Porcine Model: Differences in Entry and Exit Wounds by Semi-Automatic Pistol at Different Shooting Distances

Wong YS[a], Khairul O[a], Atiah AAG[a], Abdul Aziz I[a], Muhd. Hilmi B[a], Noor Hazfalinda H[a], Sri Pawita Albakri AH[a*]

[a] *Forensic Science Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia.*

ABSTRACT: Semi-automatic pistol is a handgun which consists of a chamber and a barrel. The trigger needs to be pressed repeatedly during firing. The used cartridge case is ejected from the pistol and a new cartridge is reloaded into the chamber automatically until the entire cartridge in the magazine is reloaded. Gunshot wound usually has entry and exit wounds. Therefore, the aim of this study was to determine the differences between entry and exit wounds using a semi-automatic pistol at three different shooting distances: contact distance (0 m), close contact distance (1 m) and intermediate distance (3 m). The test firing was conducted at the shooting range of PALAPES UKM. The targets used were six swines. Size, shape and presence of GSR material on the gunshot wound were documented. There was a significant difference in the size between entry and exit wounds at contact shooting distance (0 m) and intermediate shooting distance (3 m). At all shooting distances, the entry wounds are made up of polygonal shape such as round and oval whereas exit wounds are of stellate and irregular shape. Presence of GSR can be used to differentiate entry and exit wound at contact shooting distance (0 m). The size of entry wounds determined the shooting distances. An equation and a model to estimate the shooting distance was developed using these morphological features. Different shooting distances produce different characteristics between entry and exit wounds. It is hoped that this study can provide more information on differentiating entry and exit wounds.

Keywords: Forensic chemistry, semi-automatic pistol, gunshot residue, gunshot wound, entry wound, exit wound

Introduction

Currently, wound ballistics has become one of the top priorities in both medical and forensic researches due to the increasing use of firearms and the corresponding rise in gunshot fatalities [1]. In 2004, a study in United States shows that a total of 26.4% of violent crimes involved firearms. At the same time, 78% of these reported violent crimes involved handguns [1] such as semi-automatic pistol, revolvers and machine pistols [2]. Every year, an estimation of a total of 70,000 victims are injured from gunshot wound of which 30,000 of these are fatal [3]. Thus, there is no doubt that crimes involving gun is an important issue to focus on.

Overall, firearms can be divided into three main groups, which are the handguns, long arms and automatic firearms [4]. Handguns were specially designed to launch small size projectiles and usually can be used with one hand. Examples of handguns include the revolver, pistol and derringer [5]. Long arms have a long barrel and usually the butt part of the weapon is touching the shoulder when shooting is carried out. Rifle and shotgun are examples of long arms. Lastly, automatic weapon is the most dangerous firearm and usually used by the military and terrorists [6] where these weapons are able to launch projectiles non-stop as long as the trigger is pulled [5].

Semi-automatic pistol is a type of handgun with a single chamber and a single barrel. It is build with low-weight polymer frame and metallic slide, thus making it a compact, lightweight and economical firearm in the market [7]. Semi-automatic pistol was first introduced in the early 20th century for military purpose. Today, it is used by the police for the maintenance of public order and by civilians for self defense [2]. Semi-automatic pistol use the semi-automatic mechanism in loading, locking, firing, extracting and ejecting the bullet. After each shot is fired, the weapon will automatically carry out the self loading of bullet into the chamber until all bullets in the magazine is used up[2]. It is not a fully automatic gun

since the trigger needs to be pull individually for each bullet to be fired out, unlike the fully automatic firearms such as the machine gun.

The study of the gunshot wound is very important especially to the forensic pathologist in interpreting the gunshot injuries [8]. This knowledge will be used in the process to recover firearm projectiles from the victim's body for the purpose of further analysis and presentation in court without causing much contamination. Besides, differentiating a firearm entry wound from exit wound or vice versa and estimating the approximate range of shooting are also important factors to be looked into when pathologists carry out autopsies [3].

If the pathologist failed to differentiate the entry or exit wound, this might cause an error in the calculation of number of projectiles that entered, exited or lodged in the victim's body. Another crucial issue is identifying the distance of firing which may be important in determining manner of death[8], be it accidental, suicidal or homicidal [3].

Firearms launch the projectiles which travel in a high velocity. Thus, projectiles are able to penetrate objects in front of it. If the objects are body tissue or surface, a gunshot wound will developed. Entry wound appear on the surface of the body where the bullet enter the body. However, the bullet may or may not exit the body, if it does there will be an exit wound; or it might also be lodged inside the body. Normally, an entry wound shows a dark ring abrasion and regular outline of skin defect around the wound. On the other hand, exit wound would show a irregular skin defect with everted jagged skin edges [9].

In this study, three firing distances were used to compare the differences between the entry wound and exit wound. Contact (0 m) range firing distance is where the muzzle of the gun is in contact with the skin or surface of object during the time of discharge [3] and usually seen in suicide shooting. Close contact (1 m) range is where the muzzle is in a close distance with the object, which is not more than 2 feet. Lastly, intermediate (3 m) shooting range distance brings a further shooting distance to 2-4 meters. The morphology of the gunshot wound which is the shape, size and the presence of gunshot residue (GSR) were observed and studied to document the difference between entry wound and exit wound.

Materials and Methodology

Materials

Young adult swines (*Sus scrofa domestica*) were used as the target since swine's body structure is quite similar to human. Swines are acceptable substitute due to the similarity to human torsos in weight, fat to muscle ratio and hair coverage [10]. The swines were slaughtered by the supplier and sent to the PALAPES shooting range at UKM, Bangi. 6 swines were used and each swine was labeled as 1, 2, 3, 4, 5 and 6. The average mass of each swine was between 25 – 30 kg. For each shooting distance, 2 swines were used in order to make comparison.

Sodium Rhodizonate was the chemical used to determine the presence of gunshot residue (GSR) [11]. The positive result of this test shows a light pink colour which will appear at area containing GSR [11]. A 9 mm Browning semi-automatic pistol with ammunition of 9 mm full metal jacket (FMJ) copper bullets were used for test firing. A specially designed metal stand was used to hang the swine. This metal stand can prevent the swine from moving around during the shooting process. A DSLR camera was used for documentation purpose.

Methodology

The shooting was carried out at the PALAPES shooting range at UKM, Bangi, done by the PALAPES members. During the whole shooting process, shooting range safety protocols were followed strictly.

The shooting distance is defined as the distance between the muzzle of the firearm to the target. Swine 1 and 2 were fired at the distance of 0 m or contact distance, swine 3 and 4 were fired at the distance of 1 m or close contact distance while swine 5 and 6 were fired at the distance of 3 m or intermediate distance.

For all shooting test, the shooter is in the standing position and the firearm held using both hands. After each shot was fired, the documentation process was carried out. After the documentation of the previous wound was done, then only the next shot was fired. For each swine, a total of 4 shots will be fired where one shot was fired at the head while three shots were fired to the abdomen of the swine. The wounds which appeared on the head were labeled as H1 while wounds on the

abdomen were labeled as A1, A2 and A3 according to the sequence.

Documentation of Gunshot Wounds

For all three shooting distances, the documentation were the same, which included the shape of the wounds, diameter of the wounds and the presence of GSR materials on the gunshot wounds. After each shot was fired, the documentation was done before the next shot. Photo with and without scale were taken first. Then, the shape of both entry and exit wound were observed and recorded. Next, the diameter of the wounds was measured by using the ruler. After this, Sodium Rhodizonate was sprayed and area which contains GSR showed a pink colour change. Another photo with scale was taken to show the presence of GSR material on the gunshot wound.

Result and Discussion

Figure 1, Figure 2 and Table 1 show all the data collected at the test firing. Repeated T-test was used to determine the difference in terms of size. Initially, Chi-square test of independence was to be used to determine the difference in term of shape and presence of GSR between entry and exit wounds. However, due to the low sample size, the requirement to carry out the test cannot be achieved. Thus, the difference in term of shape and presence of GSR between entry and exit wounds are explained by descriptive analysis.

Differences between entry and exit wound at contact (0 m) shooting range

Statistical tests prove that at this shooting distance, there is a significant difference in the size between the entry and exit wound, with $t(7) = 4.462$, $p < 0.05$, $d = 2.30$. The mean size of entry wounds are 0.47 cm smaller than mean size of exit wounds. All gunshot wound produced at this shooting range are quite small in diameter. The size of gunshot wounds are affected by factors such as size of the projectile, speed of the projectile and the elasticity of the target's body [12]. When the muzzle of the firearm is totally in contact with the target, the bullet fired will travel at a very high speed and thus producing a small gunshot wound.

The shape of entry wound at this distance were mostly made up of polygonal shapes such as round and oval while most of the exit wounds showed an irregular shape with tearing effect. When a projectile is shot into the body of the target, the shape of the projectile tends to be altered due to contact with internal structures such as bones or organs. When this altered projectile leave the body of the target, it tends to tear the inner surface of the exit wound, thus easily producing an irregular exit wound due to the tearing of the skin by the altered projectile [13].

GSR was found at all entry wounds but absent at all exit wounds at contact shooting range. At this very close shooting distance, all the GSR material was transferred from the muzzle of the pistol to the surface of the entry wound. For the exit wound, GSR was hardly found since firearm residue will only be detected at the surface facing the shooter. Thus, the presence or absence of GSR at entry and exit wound is very useful to differentiate both gunshot wounds at contact shooting range [14].

Differences between entry and exit wound at close contact (1 m) shooting range

Statistical tests prove that at this shooting distance, there is no significant difference at the size between entry and exit wound with $t(7) = 2.296$, $p > 0.05$, $d = 1.42$. At this distance, both entry and exit wounds showed similar sizes.

At this shooting distance, the exit wounds are still dominated by irregular shapes, while the entry wounds are still made up by polygonal shapes. Usually, the characteristic of irregular shape can be a very good indicator to identify a gunshot wound as an exit wound since entry wound seldom show irregular shape [15]. Entry wound will only develop an irregular shape if the bullet entering the target has altered in shape.

The exit wounds show no presence of GSR at this shooting distance. However, some of the entry wounds show slight colour change to light pink but the orange colour of Sodium Rhodizonate still dominate. We define this presence of GSR material as slight presence of GSR. Usually, GSR can be detected at close contact shooting distance, but in our research, we define close contact range into a longer distance, which is 1 meter. Normally, close contact distance is around 20 cm to 40 cm between the muzzle of the weapon towards the surface of the shooting target, with the muzzle not in contact with the surface of target [12].

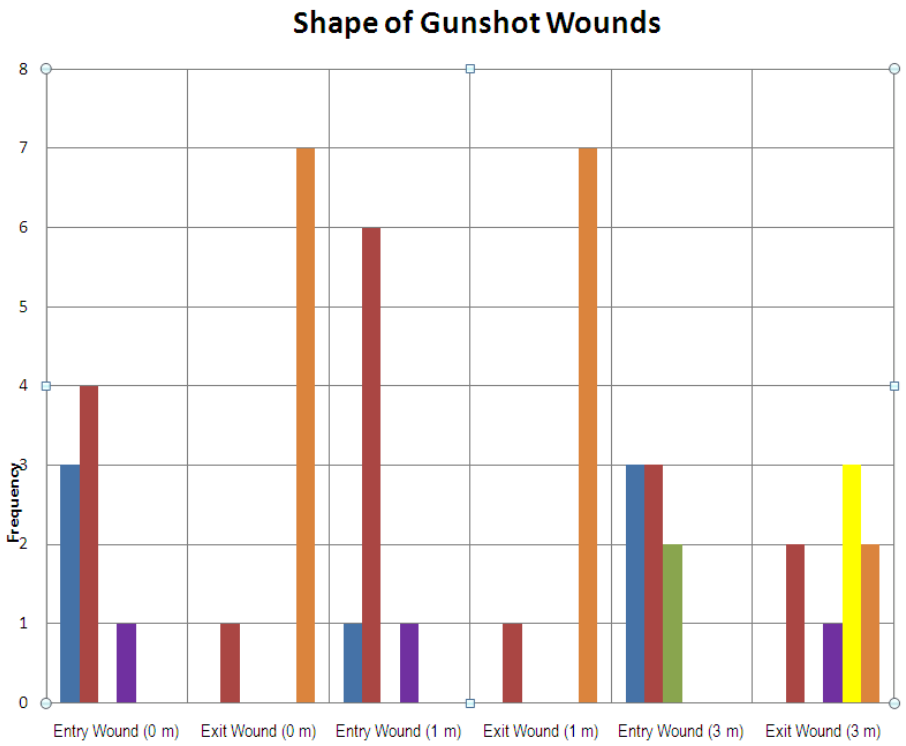

Figure 1: Shape of gunshot wounds at all shooting distances

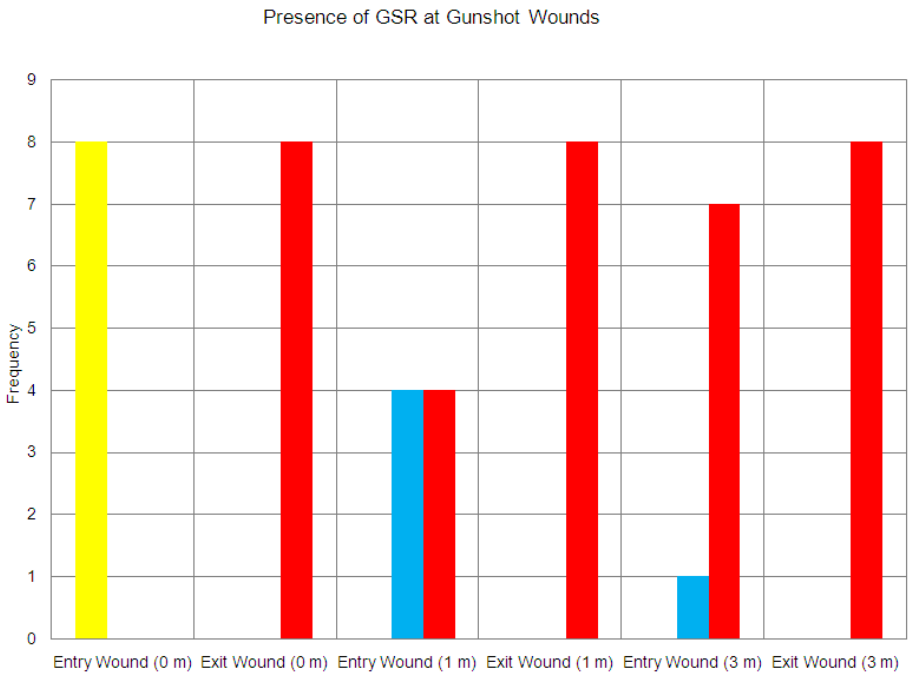

Figure 2: Presence of GSR at gunshot wounds for all shooting distances

Table 1: Average diameter for gunshot wound

No. of shot	Average Reading (cm)					
	Contact (0 m)		Close Contact (1 m)		Intermediate (3 m)	
	Entry Wound	Exit Wound	Entry Wound	Exit Wound	Entry Wound	Exit Wound
1	0.40	0.93	0.77	1.10	0.87	0.97
2	0.60	0.90	0.60	1.57	0.73	1.33
3	0.43	0.80	0.50	0.80	0.73	1.33
4	0.67	1.23	0.77	0.50	0.52	0.80
5	0.57	0.50	0.57	1.17	0.50	1.07
6	0.57	1.03	0.70	1.07	0.63	0.97
7	0.53	1.17	0.70	0.77	0.63	1.13
8	0.60	1.57	0.77	0.83	0.90	1.00

Differences between entry and exit wound at intermediate (3 m) shooting range

Statistical tests prove that at this shooting distance, there is a significant difference in the size between the entry and exit wound, with $t(7) = 5.147$, $p < 0.05$, $d = 2.33$. The mean size of entry wounds are 0.39 cm smaller than mean size of exit wounds. At this shooting range, most of the entry wounds are smaller than the exit wounds. Generally, common consensus is that exit wounds are bigger than entry wounds. Actually, exit wound can be in variety of range, either big or small, depending on the rotation of the bullets when it exits the target [13]. If the rotation of the bullet is the same from the moment it enter until it exit the body, the size of exit wound form will be small in diameter. If the bullet hit body structures such as organ or bone, the bullet will undergo a drastic change in rotation and when it exits the body of target, a tearing effect will occur, causing a big exit wound. Figure 3 shows that although the shooting distance is the same, the exit wounds appear in different size.

From the aspect of shape, the exit wound shows a lot of different shapes which include oval, ellipse, stellate and irregular shape. Exit wound has a wide variation in shape compared to entry wound [3]. This happen where the rotation of the bullet can change widely when it traveled inside the body. When the bullet exits the body, many shapes can be produced. However, for entry wound, a very uncommon square shape was observed. It is seldom to have a square shape at either entry or exit wounds. It can be deduced that the square shape are formed due to the experiment's design. The skin of the target or pig might be in a stretched condition after it is hung on the metal stand for a long period. Also worthy of note, direct sunlight at the outdoor shooting range also contributed to further stretching the skin of the pig. Due to the stretching on the skin, uncommon square shape was formed at entry wound. Figure 4 shows the uncommon square shape at the entry wound.

Figure 3: A big exit wound at intermediate shooting range

Figure 4: An uncommon square shape at the entry wound

All entry wounds and exit wounds at this shooting range also show no presence of GSR material. This reflects other studies' finding that at this long distance, the GSR will not be found at the gunshot wound [16].

Relationship between shooting distances with the size of gunshot wound

From the scatter plot in Figure 5 and Figure 6 and Pearson product-moment correlation test in Table 2, the value of p shows that there is a relationship between shooting distances with the size of entry wounds while there is no relationship between shooting distances with the size of exit wounds. An equation to estimate the shooting distances using the size of a random entry wound can be formed as follow with the Linear Regression Test at Table 3:

$y = mx + c$

Shooting distance = 4.901 × diameter of entry wound + (-1.268)

However, the R Square value shows only a significance of 17.1 %. This might due to the low sample size and low number of data in forming the equation. A better estimation using equation can be formed if sample size is increased to generate more data.

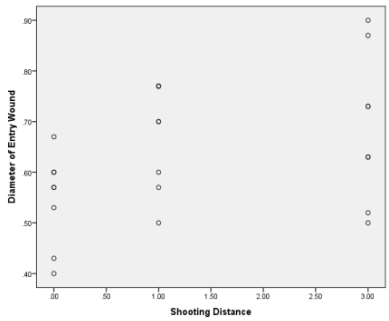

Figure 5: Scatter plot between shooting distance against diameter of entry wounds

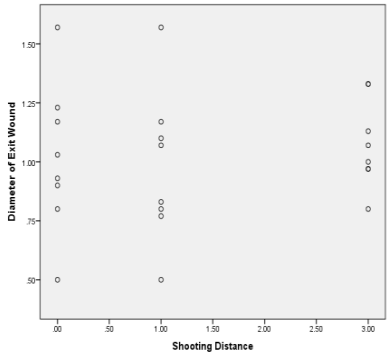

Figure 6: Scatter plot between shooting distance against diameter of exit wounds

Table 2: Correlation between shooting distance with size of gunshot wounds

Correlations		Shooting Distance	Diameter of Entry Wound	Diameter of Exit Wound
Shooting Distance	Pearson Correlation	1	.414*	.111
	Sig. (2-tailed)		.044	.606
	N	24	24	24
Diameter of Entry Wound	Pearson Correlation	.414*	1	.048
	Sig. (2-tailed)	.044		.825
	N	24	24	24
Diameter of Exit Wound	Pearson Correlation	.111	.048	1
	Sig. (2-tailed)	.606	.825	
	N	24	24	24

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3: Linear Regression test to form equation

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.414[a]	.171	.134	1.18587	.171	4.547	1	22	.044

a. Predictors: (Constant), Diameter of Entry Wound

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.268	1.243		-1.019	.319
	Diameter of Entry Wound	4.091	1.918	.414	2.132	.044

a. Dependent Variable: Shooting Distance

A model to estimate the shooting distance using Clementine Software

By combining all 24 sets of data obtained from the shooting test, a model to estimate a shooting distance can be built by studying the morphology of gunshot wound using size, shape and presence of GSR material on the gunshot wound. Figure 7 shows the model built using the Clementine Software.

This model was built using low amount of data. At the same time, the shooting distance used to study the differences between entry and exit wounds was only focused on three different distance only. Thus, this model can only be used to estimate shooting distance less than 3 meters. The model can be more accurate if the study increase its sample size and add in different shooting distances.

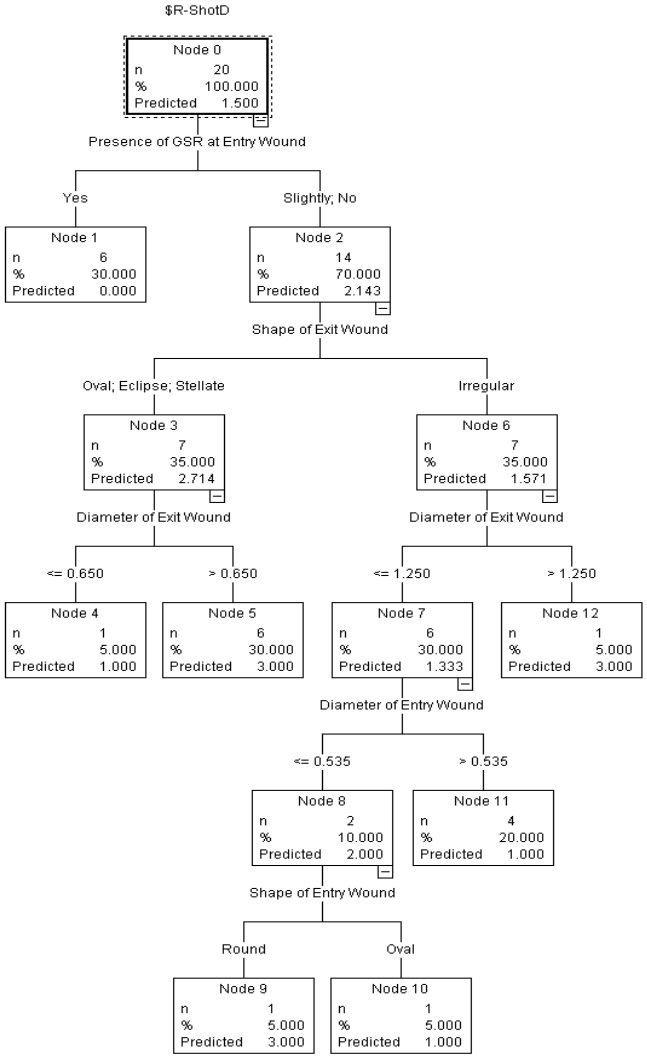

Figure 7: A model to estimate the shooting distance

Conclusion

At the contact shooting range, both entry and exit wounds can be differentiated by studying the size, shape and presence of GSR material at the gunshot wound. At the close contact shooting range, both entry and exit wounds can only be differentiated by looking at the shape and presence of GSR material at the gunshot wound. At the intermediate shooting range, both entry and exit wounds can only be differentiated by studying the size and shape of the gunshot wounds. There is a relationship between the shooting distances with the size of entry wounds and an equation to estimate shooting distance using the size of entry wound can be formed:

Shooting distance = 4.901 x diameter of entry wound + (-1.268)

A model to estimate shooting distance by looking into all morphology of gunshot wounds studied in this research can also be formed.

In conclusion, different shooting distances produce different features and characteristics in both entry and exit wounds. By studying and analyzing the morphology of gunshot wounds such as size, shape and presence of GSR material at the gunshot wound, information such as shooting distance or distance between the firearm towards the shooting target can be obtained.

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Additional information and reprint request:
Dr Sri Pawita Albakri Dr Amir Hamzah
Email:drsripaah@gmail.com
Forensic Science Programme
Faculty of Health Sciences
Universiti Kebangsaan Malaysia
Jalan Raja Muda Abdul Aziz
50300 Kuala Lumpur, Malaysia.