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ORIGINAL ARTICLE

Blunt force trauma to skull with various instruments

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Abstract

Deaths due to blunt force trauma to the head as a result of assault are some of the most common cases encountered by the practicing forensic pathologist. Previous studies have shown inflicting injury to the head region is one of the most effective methods of murder. The important factors that determine severity of trauma include the type of weapon used, type and site of skull fracture, intracranial haemorrhage and severity of brain injury. The aim of this study was to determine the characteristics of blunt force trauma to the skull produced by different instruments. Nine adult monkeys (*Macaca fascicularis*) skulls were used as models. Commonly found blunt objects comprising of Warrington hammer, hockey stick and open face helmet were used in this study. A machine calibrated force generator was used to hold the blunt object in place and to hit the skulls at forces of 12.5N and 25N. Resultant traumatic effects and fractures (linear, depressed, basilar, comminuted, and distastic) were analyzed according to type of blunt object used; surface area of contact and absolute force (N/cm^2) delivered. Results showed that all investigated instruments were capable of producing similar injuries. The severity of trauma was not related to the surface area of contact with the blunt objects. However, only high absolute forces produced comminuted fractures. These findings were observational, as the samples were too small for statistical conclusions.

Keywords: blunt trauma, skull, fracture, blunt object, forensic science

INTRODUCTION

Deaths resulting from blunt force trauma to the head are some of the most common cases encountered by practicing forensic pathologist. Recovery of skeletal remains with signs of trauma to the skull may very likely involve crime and homicide. Previous studies have shown that inflicting injury to the head region is one of the most effective methods of causing death – hence homicide.[1] Selection of this region by assailants is due to this area being usually unprotected and serious injuries can be made with minimal effort.[2]

Blunt force trauma to the head is also routinely observed in cases classified as accidents, suicide and homicide. It is the most common cause of death in road traffic accidents and falls or jumping from high places.[3]

As past studies have indicated that the presence of fracture indicates severity of force on the site of impact, it would be logical to postulate that the outline of the blunt object will also be present.[4] This would allow the pathologist to conclusively determine the causative instrument, number of blows, sequence and directionality especially since different instruments produced different blunt force trauma to the skull as previous studies have indicated.[5, 6]

Due to the limited elasticity of the skull, a severe impact would eventually deform the bone. If the elastic limit of the bone is exceeded, blunt force trauma may cause fractures at the site of impact and dislocations of bony structures. Studies have shown that skull fractures produced by blunt force trauma usually begins at the impact site and then radiate outwards. Individual impact may be patterned and the characteristics of the skull fracture may suggest the particular type of blunt object used. In certain circumstances, the pattern may appear non-specific. In general, the skull fracture pattern can be classified as linear, radiating, depressed, hinge, ring or contra-coup.[7]

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It is interesting to note that the severity of trauma to the skull is closely dependent on several factors. The two important factors include characteristic of the blunt object that had acted as the weapon and the site of impact. Severity of trauma also depends on the amount and thickness of hair, the thickness of the scalp and skull at the impact site. In general, a greater force of impact produced by a smaller surface area of blunt instrument with short duration of contact will result in a much more severe skull damage compared to a blunt instrument with a wide head.[8]

Blunt force trauma to the head could potentially result in death. When the victim is attacked on the head and neck with a blunt object, the presence of underlying damage to the brain or its covering is more likely to determine the outcome for the victim – alive or dead. It has been noted that death in this condition can occur without the presence of a skull fracture. However, this phenomenon is rarely seen and skull fracture can be regarded as an indirect indicator of severity of the resulting trauma.[9]

This research was conducted to study the different forms of traumatic injuries from force-standardized blunt force to the skull using various common blunt objects. These objects include hammer, hockey stick and helmet. In this study, blunt force trauma is defined as a blunt object striking the body. This definition would thus allow us to cover trauma caused by a blow or movement of a body striking against a blunt object.

MATERIALS AND METHODS

Nine adult monkey (*Macaca fascicularis)* skulls were used as models in this research. *Macaca fascicularis* used was provided by the Malaysian Wildlife Department. Approval for the use of these animals for this study was granted by the Animal Ethics Committee of the National University of Malaysia (UKMAEC). Adult *Macaca fascicularis* weighing approximately 5 to 6 kilograms were chosen. All subjects used were male and of near similar size. All *Macaca fascicularis* were then killed by intramuscular injection of 2% of phenobarbital with a dosage of 3 to 6 milligram per kilogram. The carcass's skin and organs of the skull were then removed. Skulls were cleaned manually.

The three blunt objects chosen for this research were a Warrington hammer, a field hockey stick and an open face helmet. Selection of the objects was based on their easy availability and access in normal life. Due to this fact, the possibility of using them as offensive weapons is high especially in cases involving crime and homicide. The specific areas of the blunt object used to inflict the blows are based on how the objects are commonly held. The contact areas of the blunt objects hitting the skull are as follows: (1) The flat surface head of the Warrington hammer, (2) the heel part of the hockey stick and (3) the vertex area of an open face helmet. Surface area of the blunt object hitting the skull was calculated in the experiment.

The striking process

The skulls were labeled from one to nine. A machine calibrated force generator was used to hold the blunt object in place and to hit the skulls. The position of the skulls was fixed to avoid movement of the skull during the striking process. Two skulls were hit at the vertex area using a Warrington hammer with the force of 12.5N. However, the force generated did not produce any trauma on the skulls. Thus, the experiment was repeated using a force of 25N to hit one skull for each blunt object. The experiment was repeated using three other different skulls by another blunt instrument with forces mentioned above (12.5N and 25N).

Analysis of trauma

Skulls were analyzed using X-ray radiographs. Visual observations were also made to determine the type of trauma or fracture formed on the skull. All results were then recorded in a standard form and photographed.

The shape of trauma was categorized into specific or non-specific patterns. Next, they were then sub-categorized onto the various types of fracture (Table 1). Once all of these have been documented, the outcome was compared among the groups based on force of delivery and type of blunt weapon.

Statistical analysis using Chi Square test was used to determine if there were any significant differences between the above-mentioned variables. Level of significance was set at $p < 0.05$.

RESULTS

Results obtained from visual observation (Table 2) indicated that Warrington hammer and open face helmet produced similar shapes, patterns and sites of fracture. Both blunt objects created fractures along suture lines with noticeable

TABLE 1: Types of skull fractures encountered

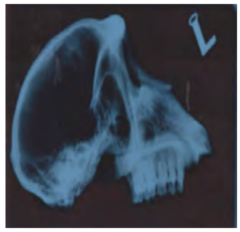
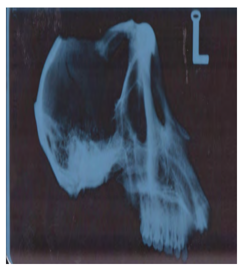
Type of fracture	Observation	
	Visual observation	**X-ray**
Linear	 Skull 1	 Skull 1
Depressed	 Skull 2	 Skull 2
Basilar	 Skull 1	 Skull 1
Comminuted	 Skull 8	 Skull 8
Diastatic	 Skull 1	 Skull 1

TABLE 2: Specific patterns of skull fracture from particular types of instrument used at force 12.5N

Instruments	Subjects	Shape	Observation Pattern / non-specific	Site of fracture
Warrington hammer	1	Along suture line	Pattern	Frontal, Occipital, Parietal, Right temporal
	2	Along suture line	Pattern	Frontal, Parietal, Left Temporal
Field hockey stick	5	No shape	Non-specific	–
	6	No shape	Non-specific	–
Open face helmet	7	Along suture line	Pattern	Frontal, Parietal, Left Temporal
	9	Along suture line	Pattern	Frontal, Parietal, Right Temporal

fractures in the frontal, parietal and temporal area of the skull. We noted that the first model that had received a blow by Warrington hammer had also produced a fracture in the occipital area. Despite this, there was no reoccurrence of this fracture in the second model and thus we concluded that the occipital fracture had occurred due to variation in the thickness of the skulls. On the other hand, no recognizable shape or pattern was seen when using a field hockey stick. There was also an absence of fracture.

Detailed analyses of skull fractures based on different forces (12.5N and 25N) show interesting results. When a low impact force (12.5N) is applied to the model skulls by any of the studied blunt objects, no distinctive shape, pattern and site of fracture was noted (Table 3). Site of fracture seem to be located in the frontal, parietal and temporal areas of the skull. Although open face helmet had produced a fracture in the occipital area, we strongly feel that the lines seen in this area were most likely due to the variation of thickness in the skull of the model.

Nevertheless, impact force above 12.5N (25N) produced more distinctive characteristics. Due to this, a more detailed analysis on the impact was conducted (Table 4). Although each blunt object had a standardized surface area of contact with the skull, the amount of pressure created and transferred from each blunt object to the skull varied between experiments. For example, although the Warrington hammer had a contact

Table 3: Specific patterns of trauma/fracture from particular types of instrument used at force 25N

Instruments	Subjects	Shape	Observation Pattern / non-specific	Site of fracture
Warrington hammer	3	No shape	Pattern	Frontal, Parietal, Temporal
Field hockey stick	4	No shape	Pattern	Frontal, Parietal, Temporal
Open face helmet	8	No shape	Pattern	Frontal, Parietal. Right and left temporal, Occipital

Table 4: The effect of surface area and absolute pressure of impact on type of fracture produced

Surface area (cm^2)	Absolute pressure (N/cm^2)	Subject	Type of fracture					
			Linear	Radiating	Depression	Basilar	Comminuted	Diastatic
Warrington hammer (3.14cm²)	3.98	1	√	-	-	√	-	√
	3.98	2	√		√	√	-	√
	7.96	3	√	-	-	√	√	√
Field hockey stick (4.00cm²)	6.25	4	-	-	-	-	√	-
	3.13	5	-	-	-	-	-	-
	3.13	6	-	-	-	-	-	-
Open face helmet (7.07cm²)	1.77	7	√	-	-	√	-	√
	3.54	8	√	-	-	√	√	-
	1.77	9	√	-	-	√	-	√

surface area to the skull of $3.14cm^2$, we noted that the absolute pressure transferred from the hammer to the skull had varied significantly. Two skulls had received an absolute pressure of $3.98N/cm^2$ while another had received a significantly higher absolute force of 7.96 N/cm^2. We found that Warrington hammer at 3.98 N/cm^2 had produced linear, basilar and diastatic fractures. A depressed fracture was also noted at this absolute pressure. Since this fracture was not reproducible in model subject 1, the fracture produced was likely unintentional. Similar characteristics were also produced by open face helmet at an absolute pressure of 1.77 N/cm^2.

It was interesting to note that when a higher absolute pressure was delivered by any of the blunt objects (Warrington hammer, field hockey stick and open face helmet), a comminuted fracture was produced.

Statistical analysis using Chi square test were performed on the data obtained. However, the samples were too small for meaningful statistical conclusions.

DISCUSSION

Since 2008, a total of 3,790 articles have been published detailing out the implications of trauma to the head region. Although most studies had concentrated on neurological pathology, a few had also studied the effect of a force onto a skull.[10] This study was constructed in a form that would allow researchers to study the impact of commonly found blunt objects onto a skull using a standardized force.

We found that utilization of either a Warrington hammer or open face helmet as a blunt weapon to cause injury to the skull produce similar characteristics. These include the presence of fractures along suture lines and fractures at frontal, parietal and temporal areas. However, these were minor fractures. A previous study had reported that the thickness of the occipital bone was greater compared to other skull bones. Therefore, larger forces are needed to cause a fracture at this region. Thus, when trauma involving the occipital site of the skull is noted in any forensic cases, it would likely indicate that the magnitude of the force applied during a blow were quite considerable and intentional.[11]

Field hockey stick on the other hand was unable to leave any discernible shape onto the surface of the skull. The absence of any shape by the field hockey stick could likely be due to the basic material of the object. The field hockey stick was made of wood and so has a high ability to absorb the impact rather than transferring the impact into the skull.[12] The above finding was supported by Ian Greaves *et al.* in a book entitled Trauma Care Manual. In his study, he noted that when an assault involving blunt objects occur, the composition of the blunt objects and its contact surface area were important in determining the energy force transferred from the weapon to the victim's impact site.[13]

Although past publications had indicated conclusively that the presence of trauma need not also show indentation on a skull, our result had indicated that this assumption remains true to only a certain point.[14] For an impact lower than 12.5 N, all blunt objects in this experiment were unable to leave any specific pattern onto the skull. Site of fracture was similar and is very likely due to the standardized area where the impact was made on the skull. Impacts of 25 N produced more definitive results.

Although each blunt object impact was standardized as much as possible, variation in surface area and absolute pressure had varied. This resulted in noticeable differences in the fractures produced. For example, Warrington hammer at an absolute pressure of 7.96 N/cm^2 tended to produce comminuted fractures compared to when a lower absolute pressure was given (3.98 N/cm^2). Similar characteristics are also found on the impact by open face helmet when a higher absolute pressure (3.54 N/cm^2) was introduced. We would like to note that the absolute pressure that had produced comminuted fractures were of different values. The Warrington hammer had required a much higher absolute pressure (7.96 N/cm^2) compared to the open face helmet (3.54 N/cm^2). It is felt that this variation is also due to the surface area in which open face helmet (7.07 cm^2) had a higher contact surface area compared to the Warrington hammer (3.14 cm^2). This would also indicate that factors that influence a fracture are dependent on absolute pressure and surface area of the weapon.

It is interesting to note that absolute pressure required to produce comminuted fractures by field hockey stick were much lower than what is required by the Warrington hammer. As mentioned above, this could likely be due to the slightly bigger surface area of contact on the field hockey stick (4.00 cm^2) compared to the Warrington hammer (3.14 cm^2).

We would like to note that the results presented were based on an animal model. Due to the structure, thickness and composition variation of the animal skull compared to human skull, interpretation and application of this result with regards the human skull must be made with caution.

CONCLUSION

In conclusion, effect of blunt force by commonly found objects onto the skull is largely dependent on the amount of force applied to the area, contact surface area of the object to the skull and the amount of absolute pressure transferred from the object to the skull. High pressure impact would result in comminuted fractures which in turn suggests severe trauma to the brain.

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