J Forensic Sci, Jul. 1974, Vol. 19, No. 3

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Casualty Criteria for Wounds from Firearms with Special Reference to Shot Penetration—Part II*

The authors have previously shown [*1*] that the casualty criterion for wounds from firearms, particularly the shot penetration, is given by the energy/area of presentation of the missile in question. The impact velocity must exceed that required for penetration of human skin. The threshold velocity for skin penetration by steel spheres is given [*2*] as 125–170 ft/s. Against this the energy criterion [*2–4*] alone (which is quoted between 40–100 ft-lb or 5.5–14 m-kg) is misleading and subject to forensic misuse. Likewise, it is imprecisely reported [*5,6*] that shotguns ordinarily have an effective range of 30–40 yd, ignoring the shot size in question. For forensic purposes, a missile is effective as long as it penetrates into the human body, irrespective of the accuracy of the ammunition. A 12-bore rifled slug is quoted [7] as having an extreme range of 800 yd, and American Eastern Buckshot 0 (equivalent to British shot size SG) a range of under 700 yards. "Whenever a Police weapon is used, the extreme range must be taken into account" [7]. It can be shown that an American Eastern Buckshot 000 (equivalent to British shot size LG) fired from a shotgun with a muzzle velocity of 800 ft/s will have sufficient wounding power (corresponding to energy/area of presentation = 3 m-kg/cm^2) even at a distance of ~200 yd and a threshold value for penetration into human skin at ~300 yd, *vide infra*. Obviously, it was of interest to evaluate experimentally the criteria for penetration of human skin by lead shot and the extent of this penetration further into human muscle as a function of energy/area of presentation, E/a, of the missile.

Experimental

Human adult cadaver samples of (thigh) muscle with skin intact were mounted in a frame, the cut sample fitting compactly into it. The skin was held taut by piercing safety pins on all sides and stretching it with twine passing through a corresponding row of eyelets on the board, on which the frame was fixed. This was necessary to simulate the human target; otherwise erratic results are obtained. The samples were relatively fresh, stored in a refrigerator freezer if necessary, thawed before use, and used within a few days of their availability. However, the limitations of simulating a natural human target

Received for publication 14 Oct. 1973; revised manuscript received 4 Dec. 1973; accepted for publication 3 Jan. 1974.

* Ref *1* may be considered as Part I of this series.

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must be borne in mind. It might appear that the above mounting of the samples may not necessarily simulate the human limb with the rigidity afforded by the femur. But looking to the agreement of our results with Pangher's data [*8*] (*vide infra*) it would appear that in the absence of a full limb, the present mounting is a fair approximation. Also, notwithstanding the variation of the samples as used from one experiment to another, the observed linear relationship between E/a and penetration shows that within the limits of experimental error, the various samples behaved similarly for the purpose in view and the manner of mounting and stretching was reproducible.

An electronic chronometer (ET 452A of Electronic Corporation of India) was used with contact start/stop screens at ~3-ft distance. The sample board was immediately behind the stop screen. The striking velocity is for all practical purposes the same as the measured velocity. The screens were modified from gate operation by opening normally closed contacts [*9*] to that by closing normally open contacts [*10*]. In the former arrangement the bullet passing through the contact screens breaks the circuit, while in the latter it momentarily establishes contact to enable counting of time.

One lead shot (American Eastern Buck Shot 000 ≡ British LG) was filled into a KF (Kirkee Factory, Indian Ordnance Factories) 0.38 revolver cartridge (replacing its own bullet) with adjustment of the propellant, if necessary, and pressing by hand for fixing the LG into the live cartridge case. The propellant in no case was less than 75 percent of the original (4 grains of cordite disks). The fired spherical shot bore land and groove marks and can be considered a spinning sphere. The penetrations recorded are those actually probed plus the diameter of the shot, that is, full penetration right through the sample.

Results

Results are compiled in Table 1 and graphically represented in Fig. 1. The threshold velocity of penetration into human skin of lead shot used here is in the range of ~200 ft/s. Despite their scatter, the 30 observations fall on a straight line plot, intersecting the E/a axis at ~1.25 m-kg/cm², which is the observed threshold value of E/a for penetration into human skin, and having a slope ~2.0 (that is, 2-cm penetration into human muscle for each 1.0 m-kg/cm², E/a, over and above the threshold value for skin penetration). The linear plot in Fig. 1 was obtained by least squares fit [*11*], namely:

$$\text{slope} = (nD - AB)/(nC - A^2)$$

and

$$\text{intercept on penetration axis} = (CB - AD)/(nC - A^2)$$

where

$$n = 30,$$

$$A = \sum_{i=1}^{30} (E/a)_i,$$

$$B = \sum_{i=1}^{30} (l_i),$$

$$C = \sum_{i=1}^{30} (E/a)_i^2, \text{ and}$$

$$D = \sum_{i=1}^{30} (E/a)_i l_i.$$

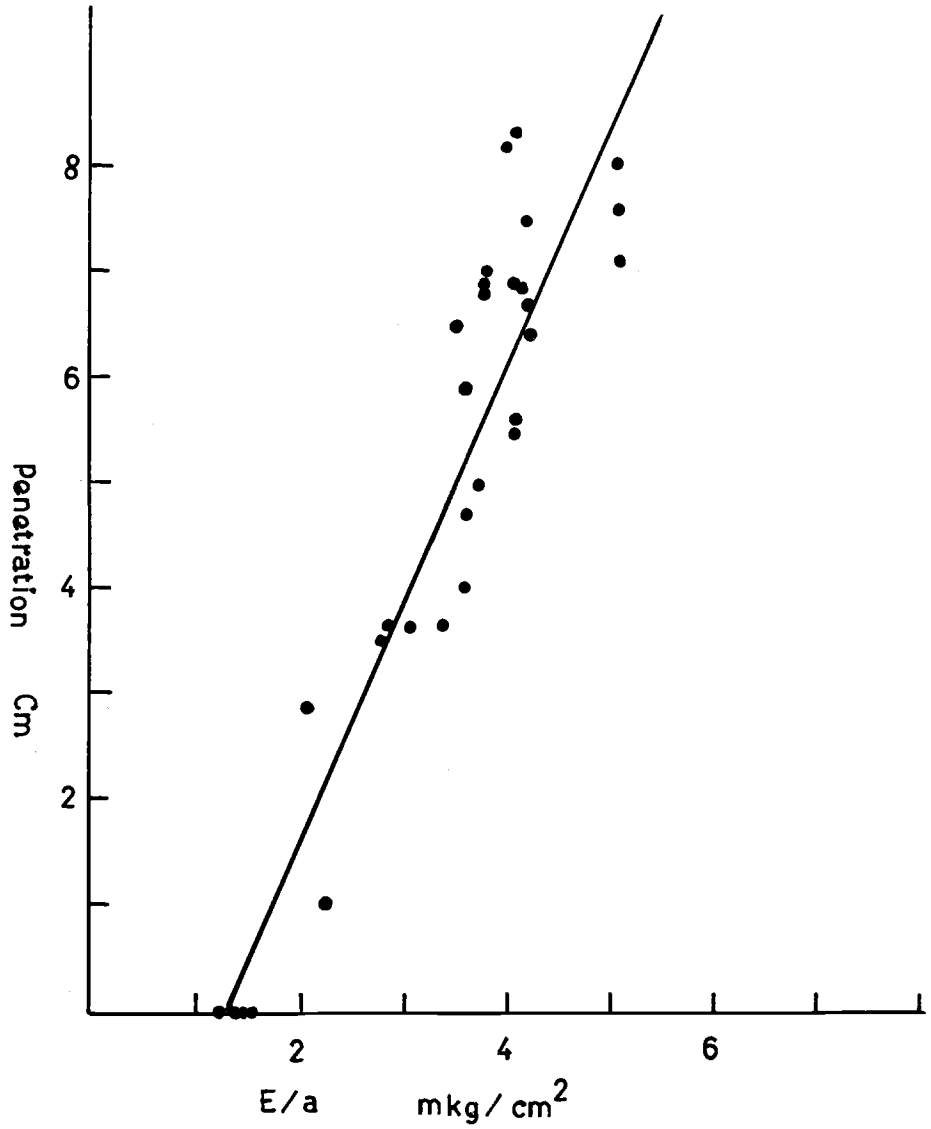

FIG. 1—*Graphical plot of penetration versus* E/a.

In these definitions

n = number of observations,
E = energy of the missile, m-kg,
a = area of presentation, cm^2, and
l = penetration, cm.

No corresponding values in the English literature are available for comparison. A reference to Pangher's data [*8*] has, however, been made by Chugh [*12*], which supports the results reported here.

TABLE 1—*Mass of lead shot fired = 4.5 g, diameter = 8.5 mm.*

No.	Velocity, ft/s	E/a, m-kg/cm^2	Penetration, cm
1	234	2.06	2.90
2	275	2.85	3.35
3	286	3.08	3.35
4	300	3.39	3.35
5	316	3.76	5.00
6	272	2.78	3.50
7	244	2.24	1.00
8	309	3.59	4.00
9	310	3.615	4.70
10	319	3.83	7.00
11	331	4.12	8.30
12	325	3.975	8.20
13	331	4.12	5.60
14	328	4.05	5.50
15	328	4.05	6.90
16	334	4.20	6.70
17	335	4.22	6.40
18	330	4.10	6.90
19	368	5.10	7.10
20	311	3.64	5.90
21	317	3.78	6.90
22	316	3.76	6.80
23	334	4.20	7.50
24	366	5.04	8.00
25	307	3.55	6.50
26	366	5.04	7.60
27	195	1.43	not penetrated
28	180	1.22	not penetrated
29	202	1.53	abrasion
30	193	1.40	not penetrated

n = 30 C = 392.04
A = 103.71 D = 592.03
B = 148.95

For explanation of symbols, see text.

Summary

Firing experiments with human cadaveric samples show that for lead shot the threshold velocity of penetration into human skin is ~200 ft/s, and the threshold E/a is 1.25 m-kg/cm^2. The muscle penetration is in accordance with ~2-cm penetration per 1.0 m-kg/cm^2, (E/a) over and above its threshold value for skin penetration.

Acknowledgment

The authors are very grateful to Dr. C. A. Franklin, Police Surgeon, Bombay for his excellent cooperation, without which this work would not have been possible.

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