COMPARATIVE STUDY OF CEREBRAL LESIONS INDUCED BY IMPACT ON DEAD AND LIVING ANIMALS

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I - INTRODUCTION

A number of studies on the energy transfer functions between the human body and the supporting structures are using human cadavers. Such substitutes do not allow the study of physiological or functional disturbances but are very helpful to get data on the human tolerance to impact, and especially on skeletal and soft tissue injuries. Injuries to the skeleton are very similar to those obtained in the accident data but soft tissue injuries are not so well correlated with real injuries sustained by occupants. This fact may be explained by the difference between cadavers and human response, the difference between age and preexposure health conditions and the wide variation from individual to individual used in the cadaver study.

The validation of soft tissue injuries requires additional and specific researches in the field, and this is the objective of this work to bring information on brain injuries in the frame of dead/living comparison.

This study* has been conducted on dead and living animals placed in the same traumatic conditions and its aim is to demonstrate that if no lesions are found on the living animal, no lesions will be seen on the dead and inversely, if lesions are found on the living, they will be seen on the dead animal.

A bidisciplinary approach has been set up to reach the objectives through a veterinary and engineer cooperation.

II - EXPERIMENTAL METHODOLOGY

This study required the development of specific methods to perform the tests. These methods concern two aspects of the experimentation :

II.1 The tested animal and the associated preparation technics
II.2 The impact production device.

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II.1 The tested animal and the preparation technics

The main objective of this research being mainly comparative, the animal to be tested was chosen under the following conditions :

a) to dispose of an advanced and short size mammal to be easily handled and held.

b) to be sure that the morphological features of the animal would be stable enough to ensure homogeneous samples.

c) to have an economic animal, easy to buy and to get.

According to these conditions, the rabbit was selected as testing animal. Its breeeding and reproduction enables to work with homogeneous groups. In relation with the aims of the study and from a physiological point of view, there are two other reasons to this choice :

- good accessibility of the circulatory system, making easy the set up of the blood pressure.

- good homogeneity of the characteristics of the skull among the subjects of the same race and family.

The preparation technics are different for the living or the dead animal :

. for the living animal, it consists of a slight anaesthesia (Imalgène or Ketamine) to make easier the preparation of the impact area and the handling of the animal till the testing device. The impact area is prepared by clearing the frontal bone of the skull.

. the dead animal is prepared as follows : first, the animal is sacrified through an anaesthetics overdose which does not induce any damage to the central nervous system. Catheters are then introduced, one in the right common artery, the other on the external jugular vein. This operation requires a great care because of the poor resistance of arteries and veins and of the size of the catheters to fix (Ø 1.5 mm). The perfusion is made through the carotid artery, circulates into the brain and goes out through the jugular vein, ensuring the good filling of the capillars. This operation of fixing the catheters must be done within a rather short period because of the very quick autolysis phenomenon. The maximum operating delay is about 15 minutes after death for the catheterism of two common carotid arteries. The perfusion liquid, a mixing of physiological salt solution and formol and Indian ink, is performed before and during the whole test. As for the living animal, the impact is produced on the frontal bone, previously cleared.

II.2 The impact production device

This work required the design of a specific impact production device with the following characteristics :

- easy adjustment of the impact severity by acting either on the speed or on the mass of the impactor.

- non agressivity of the impactor against the skull of the rabbit (the skull must not be a stopping system for the impactor).

- good reproducibility of the parameters linked with the impactor functioning (speed - position according to the rabbit).

- possibility of acceleration measurement on the impactor.

Because of the lack of data on the level of load producing skull fractures on the rabbit, a preliminary study was conducted with a simplified impactor. This first step brought very useful data to adjust the mass of the impactor and the speed range to produce lesions or not to the rabbit. These data were the basis for the conception of the impact production device. Another difficulty being to prevent the skull fractures to the rabbit, the following device (fig. 1) was suggested : a main sled (1) is rolling between two vertical bars (2). This sled is connected to a traction sled (3) by means of an electromagnetic bolt which may be switched off (4) to release the main sled. By adjusting the falling height from 0 to 4.70 meters, a wide range of speed may be obtained. At the end of the fall, the main sled is stopped by the penetration into the sand of a trumpet like steel rod (5).

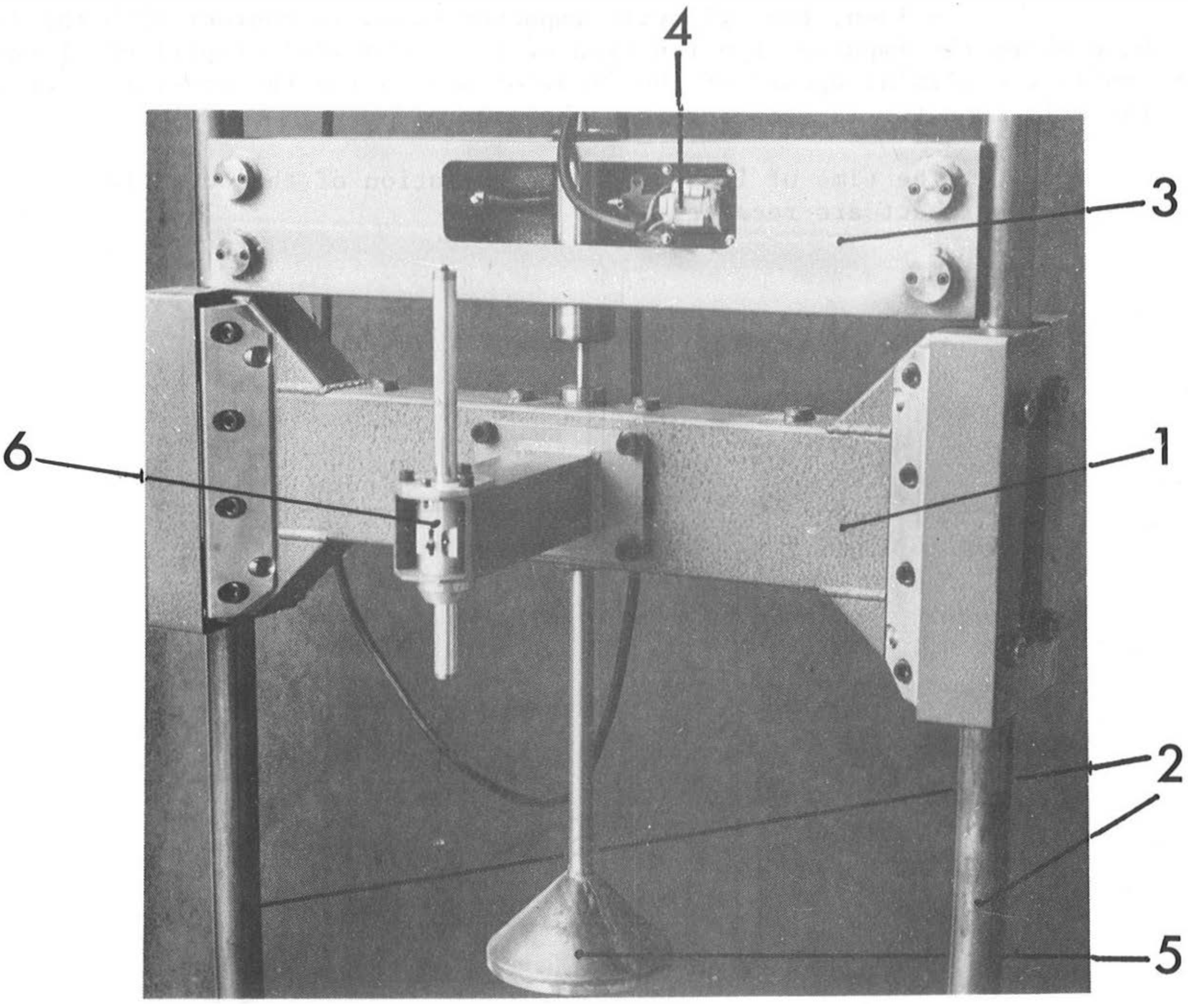

Figure 1 : Impact production device

The device for impacting the rabbit skull is fixed on the lateral side of the main sled (6). It consists of a cylindric impactor (fig. 2) sliding vertically in a ball bearing plummer block. On the top of the impactor, is mounted a uniaxial accelerometer and on the other extremity is sticked a disk of damping material. A locking system, placed on the side of the impactor, prevents the impactor to rebound on the rabbit skull. With such a device, the impact sequence is the following :

- First, the rabbit is placed in the right position according to the impactor axis and attached on the table in that position (dorsal decubitus). The rabbit head lays on a small cushion and is kept in position by a small wire going through the gums and fixed on the table. The impactor is put in a low position, the accelerometer being in contact with the ball bearing.

- Secondly, the main sled is actuated till a predetermined height, then the electromagnetic locking device is switched off and the main sled falls down.

- Then, the cylindric impactor comes in contact with the rabbit head where the impulse is a function of the mechanical properties of the skull, the sliding upward of the impactor preventing the fractures, while the main impactor is stopping into the sand.

The time of impact and the variation of the acceleration/time during the impact are recorded.

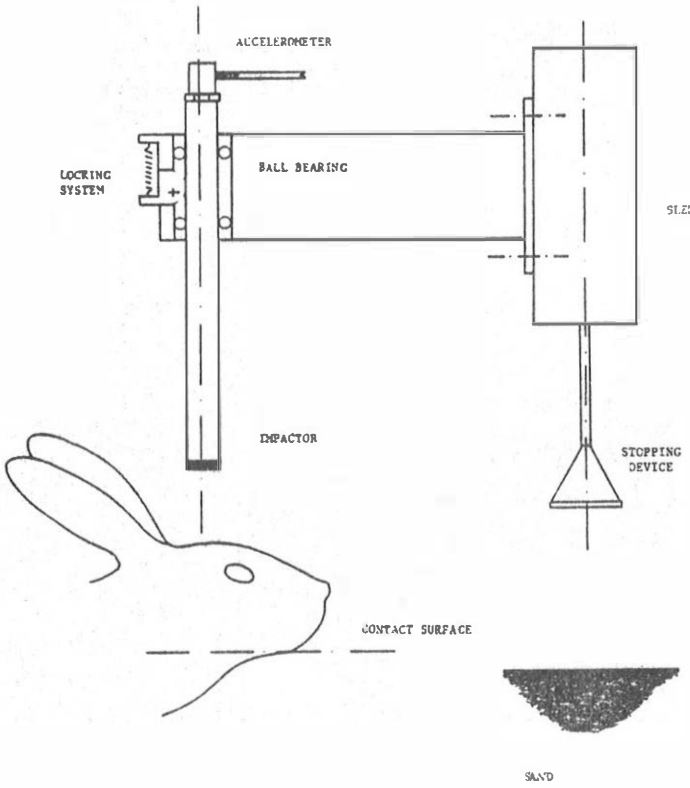

Figure 2

In these conditions, the calibration of the levels of impacts inducing or not brain lesions to the rabbit could be made and the corresponding energy values according to the rabbits races used have been fixed at 0.8 Joules for the infra-lesional level and 2 Joules for the lesional one.

III - PROCEDURE OF LESIONS DETECTION

A similar procedure was used to detect brain lesions in living and dead animals. Because of a very quick autolysis phenomenon, the lesions observation is made just after the impact according to the following rules :

a) first, lesions to the skull are carefully examined. These lesions consist generally in disjunctions with or without displacements, fractures with collapse, displacements of the lateral face of the skull.

b) the animal, if still living after impact, is sacrified and its brain is carefully extracted (the same for the dead one). Then, perceptible lesions are noted in all parts of the brain. The lesions which are more difficult to detect are seen through binocular glasses.

Cerebral lesions which were systematically looked at are :

petechials, vascular ruptures, oedema exclusions, structure destructions, cerebral hemorrhages. The first three types of lesions may be found in all parts of the brain, the two others are very specific. Short definitions of these types of lesions may be given as follows :

- Petechials : punctiform hemorrhages spots at the surface and inside the brain material ($\simeq$ 0.1 mm deep) with a size going from a point to a pin head.

- Vascular rupture : hemorrhagic spot spreading following the vascular line. In most cases, the start point of the spot is a vein. It is sometimes possible to see an arteria integrated in the blood clot.

- Exclusion : generally located around the oedema areas and at the center of these. The vascularisation is bloodless or not coloured.

- Destruction : through "destruction", we call an irreversible brain structure injury which may be cutted, or slashed. These destructions are always located at the lobus olfactoris for a simple reason : either the rabbit is not well positioned according to the impactor axis, or the skull material is weak, there the impactor creates a cranio facial disjunction, this disjunction provokes a collapse of the frontal sinuses which destroys the lobus olfactoris.

- Cerebral hemorrhages : they are arachnoidian hemorrhages spreading and located generally on the cerebral hemispheres behind the impact point.

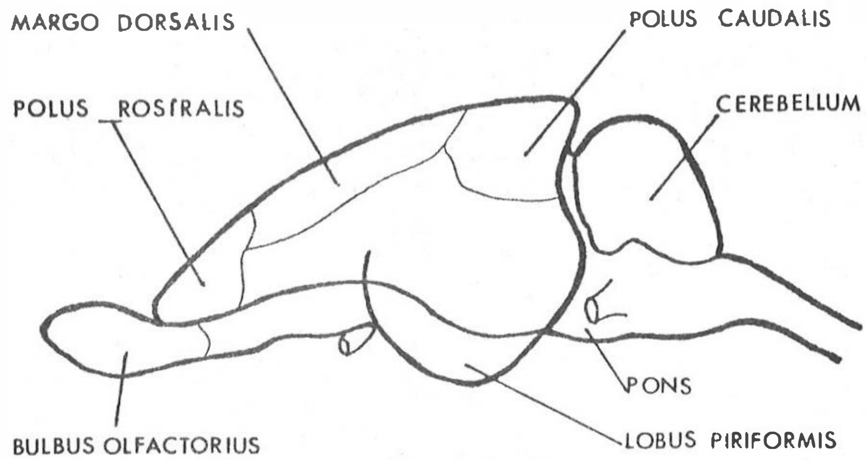

Fig. 3 - Brain - lateral aspect

Figure 3 shows a lateral view of a rabbit brain where are drawn seven main areas with the following characteristics :

- Bulbus olfactorius : olfactive area
- Polus rostralis : area of association equivalent to the human brain frontal lobus
- Margo dorsalis : psycho-motor area
- Polus caudalis : area of sensorial afferences
- Cerebellum : motive coordination
- Pons : area of motive order
- Lobus piriformis : area of sensorial afferences.

IV - EXPERIMENTAL RESULTS

Two groups of results are to be considered, one for the infra-lesional level, the second for the lesional level :

IV.1 Infra-lesional level

Twenty rabbits (10 living, 10 dead) were impacted in the same conditions at this level. Among the 10 living submitted after impact to a clinical observation during 4 days, only 2 animals were suspected of cerebral lesion. Autopsies were performed on all animals confirming the lack of injuries in eight cases and the presence of slight injuries (petechials of left lobus piriformis) in two cases. For these two animals, the lesions did not lead to irreversible functional disturbances. For the 10 dead animals impacted in the same conditions at this level, the autopsy did not show any brain injuries.

This first step shows that there is a good correlation between the results on living and dead animals at the infra-lesional level.

IV.2 Lesional level

Sixty animals were used, all male rabbits, and among them, only 52 (27 living, 25 dead) were kept for results analysis. When looking at the results, it may be seen that in the same initial conditions, 85 % of the living rabbits tested presented at least one cerebral lesion and 15 % none. In the same way, on dead animals, 96 % presented at least one cerebral lesion and 4 % none. When correlating these results to the weight range of the animals, it can be found that the average number of cerebral lesions is always higher in dead animals than in living, which leads to the main conclusion that serious lesions found in living correspond to serious lesions in dead animals (fig. 4).

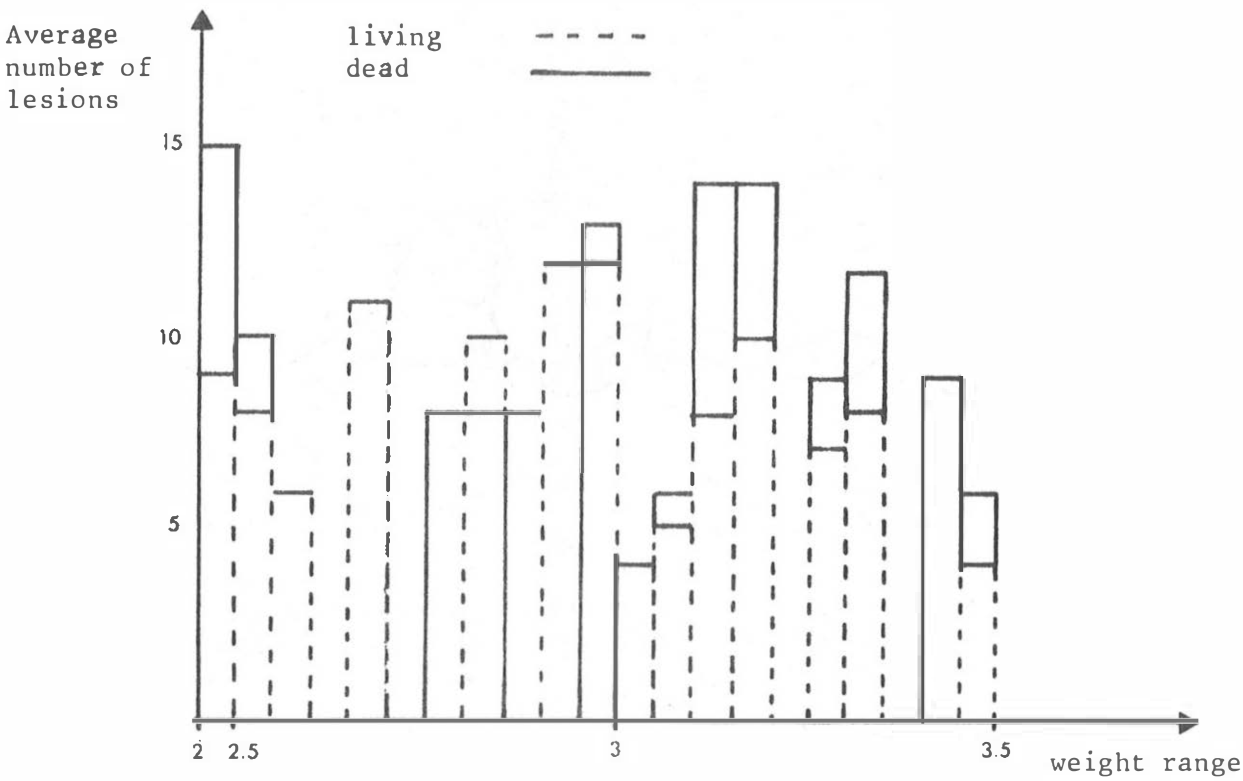

Fig. 4 : Average number of lesions according to weight range

More interessant is to compare the injuries according to their type and their location. This comparison must be limited to the two most observed types of lesions : petechials and vascular ruptures, the results on oedema exclusions having to be considered carefully because of the great unbalance between dead and living animals.

Petechials : when looking at Fig. 5, it may be seen on the above drawing the lateral view of the rabbit brain with its seven main parts.

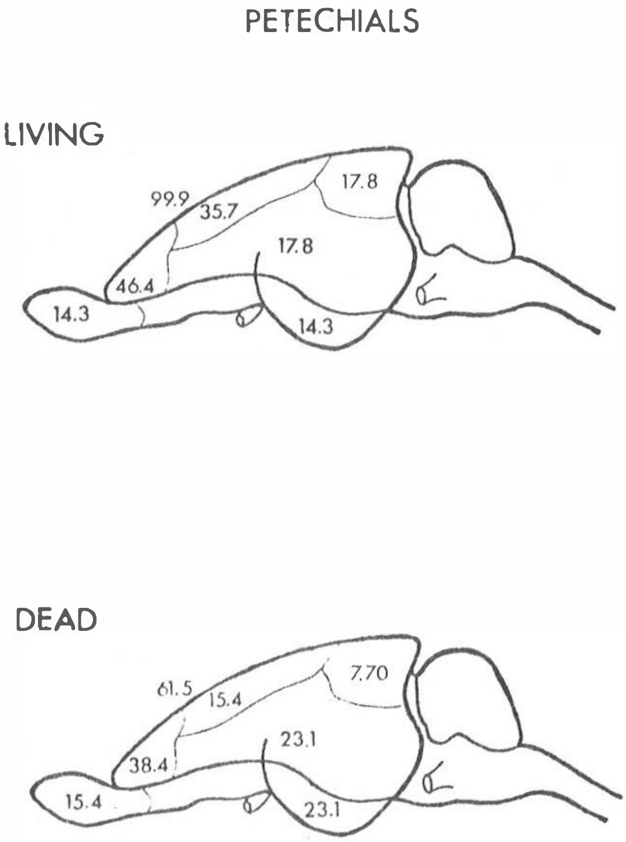

Figure 5

The results on living are written inside each area. On the lower drawing, are found the results on dead animals. The results are expressed in percentage of occurance for each area.

- The amount of lesions found in olfactive bulbs is very similar in living and dead animals : 14.3 (living) - 15.4 (dead).

- The number of petechials found in cerebral hemispheres is more important in living (99.9) than in dead (61.5), the diffusions being approximatively of the same value (17.8 for living, 23.1 for dead animals).

- Petechials of the lobus piriformis are more important in dead animals than in living.

According to these results, it may be seen that the petechials are the only type of injuries which is most observed in living than in dead, at the contrary of the other lesions. This fact could be explained by the poor penetration of the perfusion in the small brain vessels and as it was described before, the petechials may be very small hemorrhages which may not be seen with the China ink.

Vascular ruptures : they are easier to detect on perfused animals because of the bigger size of lesions. The results show that this type of lesions is more often seen in dead than in living. Fig. 6 shows the ventral aspect of a rabbit brain where are drawn the arteria basilaris with the arteria vertebralis and the polygon formed by the two cerebral arteries which is ended by the two olfactive arteries. This figure is cut in four main parts and it can be observed that if the number of vascular ruptures is similar for the chiasma and pons area in dead and living animals, the results are in opposition for the other areas : it appears that the ruptures of the olfactive arteries are twice more important in living than in dead and the ruptures of the basillar artery 4 times more important in dead than in living.

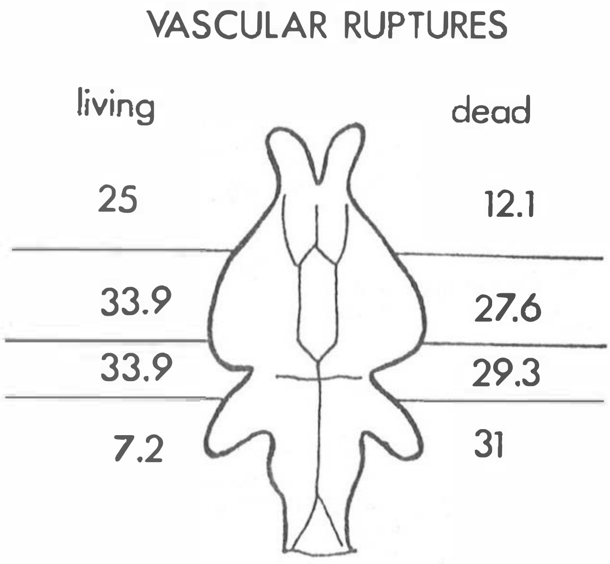

Figure 6

V - DISCUSSION

The results of the brain injuries investigation on dead and living animals at the lesional level, if they are reduced to the average number of lesions according to the type, are shown in figure 7 :

OBSERVED LESIONS PER ANIMAL

	LIVING	DEAD
Petechials	1.6	1.23
Main vessels rupture	1.93	2.23
Oedema and exclusion areas	0	1.92
TOTAL	3.53	5.38

Figure 7

These numbers indicate that, generally, the average number of lesions found in dead animals is much higher than in living animals, but inside each type of injuries, a great unbalance may be found.

This fact may lead to a specific conclusion that the lesions are typical and a function of the state of the tested animal. Indeed, no oedema are found on living animals, more vascular ruptures are seen on dead animals, while more petechials may be observed on living animals.

This observation gives another main conclusion that the type of injuries depends of the state of the animal (living or dead) and especially of the type of perfusion which is performed on the animals.

When impacted, the dead animal, even perfectly perfused with the China ink - formol and saline solution, if a vascular rupture occurs, shows consequently an oedema exclusion. The same case on a living animal does not bring the same observation, because of the automatic compensation effect in the circulatory system leaving brain vessels full of blood (without pressure) and filling the others with the right pressure. The presence of formol increases this no compensation effect in dead animals.

VI - CONCLUSION

This experimentation shows that there is a good correlation between the impact consequences on a dead and living rabbit, either at the infra-lesional level or at a lesional level. This was the main objective of the research to make this comparison. It appears secondly that the lesions are different in number and in position in living and dead animals and probably, this characteristic is a consequence of the perfusion.

An extrapolation of these results to human is not simple because of the great differences of the brain geometry between the rabbit and human. The lesions which are mainly peripheric in the rabbit, are more in depth in human. The size of brain vessels is also very different and a number of other biological reasons do not allow a direct transfer of the conclusions of this study.

Therefore, an effort must be made to get the possibility of applying on human the results of experimentations conducted with animals, and especially by working on more elaborated animals allowing a very useful clinical observation. Such studies using living biological materials must be developed because they are the only possibility to get technical data on the mechanism and the consequences of injuries.

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