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Comparison of Contact Shotgun Wounds of the Head Produced by Different Gauge Shotguns

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ABSTRACT: A series of 89 contact shotgun wounds of the head were evaluated to compare the extent of wounding produced by different gauge shotguns. Twelve gauge shotguns were the most common, accounting for 69% of the cases, followed by 20 gauge (18%), .410 caliber (10%), and 16 gauge (3%). The mouth was the most common entry site, used in 62% of cases. Comparison of contact intraoral shotgun wounds revealed statistically significant differences between 12 gauge and 20 gauge wounds. Whereas the extent of internal destruction was similar with both gauges, intraoral 12 gauge shotgun wounds caused bursting of the head with lacerations of the face, forehead, and scalp in 74% of cases, while only 9% of 20 gauge wounds produced a similar extent of external disruption. The external head remained fully intact in 55% of 20 gauge intraoral wounds. To account for the threshold effect for head bursting between 20 gauge and 12 gauge shotgun blasts, commercial shotshell and reloading data were analyzed. While there was considerable overlap between the two gauges, a common 12 gauge load would generate 50% more kinetic energy and 40% greater volume of gas than a common 20 gauge load. Comparison of shotgun blasts at entry sites outside of the mouth showed similar differences. Wounds from .410 shotguns were similar to those from 20 gauge weapons, and 16 gauge shotguns produced wounds intermediate between 20 and 12 gauge.

KEYWORDS: pathology and biology, firearms, contact shotgun wounds, wounding potential, autopsy, suicide

Contact shotgun wounds of the head represent some of the most devastating injuries seen in forensic pathology. This observation is well recognized by any experienced death investigator and is recounted in a journal report [*1*] and virtually all of the forensic pathology textbooks [*2,3*]. The standard textbook description is that contact shotgun wounds often cause bursting of the head and evisceration of the brain. While this is quite true, there appears to be no quantification of "often" and no accounting of how the bursting effect varies with different weapons.

With the prospect of closing this gap in the understanding of shotgun wounds, we reviewed a number of suicidal shotgun wounds of the head and evaluated the wounds with respect to the guns employed. The results of this evaluation, reported herein, show that there are significant differences in wounds caused by different gauge shotguns.

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Methods and Materials

Search of the King County Medical Examiner Office database yielded records for all cases of suicidal shotgun wounds of the head for years 1984 to mid-1994. For these cases, the investigator reports were reviewed to determine the manufacturer of the shotgun, its gauge, and the shot size. From the corresponding autopsy reports, body examination diagrams, or photographs from the case, the entry site and other details of the shotgun wounds were recorded. To simplify tabulation of the results, wounds of the scalp and temple were not separated according to side.

In order to compare wounds from different cases, a simple scheme was devised based on the level of skin lacerations associated with the wounds. The first level was the face. This included all skin structures, including nose and periorbital region, below the level of the supraorbital ridges. The second level was the forehead, constituting the region from the supraorbital ridges to the usual location of the hairline. The scalp was the third and highest level, which included all of the usual hair-bearing regions above the level of the ears. Perioral stretch lacerations, consisting of short linear lacerations radiating from the mouth, were recorded separately from other lacerations of the face.

Using this scheme of three levels, the external injuries of each shotgun wound were scored according to where lacerations appeared. For example, a wound with complete bursting of the head was scored as having lacerations in all three levels—face, forehead, and scalp. On the other hand, when the head remained intact, no lacerations were scored in any of the three levels. This method did not take into consideration the internal injuries, which, in fact, were quite similar from case to case and offered little differentiating value for comparing wounds.

Tests of significance were performed by the chi-square method.

Results

There were a total of 89 suicidal shotgun wounds of the head evaluated for this report, all of which were in essentially contact range. Over the period of review, this number represented 4.1% of all suicides and 8.5% of suicides by firearms. In the 89 cases reported here, the average age of the decedents was 45 years, with a range of 15 to 87 years and a median of 39 years. All but 2 of the decedents were male, and all but 3 were white Caucasians.

The manufacturers of the shotguns are shown in Table 1. The three top manufacturers, Remington, Winchester, and Harrington and Richardson, together accounted for 43% of the weapons used. There were no obvious differences in wounds produced by shotguns of the same gauge from different manufacturers.

Table 2 shows the sites of entry in relation to the gauge of the shotguns. Twelve gauge shotguns were by far the most frequent

TABLE 1—*Manufacturers of shotguns used in 89 suicides.*

Manufacturer	Number of Cases
Browning	3
Harrington and Richardson	10
Mossberg	6
New England Firearms	7
Remington	15
Sears	6
Stevens	9
Western Field	2
Winchester	13
Other, one case each	15
Unspecified	3

weapon and represented 69% of all cases. The second most common was 20 gauge, which accounted for 18%, followed by .410 caliber (10%). The least common was 16 gauge (3%). The mouth was the most common entry site, used in 62% of cases. The temple or scalp region, either right or left, and the submental region were essentially equally represented as the second most common entry sites (15% and 13%, respectively). Forehead and face were the least frequent entry sites.

A description of the shot size appeared in only 31 of the investigators' reports. In this group, 71% were probably with small shot, 23% with buck shot, and 6% with rifled slugs. Although the shot size did not appear in the reports with sufficient frequency to allow a meaningful correlation, it did not play a major role in influencing the appearance of the wound. However, in cases with buck shot, individual pellet exit wounds were likely to be present, which were not noted with smaller size shot. Exit wounds were also present in cases with rifled slugs.

Nearly all of the shotgun wounds showed similar internal features, consisting of extensive destruction of all bony and soft tissue structures in the path of the wound with frequent evisceration of brain and skull fragments. The major variable influencing the distribution of internal injuries was the site of entrance. Temple, forehead, and scalp wounds generally caused extensive fractures of the skull and maceration of brain but left the facial structures intact. In comparison, mouth and submental wounds destroyed facial structures in addition to the basal skull, calvarium, and brain.

Because internal injuries offered little differential value, these were not considered in any detail. On the other hand, there were considerable differences in the external injuries; hence, the pattern of skin lacerations provided the basis of comparing wounds from different shotguns.

Considering only the wounds in the mouth allowed a comparison between 12 gauge and 20 gauge shotguns. Twelve gauge shotguns produced 38 wounds entering in the mouth, and 20 gauge shotguns produced 11 intraoral wounds. Table 3 compares the differences in skin laceration patterns between these two gauges. Of the 12 gauge wounds entering the mouth, 28 (74%) caused bursting of the head that extended into the level of the scalp. However, of the 20 gauge mouth wounds, only 1 (9%) caused lacerations that reached the scalp. These differences are significant ($P < .001$). Conversely, the external head remained intact, with at most perioral lacerations, in only 3 cases of the 12 gauge wounds (8%), while 6 (55%) of the 20 gauge wounds left the external head intact. These results are also statistically significant ($P < .001$). Furthermore, fully 91% of the 20 gauge wounds caused lacerations no higher than the face, while only 16% of 12 gauge wounds had lacerations limited to the face. Regardless of the presence or absence of external injuries, all shotgun wounds in the mouth produced extensive internal destruction involving facial bones, basal skull, calvarium, and brain. Hence, the differences between wounds from 12 gauge and 20 gauge shotguns depended on whether or not the integument remained intact.

The three intraoral wounds with 16 gauge shotguns appeared intermediate between those of 12 gauge and 20 gauge shotguns. One of these caused no lacerations beyond the mouth, one caused face lacerations only, and one produced bursting with lacerations of face, forehead, and scalp.

Although the number of different gauge shotgun wounds at sites other than the mouth were not sufficient to allow a statistical comparison, there were apparent differences according to gauge. For the submental wounds, 12 gauge shotguns caused lacerations that extended to the forehead or scalp in 8 of 11 cases, while the sole 20 gauge submental wound had lacerations limited to the face. For wounds entering the forehead, scalp, or temple, 12 gauge shotguns produced extensive lacerations in all 11 cases, whereas similarly placed wounds from 20 gauge weapons had lacerations limited to the entrance site in 1 of 3 cases. Also in contrast to the 12 gauge wounds, 2 of 6 .410 shotgun wounds had lacerations limited to the entrance site. Overall, these data show that 12 gauge shotguns, on average, cause more extensive lacerations and a greater frequency of bursting of the head when compared to the smaller gauge weapons.

Perioral stretch lacerations were limited to intraoral wounds and were noted in 14 of the 55 shotgun wounds in the mouth (25%). This number likely represents an underestimate of the frequency because these usually small lacerations may not be described as a separate entity or they may be obscured by larger facial lacerations. Twelve cases with perioral laceration occurred with 12 gauge shotguns, one case occurred with a 20 gauge shotgun, and one occurred with a .410 shotgun.

Discussion

Previous studies have shown that approximately half of all suicidal shotgun wounds occur in the head [4,5]. In the current study,

TABLE 2—*Gauge of shotguns and sites of entry for 89 cases.*

	Number of cases at each entrance wound site				
Gauge	Mouth	Submental	Temple/Scalp	Forehead	Face
12	38	11	6	5	1
16	3	0	0	0	0
20	11	1	3	0	1
.410	3	0	4	2	0

TABLE 3—*Comparison of 12 and 20 gauge shotgun wounds in mouth—extent of lacerations.*

Level of Lacerations	12 gauge (N = 38)	20 gauge (N = 11)
No lacerations, or only perioral	8%	55%
Face lacerations, no higher	8%	36%
Forehead lacerations, no higher	10%	0%
Scalp lacerations	74%	9%

62% of the head wounds were in the mouth, compared to previously reported rates of 30% to 36% [4,5].

However, the objective of this study was not to analyze the distribution of entry sites but to correlate the extent of wounding with the gauge of the shotgun. The number of intraoral wounds allowed a statistical comparison between wounds from 12 gauge and 20 gauge shotguns. The results show that contact wounds from 12 gauge shotguns were much more likely to produce bursting of the head, while 20 gauge shotguns usually left the head relatively intact externally, even with essentially the same degree of internal injuries. Contact wounds from .410 shotguns were also less devastating than 12 gauge wounds, and the infrequent 16 gauge shotgun wounds were intermediate between 12 gauge and 20 gauge shotgun wounds. The differences among the wounds depended on whether or not the skin of the head remained intact. For most 20 gauge wounds, the elasticity of the skin accommodated the head expansion from the blast. In contrast, the discharge from 12 gauge shotguns usually caused expansion of the head that exceeded the skin's elastic limits. The threshold of this limit was somewhere between the blast effects of 20 gauge and 12 gauge shotguns.

Three components of a firearm's discharge influence the wounding effect at contact range: the mass of the projectile(s), the velocity of the projectile(s), and the volume of gas generated that is injected under pressure into the wound. The mass and velocity of the projectiles together determine the kinetic energy by the $E = \frac{1}{2} mv^2$ relationship. Table 4 shows features of commercial 12 and 20 gauge shotshells [6]. Although there is overlap between the gauges, 12 gauge shotshells have, on average, a greater mass of pellets and a slightly higher velocity. Taking data from this table for a typical 20 gauge field load of 1 oz and a typical 12 gauge load of 1.25 oz yields 1958 Joules of energy for the 20 gauge example, compared to 2918 Joules for the 12 gauge discharge.

The volumes of gases generated are somewhat more complicated to estimate. Table 4 shows some common commercial shotshell loads reported in the usual "dram equivalents" of gunpowder. However, this number is not necessarily proportional to the weight of gunpowder in the shotshell but expresses the equivalent amount of black powder that would be necessary to propel the mass of pellets at the specified velocity. Depending on the type of gunpowder, the "dram equivalents" could mean widely varying amounts of actual gunpowder used.

Table 5 is a compilation of the actual weights, in grains, of several brands of gunpowder used for reloading shotshells [7]. Immediately obvious are the large variations in different gunpowders used to achieve the desired velocities. These data further show considerable overlap between the two gauges, indicating that wounds from 20 gauge weapons could easily have characteristics identical to those from 12 gauge shotguns. Because of the overlap, however, the data are not helpful in comparing the volumes of gases discharged.

TABLE 5—*Reloading data for 20 and 12 gauge shotshells using several different brands of gunpowders.*[a]

Shot Ounces	Gunpowder Grains	Muzzle Velocity Feet/Second
	20 Gauge	
7/8	15.5–27.5	1205–1400
1	14.5–27.5	1080–1275
1 1/8	15.0–27.5	1070–1220
	12 Gauge	
1	16.0–28.0	1150–1395
1 1/8	18.5–34.5	1255–1395
1 1/4	17.5–38.0	1125–1390
1 3/8	23.5–37.5	1155–1320
1 1/2	23.5–44.5	1105–1320

[a]Data compiled from reference 7.

Additional reloading data for a single brand of gunpowder [8] are shown in Table 6. These data show that, with the same brand of gunpowder, there may be from 10% to 80% more gunpowder in the 12 gauge shotshells, compared to 20 gauge shotshells. For most double base gunpowders used in shotshells, the explosion of one gram of gunpowder generates approximately 0.04 moles of gases at temperatures of 3300° K or greater [9]. Using these figures and average gunpowder weights from Table 6 to compare a typical 1 oz 20 gauge load with a 1.25 oz 12 gauge load allows the calculation of 12 liters of gases generated from the 20 gauge discharge, compared to 17 liters from the 12 gauge.

Admittedly, these calculations are rough estimates based on data that show wide variations in gunpowder and shot loads. Nevertheless, they do demonstrate that a 12 gauge shotgun would commonly generate in the range of 50% more kinetic energy and 40% greater gas volume than a 20 gauge shotgun. These differences are apparently sufficient to exceed the threshold between 20 gauge and 12 gauge shotgun blasts for bursting of the head. Considering the magnitude of the forces involved, it is not surprising that bursting of the head is a feature of contact shotgun wounds. What seems truly remarkable is that the elasticity of the cranial integument in most cases can contain the pressure and energy from a 20 gauge shotgun discharge.

TABLE 4—*Commercial shotshell characteristics.*[a]

Shot Ounces	Gunpowder Dram Equivalents	Muzzle Velocity Feet/Second
	20 Gauge	
7/8	2 1/2	1210
1	2 3/4	1220
1 1/8	2 3/4	1175
	12 Gauge	
1	3 1/4	1290
1 1/8	3 1/4	1255
1 1/4	3 3/4	1330
1 1/2	3 3/4	1260
1 5/8	4	1250

[a]Data compiled from reference 6.

TABLE 6—*Reloading data for 20 and 12 gauge shotshells using IMR "Hi-Skor" 800-X gunpowder.*[a]

Shot Ounces	Gunpowder Grains	Muzzle Velocity Feet/Second
	20 Gauge	
7/8	16.8–18.0	1190–1215
1	16.5–20.0	1150–1230
1 1/8	17.0–19.0	1120–1180
	12 Gauge	
1 1/8	24.0–30.0	1200–1400
1 1/4	23.5–29.0	1210–1335
1 3/8	24.0–28.0	1200–1310
1 1/2	22.0–28.0	1090–1270

[a]Data compiled from reference 8.

In summary, this study has shown that there are significant differences between 12 gauge and 20 gauge contact shotgun wounds of the head. The larger gauge wounds usually result in bursting of the head, while the head usually remains intact with the smaller gauge weapons. The differences are understandable in terms of the kinetic energy of the shot as well as the volume of gas generated by the gunpowder explosion. However, there is substantial overlap of 12 gauge and 20 gauge shotshells, so it is quite possible that some 20 gauge wounds resemble 12 gauge wounds and vice versa.

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