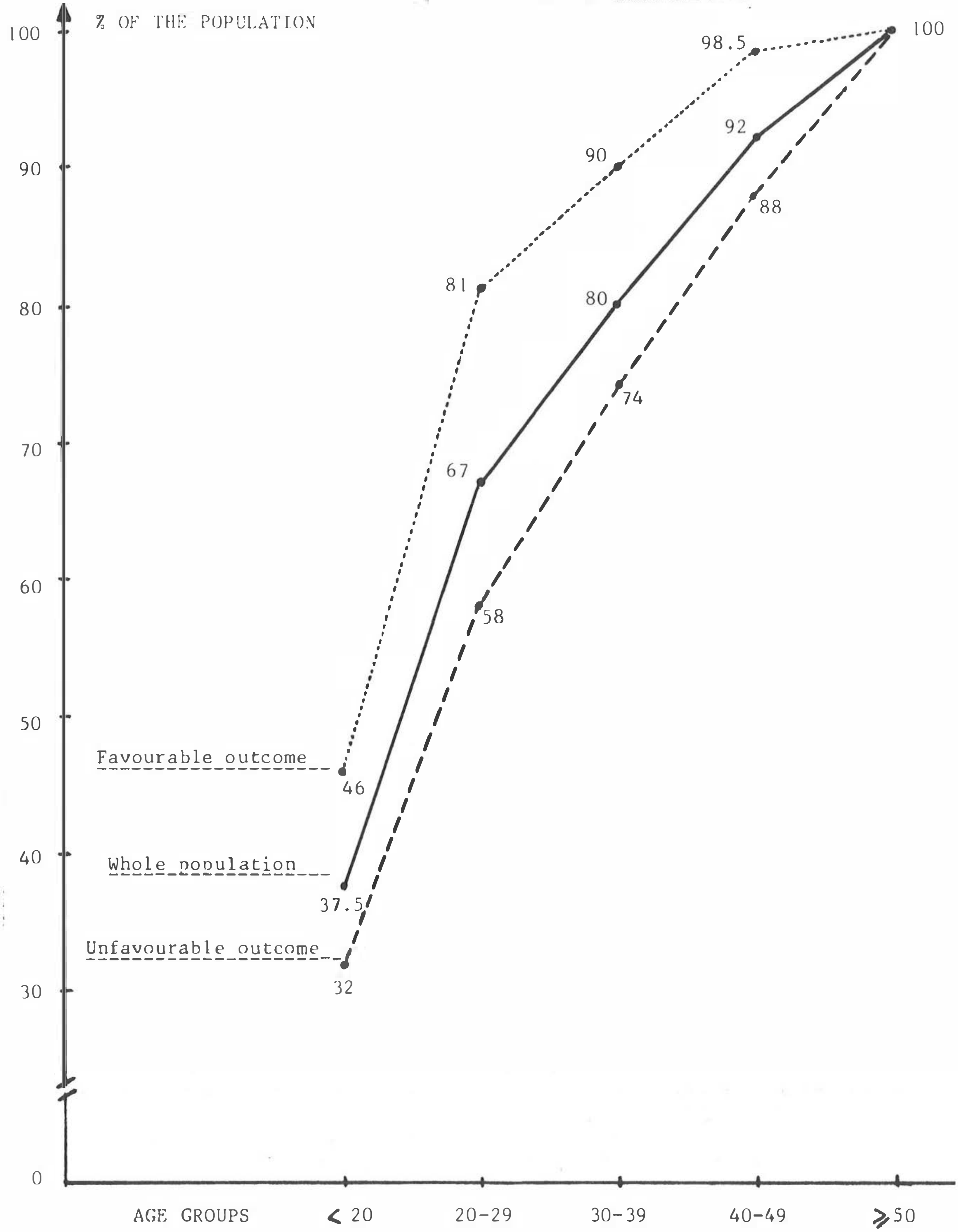

Figure 3 : **Age cumulative distribution on the whole population, of patients with a favourable outcome and of those with an unfavourable one**

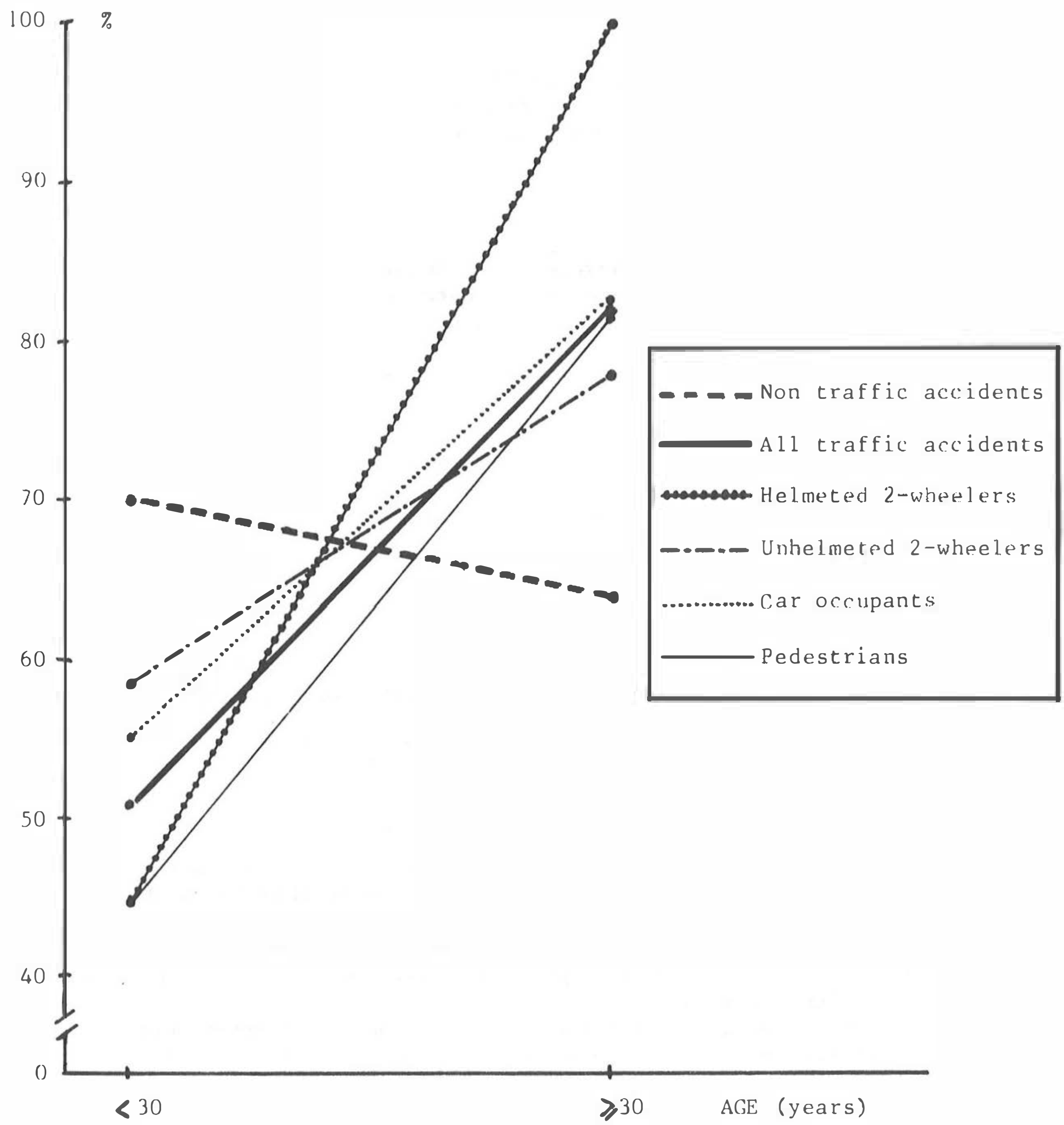

Figure 4 : Rates of unfavourable outcomes (fatalities and severe outcomes) for the younger and older age groups (< 30 and ≥ 30 years)

This difference may be explained by the fact that the mean age is far higher in non-traffic accident cases (36 years) than in traffic accidents (24 years). Moreover, as stated before (see Figure 2), the distribution of injury types is different in the group of non-traffic accidents.

3) Effect of a skull fracture

When considering the population as a whole, Table 6 shows there is no significant difference in outcome whether there is a skull fracture or not.

	Fatality	**Severe Outcome**	**Moderate Outcome**	**Recovery**	**Total**
SKULL FRACTURES	35 (47%)	9 (12%)	11 (15%)	19 (26%)	74 (100%)
NO SKULL FRACTURE	45 (44%)	18 (18%)	11 (11%)	28 (27%)	102 (100%)
TOTAL	**80 (45%)**	**27 (15%)**	**22 (13%)**	**47 (27%)**	**176 (100%)**

Table 6 : Distribution of outcomes depending on the presence or absence of a skull fracture

On the other hand, the effect of a skull fracture significantly differs from one type of accident to another ($P < 0.02$). From Figure 5, 3 groups can be differenciated :

* **non-traffic accidents and accidents involving helmeted two-wheelers :** the rate of unfavourable prognosis is clearly higher without fracture than with fracture
* **accidents involving car occupants and pedestrians :** the presence or absence of a skull fracture does not seem to modify the outcome substantially
* **accidents involving unhelmeted two-wheelers :** the presence of a skull fracture seems to worsen the outcome.

When comparing the effect of a skull fracture on the outcome for each type of injury, Figure 6 shows the outcome is worse with a skull fracture only for EDH cases. However, this difference is not significant.

In conclusion, the occurrence of a skull fracture has globally no effect on the outcome. However, in view of improving our knowledge of injury mechanisms, it is important to note that this conclusion does not apply to types of accident when considered separately, and it may not be true also in cases of EDH.

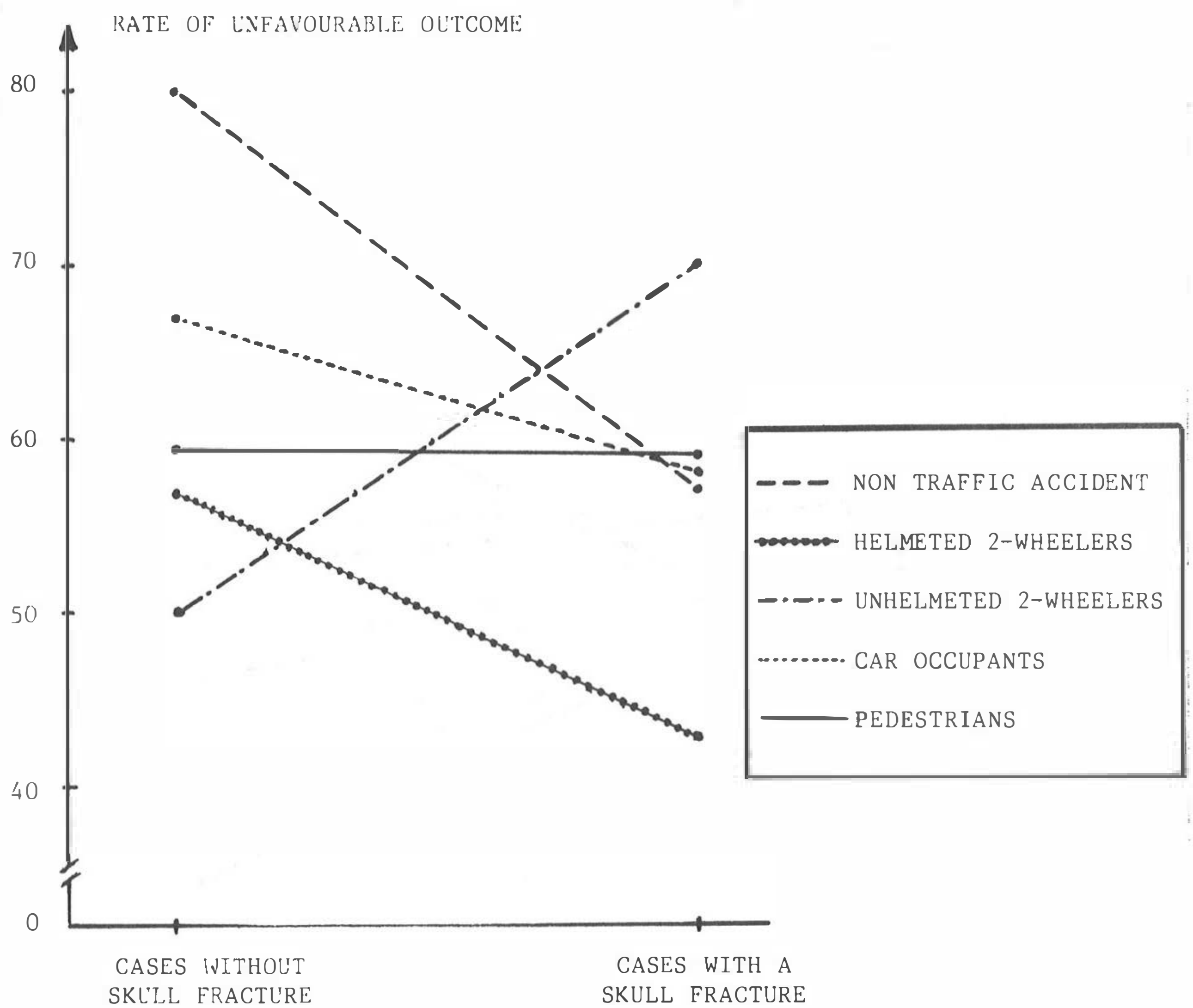

Figure 5 : Rate of unfavourable outcome depending on the presence of a skull fracture for each type of accident

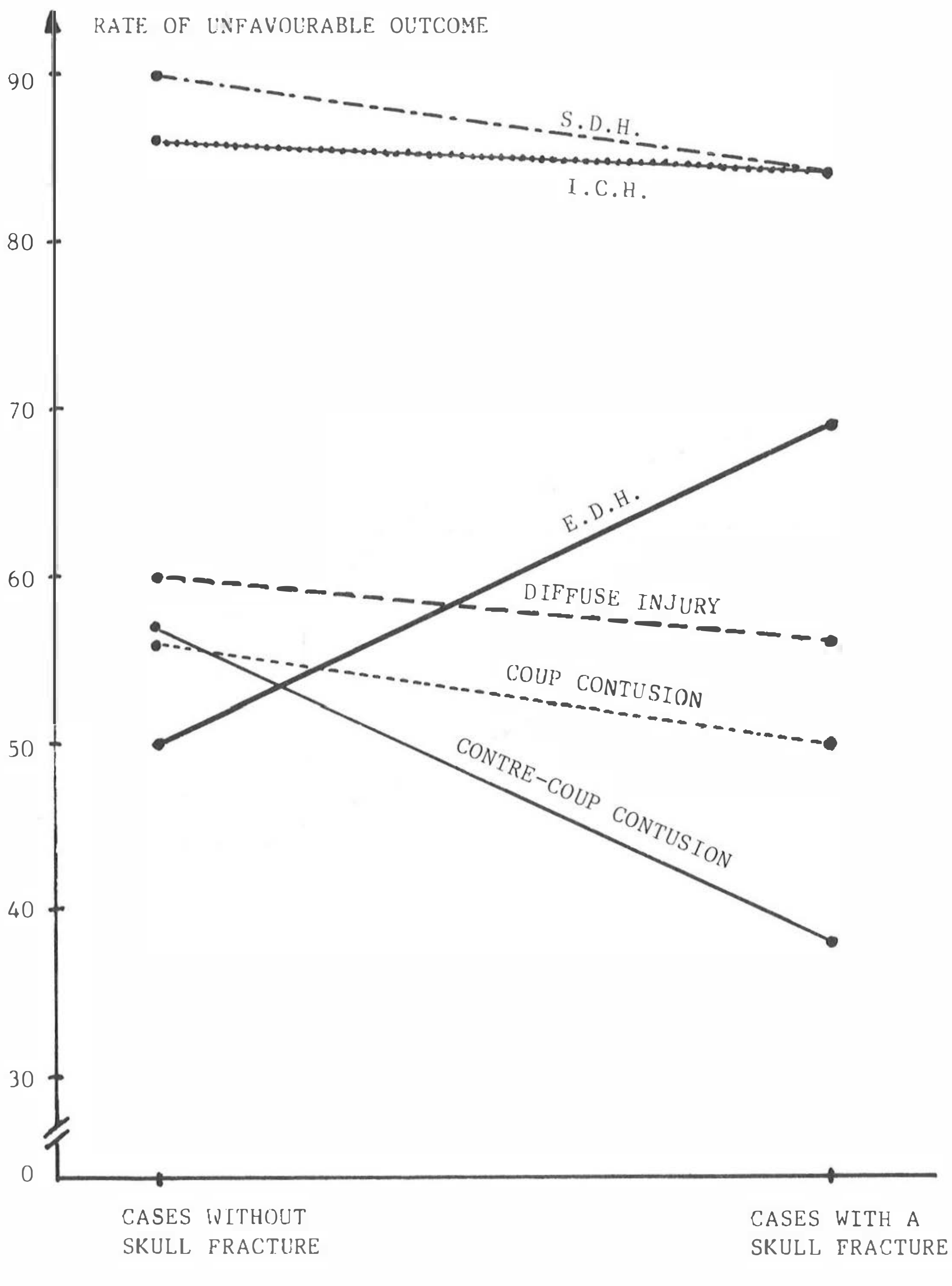

Figure 6 : Rate of unfavourable outcome depending on the presence of a skull fracture for each type of best diagnosis

4) Effect of the accident type

4.1 - Non-traffic accidents

Figure 2 indicates that in non-traffic accidents, diffuse injuries represent 8.5 % only of all injuries (vs 38.5 % in traffic accidents). On the contrary, as compared with the other types, non-traffic accidents have the highest rate of EDH (as it could be expected) and the highest rate of SDH as well (which was unexpected). The study of cases taken separately shows that 4 out of the 7 SDH result from a falling downstairs. Furthermore, the patients suffering from SDH are noticeably older than the others (mean age : 44 years vs 36) and they were often found to be habitual drinkers and/or to have a substantial amount of alcohol in their blood after the accident. It is well known that both age and alcohol are factors making blood vessels brittle, which may facilitate the occurrence of an hematoma (3). A falling downstairs results in a particular kinematics which gave rise to a skull fracture in only 1 out of the 4 cases.

On the contrary, the numerous EDH found in non-traffic accidents are related to a high rate of skull fracture (89 %). This is explained by the fact that EDH results from a head impact against a hard surface involving important forces (falls from scaffoldings or from ladders onto the pavement, assault with an iron bar, industrial accidents in which head is impacted by an heavy metallic object....).

As a conclusion, besides its low rate of diffuse injuries, the group of non-traffic accidents is not homogeneous ; in spite of the high percentage of EDH (37 % of injuries) associated with numerous skull fractures, the outcome is more severe when there is no fracture (see Figure 5). SDH, indeed, which present a low rate of fracture, are more severe than EDH ; this applies to the 2 cases of ICH also.

4.2 - Car occupants

As compared with the whole population of this study, the fatality rate of car occupants is globally lower but, on the contrary, the rate of severe outcome is almost twice. The rate of fracture is also a little lower than the average (though the difference is not significant). However, it can be seen from Table 7 there is no direct relationship between the low rate of mortality and the low rate of fracture since the mortality rates of patients with and without fracture are very close.

	Fatality	**Severe outcome**	**Moderate outcome**	**Recovery**	**Total**
CASES WITH A SKULL FRACTURE	6 (37.5)	3 (18.5)	2 (13)	5 (31)	16 (100)
CASES WITHOUT A SKULL FRACTURE	10 (33)	10 (33)	4 (14)	6 (20)	30 (100)
TOTAL	16 (35)	13 (28)	6 (13)	11 (24)	46 (100)

Table 7 : Outcome depending on the presence of a skull fracture in car accidents

On the other hand, one third of patients without fracture have a severe outcome. It has to be noted that 69 % of unfavourable outcomes (fatality + severe outcome) occurred without skull fracture. In 4 cases, there was a face fracture ; in 55 % of cases, there was neither face fracture nor skull fracture associated with an unfavourable outcome. In belted occupants (16 cases), the fracture rate is even lower (25 % for skull alone, 38 % for skull + face) and unfavourable outcomes occurred without any fracture in 64 % of cases. This is not in agreement with some data (4) indicating that in most cases of car accidents, there is almost no fatal intra-cranial injuries in the absence of fracture.

An unexpected and unexplained result is that unbelted occupants had a best outcome than belted ones. The samples are indeed small (16 belted, 25 unbelted and 5 for which the belt wearing was unreported) ; this fact, therefore, would not have been reported if the difference had not been substantial : the fatality rate of belted occupants is twice that of unbelted ones (56 % vs 28 %). Some hypotheses may explain this paradoxical result : first, among unbelted occupants, 7 were ejected and ejection is known to be an important cause of fatality and yet only 1 out of the 7 died - the 6 others were certainly lucky ! The second explanation could be that the population of this study only involves patients admitted to hospital and maybe most unbelted occupants die on the accident site or before admission. At last, but this study does not enable to check it, accident and vehicle characteristics should be proved to be comparable for belted and unbelted victims. This stresses the necessity to have much larger samples so that unverified variation factors are balanced.

As concerns injury distribution, Table 8 indicates that while diffuse injuries are the most numerous, they have a low rate of fatality. However, due to their number and because they are responsible for almost half of severe outcomes, they have to be considered as prevailing. EDH and coup contusions have the highest mortality index but they give less vegetative state and disabiliting sequelae than diffuse injuries.

	Number of skull fractures	Fatality	Severe outcome	Moderate outcome	Recovery	Total	Mortality index (death/10000)
DIFFUSE INJURY	3	3	6	2	5	16	652
S D H	1	2	1	-	-	3	435
I C H	4	3	-	1	-	4	652
CONTRE-COUP CONTUSIONS	1	-	2	1	2	5	-
COUP CONTUSIONS	5	4	3	1	3	11	870
E D H	2	4	-	1	1	6	870
OTHERS	0	-	1	-	-	1	0
TOTAL	16	16	13	6	11	46	3479
	(35%)	(35%)	(28%)	(13%)	(24%)	(100%)	

Table 8 : Distribution of injuries and outcomes in the car occupant group

4.3 - Pedestrians

Pedestrian accidents are less fatal when there is a skull fracture than when there is not. They essentially differ from accidents involving car occupants (see Table 9) by a low rate of severe outcome (5 % vs 35 %) jointly with a much higher rate of fatality (55 % vs 35 %) as if protection afforded to car occupants changed a certain number of fatalities into severe outcomes.

The injury distribution clearly shows that diffuse injuries and contre-coup contusions prevail by their number and their mortality as well (both together they account for 63% of fatal cases). On the contrary, EDH and coup contusions which are responsible for 50% of fatalities in car occupants only account for 12% in pedestrians. As seen in § 4.1 (non-traffic accidents), EDH occur when the head impacts a hard surface giving rise to a high rate of skull fractures ; this is also true for coup contusions, but to a lower extent. The fact that in pedestrians the fracture rate is not very high and that there are few EDH and coup contusions leads to think that the prevailing injury mechanism is likely due to the impact of the head against the vehicle and not against the hard surface of the road. The number and the severity of diffuse injuries also seem to indicate that the main point in terms of injury mechanism in pedestrian accidents would be the rotational change of head kinematics during the head/vehicle impact.

	Number of skull fractures	Fatality	Severe outcome	Moderate outcome	Recovery	Total	Mortality index (death/10000)
DIFFUSE INJURY	3	10	2	2	4	18	2273
S D H	2	3	0	0	1	4	682
I C H	1	2	0	1	1	4	455
CONTRE-COUP CONTUSIONS	5	5	0	1	2	8	1136
COUP CONTUSIONS	4	1	0	1	2	4	227
E D H	1	2	0	0	1	3	455
OTHERS	1	1	0	0	2	3	227
TOTAL	17 (39%)	24 (55%)	2 (5%)	5 (11%)	13 (29%)	44 (100%)	5455

Table 9 : Distribution of injuries and outcomes in the pedestrian group

4.4 - **Two-wheelers**

An analysis of the data concerning two-wheelers was presented at IRCOBI Conference last year (5). Though, since then, the number of cases has been increased, the present results confirm the former. Table 10 shows the main results in a synthetic way.

The conclusions which can be drawn are summarized in the following way :

* the lower fatality rate in helmeted two-wheelers, as compared to unhelmeted ones, confirms the protective effect of helmet.

* the protection afforded by the helmet is effective only against injuries resulting from the contact phenomenon mechanism : in helmeted victims, there is no fatal EDH and only 10 % of fatalities are associated to a skull fracture (compared to 70 % in unhelmeted victims).

* the contact phenomenon mechanism which is involved when head impacts an unpadded surface does not seem to be important to induce injuries such as ICH and contre-coup contusions since they are fatal in helmeted two-wheelers essentially (in which they account for 50 % of fatal cases) and without skull fracture in 80 % of cases.

5) Effect of the impact location on the head

Figure 7 shows the main locations of impacts on the head accounting for most cases (from 78 % for coup contusions up to 92 % for EDH) for each type of injury and whatever the type of accident is. It indicates the following points :

* for 23 cases, there was no evidence of impact neither on the head nor on the helmet. Most of these cases are related to diffuse injuries and also to SDH and ICH. Two of them are related to contusions which were considered as contre-coup contusions since there was no evidence of impact and then it was not possible to state they were coup contusions. This means that intra-cranial injuries without head impact may occur in real cases of accidents and not only in less realistic conditions of animal experiments (6) (7). Among these cases, some impacts may have occurred but they were probably so soft that they were overlooked. These cases without evidence of impact were not less severe than the others since 10 out of 23 resulted in fatality (i.e. 43 %).

* face impacts occurred in 18 cases. Sixteen among them (i.e. 89 %) are related to either a diffuse injury or a SDH.

* impacts to the frontal bone are the most currently found and are associated to any type of intra-cranial injury. There are some differences however depending on the exact location of the impact on this bone : when the impact is anterior, it essentially results in SDH, coup contusions and diffuse injuries and there is almost never a contre-coup contusion, which confirms previous data from SANO (8) and from OMMAYA (9) ; when it is lateral, it gives contre-coup contusions, diffuse injuries and EDH but almost never SDH.

* EDH essentially occur when the impact is located along a band from the frontal bone to the occipital one including the temporal bone surface while ICH seems to result from upper located impacts involving the parietal bone rather than the temporal one.

In addition to the localization of the impact zone, it would be necessary to know the direction of forces at the impact time to better understand injury mechanisms. Definitive conclusions, therefore, cannot be deduced from the above results. However, in accidents there is always a certain degree of rotational motion of the head which is likely the more

	UNHELMETED (34 cases)				HELMETED (28 cases)			
	Skull fracture	Mortality index	Severe outcome index	Number of injuries	Skull fracture	Mortality index	Severe outcome index	Number of injuries
DIFFUSE INJURY	8	1765	882	14	1	1429	357	11
S D H	1	588	0	2	0	357	0	1
I C H	1	294	0	1	1	1071	357	4
CONTRE-COUP CONTUSION	5	294	294	6	2	714	357	6
COUP CONTUSION	1	294	0	2	2	0	714	
E D H	4	1176	294	7	1	0	0	1
OTHERS	0	294	0	2	0	0	0	1
TOTAL	20	4705	1470	34	7	3571	1785	28
WITH SKULL FRACTURE		3234	882			357	714	
WITHOUT SKULL FRACTURE		1471	588			3214	1071	

Table 10 : Comparison of skull fractures, mortality index and index of severe outcome between helmeted and unhelmeted two-wheelers

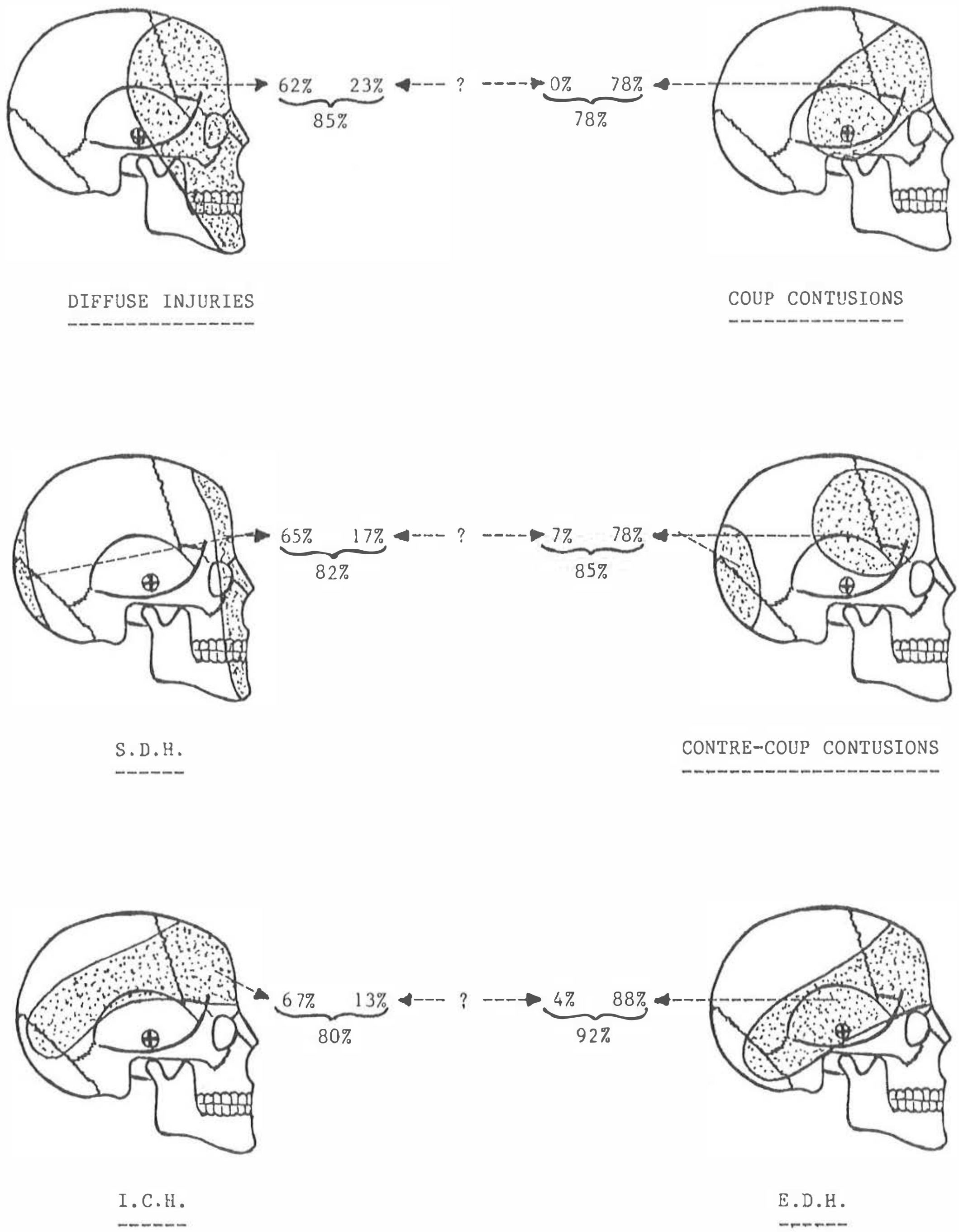

Figure 7 : Main zones of impact associated with each type of best diagnosis

(? : no impact was found

⊕ : projection of the head center of gravity) important as the impact point is more distant from the head center of gravity. In these cases, a substantial amount of energy is dissipated in modification of head kinematics and not in skull deformation, resulting then in a low rate of fracture. When the impact point is closer to the center of gravity (i.e. inferior temporal zone in side projection), the moment is not so high (of course if the force vector is roughly perpendicular to the skull surface) and most of the impact energy is used to deform the skull leading to a high rate of fracture.

CONCLUSION

This paper gives the main results of a study of 176 cases involving victims of accidents with a severe intra-cranial injury and a traumatic unconsciousness lasting more than 24 hours. The mean age of the population is 26 years with noticeable differences depending on type of accident (traffic : car occupants, helmeted and unhelmeted two-wheelers, pedestrians ; non-traffic). As a whole, the fatality rate is 45 % and 15 % of victims have a severe outcome. Results show the importance of diffuse injuries which are the prime cause of fatalities and of severe outcomes before EDH and SDH. However, the prevalence of diffuse injuries is not the same for all types of accidents : while they are prevalent at various degrees in traffic accidents, they are quite uncommon in non-traffic ones. In pedestrian accidents, diffuse injuries account for 42 % of fatalities while EDH and coup contusions, both together, account for 12.5 % only ; this seems to indicate that pedestrian intra-cranial injuries result more from changes in head kinematics during the head/vehicle impact than from the impact against the hard surface of the road as it is the case in non-traffic falls.

A skull fracture is not a factor of severity except in the case of EDH and the fact that the presence of a skull fracture worsens the outcome in unhelmeted two-wheelers must be related to the frequency and the severity of EDH in this group of road users.

The distribution of impact zones on the head related to each type of injury as well as the respective rate of skull fracture for each type of injury and of accident lead to think that the contact phenomenon resulting in skull deformation (up to fracture) is not the leading mechanism of injury except for EDH and for coup contusions. For the other kinds of injury, changes in head kinematics involving high angular accelerations, which result in tension and shear stresses within the intra-cranial structures, seem to be the prevailing mechanism of injury.

At last, it is important to note that the population of this study is representative only of victims with AIS 5 level injuries admitted to hospital in intensive care unit. This means that it accounts for 1) a very small proportion of all head injuries, 2) a higher proportion of fatalities from head injuries (maybe 30 % to 40 %) and 3) most cases of severe sequelae from head injuries. In fact, it is difficult to accurately estimate the representativity of the sample because there is no reliable epidemiologic data concerning the ratio between immediate and delayed fatalities. Fourteen per cent of our patients died more than 30 days after the accident and it can be expected that a certain number of the victims with a severe outcome (some in a vegetative state) will die from their head injury. It stands to reason that too short a period of reference to estimate accident mortality leads to a noticeable underestimation, but the problem is to know how much this underestimation is.

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