Original Article

Medico-legal Study of Shockwave Damage by High Velocity Missiles in Firearm Injuries

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Summary:

Background: Many variables determine the destructive capacity of a weapon; missile velocity is an important consideration. Wounding capability of a missile depends on the amount of kinetic energy dissipated in the tissues. A penetrating high velocity missile (usually bullets) transfers a destructive energy called shock wave to the surrounding tissues.

Objective: To detect and estimate tissues damage away from the main track of high velocity missiles in firearm rifled weapons injuries.

Methods: This cross-sectional study is performed in medico-legal institute in Baghdad for (8) month's duration from (1-1-2010) to (1-9-2010). Full proper autopsy including external and internal examination of the body for all cases was performed, and complete medico-legal history was obtained to determine the type of the weapon used so as to include only the cases of high velocity missile injures.

Results: The study included (30) cases; (21) men and (9) women with their ages ranged between (15 –70) years. The total body injures in all cases were (69) in the main track and (43) away from the main track of the missiles. Head and neck region was affected more than other body regions by primary injury, while the chest region was the most affected by distant injuries due to shock wave.

Conclusion: The shock wave damage had happened in all cases of high velocity missile firearm injures in this study. Most of them were in the chest; the lower limbs were the least frequently affected. This should be put in consideration of forensic pathologist.

Key wards: Firearm injuries, Rifled weapon, High velocity missile, Shock wave.

Introduction:

The type of firearm wounds varies according to the type of firearm weapon used. There are two groups of firearm weapons; the first includes the smooth bore weapons, whereas the second includes the rifled weapons, which are the most important. (1) Principally, there are three mechanisms of tissue damage due to missiles; laceration and crushing, shock waves, and cavitation. The first mechanism is generated by the missile displacing the tissues in its track and are recognized as the primary wounding mechanism,(2) The degree and amount of laceration and crushing are dependent upon missile velocity, its shape, and angle of impact; however, the shape and construction of a missile are not significant factors at such low-velocities as observed in handguns. Shock waves; the second mechanism often cited as significant in wounding, they occur by the compression of tissues that lay ahead of the missile, and are generated by high velocity missiles generally exceeding 2,500 feet per second.(3) The missile has ability to produce a temporary cavity, Which is considered an important component in wound production and the degree of destruction. When a missile enters the body; the kinetic energy imparted on the surrounding tissues forces them forward and radially producing a temporary cavity or temporary displacement of tissues. The temporary cavity may be considerably larger than the diameter of the missile, and rarely lasts longer than a few milliseconds before collapsing into the permanent cavity or wound (missile track) (4). The nature of internal tissue injuries from rifled firearm weapons depend greatly on the velocity of the missile. There are two types of missiles according to velocity; the first one is the low velocity missile that travels in a speed (below 2,500 feet per second), and the second one is the high velocity missile that travels in a speed (exceeding 2,500 feet per second).(5)For damage to occur some or all of the kinetic energy of the missile has to be absorbed by target tissues So the mode of injury depends on the velocity of the missile, (6) relatively the missile that travels in a speed (exceeding 2,500 feet per second) when it passes through the tissues sends a shock wave of compression ahead from the laceration track. (7) That wave lasts only for a brief period but it raises the tissue pressure up to thousands of kilopascals that can cause severe damage into fluid-containing tissues like vessels lying away from the missile track. (8) Direct effect of missile is the

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permanent tissue loss along the local track; the tissues are compressed ahead of the track by a compression in the form of shock waves of spherical form so that tissue damage can be produced in a considerable distance away from the original missile track. (9) High energy is absorbed by local tissues from a high velocity missile; thus the tissues are accelerated violently in both forward and outward direction (10) The momentum gained by the tissues causes them to continue this movement even after the passage of the missile; this phenomenon creates a temporary cavity in the tissue that can be up to 40 times bigger than the diameter of the missile. (11) Penetrating missile transfers destructive energy to surrounding tissues, the impact imparts a temporary pressure wave perpendicular to the path of the missile which accelerates the tissues forwards and sideways. (12) Due to the inertia, the tissue particles continue in their forward movement after the missiles have passed and a cavity up to 30 times the original cross-sectional area of the missile is formed followed by a quick collapse. (13) The stress waves which are directly related to the velocity of the missiles destroy or push a side structures on the bullet track. (14) Cavity collapse is influenced by tissue elasticity, hemorrhage and edema leaving behind a smaller permanent pathway filled with vapor bubbles, and missiles fragments. (15) The velocity of the missile as it strikes the target is the main determinant of the wounding capacity which is directly proportional to the amount of energy transferred and to the actual energy expended. (16) The greater the energy of the missile at the moment of impact the greater is the tissue destruction. (17) The striking energy of a missile is the product of its mass or weight multiplied by the square of its velocity, (18) and because it is squared, velocity is the most important factor not the size or caliber of the missile. High impact has a greater destructive power to cause shock leading to death. (19) Hydrostatic shock is a theory of terminal ballistics that wounding effects are created by a shock wave in the tissues of the target, evidence of such shock can be seen in ultra-high-speed images of supersonic missiles passing through various objects such as damage to the brain from hydrostatic shock from a shot to the chest occurs in humans. (20) In ballistics, energy is a function of mass and the square of velocity. Generally speaking, it is the intention of the shooter to deliver an adequate amount of energy to the target via the missile. (21) The relationship between the velocity of the missile and the amount of energy expended is given by the following formula: (22) E=MV2 E=Energy transferred , M=Mass of the missile , V=Velocity of the missile Shock waves compress the medium and travel ahead of the missile, as well as to the sides, but these waves last only few microseconds and do not cause profound destruction at low velocity. At high velocity, the generated shock waves can reach up to 200 atmospheric pressure. (23) Several scientific papers reveal that ballistic pressure wave effects on wounding and incapacitation, including central nervous system injuries from hits to the thorax and extremities, so a high-frequency oscillating pressure wave with large amplitude and short duration was found in the brain after the extremity impact by a high-energy missile. (24)

Methods:

This cross-sectional study is performed in medico-legal institute in Baghdad for (8) month’s duration from (1-1-2010) to (1-9-2010). The procedures and techniques are the same as in any other medico-legal autopsy; a history of the incident should be obtained before commencing the autopsy examination which should include examination of clothing and radiological examination of the body. The autopsy examination proper should be full and complete including external and internal examination of the body. Often the true circumstances of death may not be known, but the history obtained from the police investigator, witnesses and relatives would help to guide the pathologist in the autopsy examination. Even contradictory accounts are useful. The pathologist can look for specific features and relevant findings that would either establish or disprove any or all the versions. The number of assailants and victims, the type and number of weapon used, the relative positions in relation to victims and assailants, the range of fire, the number of shots, the sequence of events and behavior of the deceased and assailants before and after the shooting, are some of the information that should be sought. The pathologist should also notice the posture, degree and distribution of postmortem changes. The clothing should be recorded as they are removed from the body. Cutting of clothing is best avoided. If necessary, it should be done along the seams and around the tears or injuries present. As the pathologist is often required to identify the clothing in court, a brief but adequate description of each piece of clothing should be recorded. However, in an unidentified body, a more detailed examination and record of the clothing is necessary. The removal and examination of clothing should be carried out with considerable care, as bullets, pellets, bullet jackets, wads, etc. lying loose in or between the clothing can be easily lost.The number, size and shape of tears and holes, and the presence of burn (melting), blackening and tattooing around them should be observed. Shredded tears of an entry hole are likely to have cloth fibers driven into the underlying body injury. The size of the 'injury' should be measured and its location in the clothing determined by its distance from the shoulder seam or waist band, and from the midline. If not the whole body, at least regions of it with injuries or missiles should be radio-logically examined before the internal examination. Antero-posterior and lateral views of each relevant region are required to accurately locate any missile or foreign body. The missile tract is revealed in radiographs as a trail of metallic or bony particles or pieces. After a complete medico-legal history (obtained from the relatives or from police investigator) we chose only the cases which were injured by high velocity missiles of firearm weapons, and then we determined the tissue damages in the main tract of the missile and those lying away from the main tract, also we determined the type of missile caliber if it found in the body, the general information like age and sex of each case. All results were converted to figures and tables. Statistical analyses were applied like P value and Chi-square-exact test to show the significance of some results.

Results:

This study included (30) cases; (21) men(70 % of the cases) and (9) women (30 %); their ages ranged between (15 - 70) years. Figure 1 shows the distribution of study sample according to age groups. Notice that the most affected age group is 30 to 39 years old followed by the age group 20 to 29 years old. The total missiles body injures (damages) was (69) injuries in the main missiles track in the total number of cases. Some of the injuries are single others are multiple in the same region. Head and neck was the most frequently affected body region by main high velocity missile wounds ; they were seen in half of the cases (50%) followed by the chest, while the abdomen was the least frequent, being observed in (23.3%) of studied cases,(table -1-). There was no statistically significant mean difference in count of primary high velocity missile wounds between the (5) anatomical body regions, since the sample size was so small to reach the level of statistical significance. Table (2) shows how frequent were multiple wounds in each body region affected by main high velocity missile wounds. One can see that abdominal body region, when affected was more prone to have multiple wounds, followed by lower limbs, head and neck and chest respectively. The upper limb was rarely affected by multiple wounds (12.5% of total upper limb wounds only). As shown in table (3), only 33.3% of subjects with main gunshot wounds had only one region affected, the majority (60%) having two different body regions affected by gunshots If you compare this table to table (6), you will notice that the majority of subjects (63.3%) had only one body region affected by distant lesions Table (4) shows the frequency distribution of the studied sample by anatomical body region affected with at least one distant lesion. There was no statistically significant mean difference in the count of distant lesions between the 5 anatomical body regions, since the sample size was so small to reach the level of statistical significance, as shown in table(5). Other important results are shown by table (6) and table (7). Table (7) shows exactly how far a primary gunshot wound associated with distant lesions in a specified body region (or combination of two or more regions) they go from the primary wound. For example if the primary wound is limited to head and neck only, three quarters would have distant lesions in chest and(25%) in the same region (head and neck). You can also see that head and neck gunshots even when combined with other regions primary gun shots, still affect mainly the chest (ranging between 33.3% to 100%) and head and neck (ranging between 40% and 66.7%) with distant lesions. So finding a head and neck gunshot wound(s) would call for the forensic physician to look for distant lesions in the head and neck as well as in the chest. Similarly you can reach to other conclusions by looking at each row of the table independent from other rows.

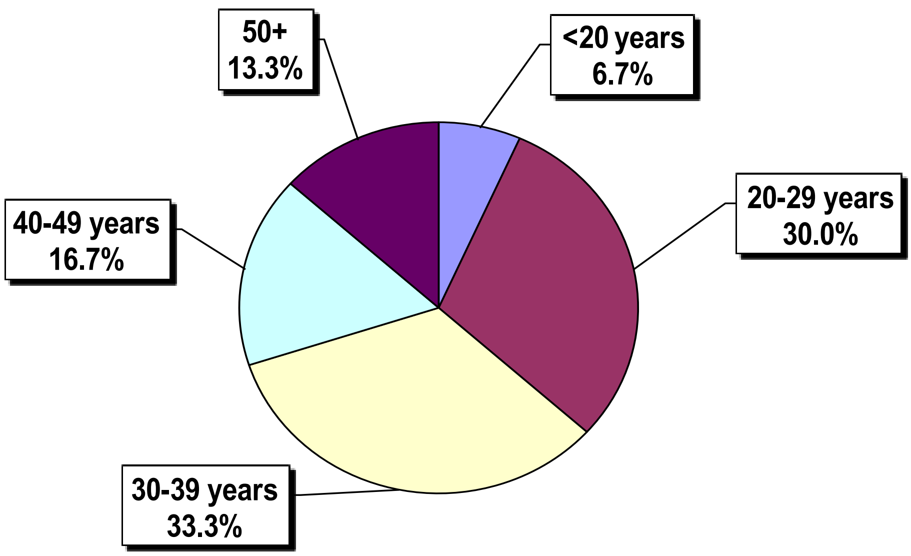

Figure 1: Pie chart showing the relative frequency of age groups in the total study sample.

Table1: Frequency distribution of the studied sample by anatomical body region affected with at least one main high velocity missile wound.

Subjects with at least one main wound in a specified site (n=30)	N	**%**
Head and neck	15	50
Chest	12	40
Lower limb	10	33.3
Upper limb	8	26.7
Abdomen	7	23.3

Table 2: The frequency distribution of subjects by count of main (primary) high velocity missile wounds stratified by 5 anatomical body regions.

Main (primary) gunshot wound	Head and neck		Chest		Abdomen		Upper limb		Lower limb	
	N	%	N	%	N	%	N	%	N	%
One wound	11	73.3	9	75	3	42.9	7	87.5	7	70
Two wounds	3	20	2	16.7	3	42.9	1	12.5	3	30
Three wounds	1	6.7	1	8.3	1	14.3	0	0	0	0
Total	15	100	12	100	7	100.1	8	100	10	100

P (Multiple measure model, with sphere city assumed) =0.43[NS]

Table 3: Frequency distribution of study sample by count of anatomical body regions affected by main (primary) high velocity missile wound(s).

Count of anatomical body regions affected by main (primary) gunshot wound	N	%
One region	10	33.3
Two regions	18	60
Three regions	2	6.7
Total	**30**	**100**

Table 4: Frequency distribution of study sample by anatomical body region affected with at least one distant lesion.

Subjects with at least one distant lesion in a specific site (n=30)	N	%
Head and neck	7	23.3
Chest	15	50
Abdomen	10	33.3
Upper limb	7	23.3
Lower limb	4	13.3

Table 5: The frequency distribution of subjects by count of distant lesions stratified by 5 anatomical body regions.

Distant lesions	Head and neck		Chest		Abdomen		Upper limb		Lower limb	
	N	%	N	%	N	%	N	%	N	%
One lesion	7	100	14	93.3	7	70	7	100	2	50
Two lesions	0	0	1	6.7	3	30	0	0	2	50
Three lesions	0	0	0	0	0	0	0	0	0	0
Total	7	100	15	100	10	100	7	100	4	100

P (Multiple measure model, with spherecity assumed) =0.18[NS]

Table 6: Frequency distribution of study sample by count of anatomical body regions affected by distant lesions.

Count of anatomical body regions affected by distant lesions	N	%
One region	19	63.3
Two regions	9	30
Three regions	2	6.7
Total	30	100

Table 7: The association of main high velocity missile wound in a specified body region by distant lesions in same or other body regions.

	Subjects with at least one distant lesion in a specific site									
Site(s) of main (primary) gun shot	Head and neck		Chest		Abdomen		Upper limb		Lower limb	
	N	%	N	%	N	%	N	%	N	%
Head and neck (n=4)	1	25	3	75						
Chest (n=3)					3	100				
Abdomen (n=1)			1	100			1	100	1	100
Upper limb (n=2)							2	100		
Head and neck+Chest (n=5)	2	40	3	60	3	60				
Head and neck+Upper limb (n=2)			2	100						
Head and neck+Lower limb (n=3)	2	66.7	1	33.3	1	33.3				
Chest+Abdomen (n=2)	1	50	1	50	1	50			1	50
Chest+Lower limb (n=1)									1	100
Abdomen+Lower limb (n=2)			2	100			2	100		
Upper limb+Lower limb (n=3)	1	33.3	1	33.3	1	33.3	1	33.3	1	33.3
Head and neck+Chest+Abdomen (n=1)			1	100						
Abdomen+Upper limb+Lower limb (n=1)					1	100	1	100		
P (Chi-square-exact test)	0.84[NS]		0.23[NS]		0.13[NS]		0.001		0.07[NS]	

Discussion:

To our knowledge this is the first Iraqi study on this subject and to this extent. It is shown by this study that the head and neck region was the most frequently affected body region by high velocity missile injuries in(50%)of the cases(table- 1-) as it is expected in the criminal cases examined in the medico-legal institute of Baghdad and due to the same cause more than one body regions are affected in majority of cases(table- 3-) There was no statistically significant mean difference in count of primary high velocity missile wounds between the 5 anatomical body regions, since the sample size was so small to reach the level of statistical significance,(table -2-).Chest region was the most affected by distant injuries due to shock wave followed by the abdomen (table- 4 -) and this could be due to the presence of lunges which are spongy in nature as they contain air and also due to the presence of the heart and great vessels in relation to chest region and to the presence of air and liquids in the intestine in relation to abdomen. The lest affected body sites are the lower and upper limbs due to the absence of spaces or spongy tissues in them. There was no statistically significant mean difference in count of distant lesions between the 5 anatomical body regions, since the sample size was so small to reach the level of statistical significance, as shown in table(5).If you compare table (3) to table (6), you will notice that the majority of subjects (63.3%) had only one body region affected by distant lesions.The association of main high velocity missile wound in a specified body region by distant lesion in the same or other body region is shown by table (7) in which the Interpretation of significance testing is difficult, because even when the difference or association is not significant statistically it is relevant clinically, simply the sample size was so small to allow statistically significant findings. For example only the association between the location of primary wound and the probability of having upper limb location of distant lesion was statistically significant here. We did not find in the available references a similar study (in relation to shockwave damage in high velocity missiles injuries) to compare this study with.

Conclusion:

Distant injuries away from the main track in high velocity missile injuries are very important and almost always present in all cases especially in the chest and abdomen and this should be put in the consideration on the part of the forensic pathologist and probably the general surgeon.

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