

Evaluation of methods for the euthanasia of cattle in a foreign animal disease outbreak

Hugh J. Baker, Howard J. Scrimgeour

Abstract

In anticipation of the need to euthanize large numbers of cattle in the event of a foreign animal disease outbreak, two models of captive bolt gun and various firearms and ammunition loads were tested in order to assess their suitability. In the first phase of the project, two models of captive bolt stunner were used in an abattoir, and assessed for effectiveness. In the second phase, several firearms and ammunition were used on isolated bovine heads and assessed for effectiveness. Little difference was found between the two captive bolt stunners. Of the firearms and ammunition evaluated, the Ruger Mini-14 and the Core-Shot round, a prefragmented projectile, were determined to be most suitable. In situations where large herds of livestock are to be depopulated, and where the restraint required for the use of captive bolt stunners is not practical, there are commercially available firearms and ammunition that are suitable for this purpose.

Résumé

Évaluation des méthodes d'euthanasie chez les bovins victimes d'épidémie de maladies étrangères

Cette étude a été réalisée en prévision du besoin de procéder à l'euthanasie d'un grand nombre de bovins à la suite de l'apparition d'une épidémie de maladies étrangères. La première phase de l'étude comportait l'évaluation de l'efficacité de deux modèles de pistolets à percussion pouvant être utilisés dans un abattoir alors que la deuxième phase comportait l'évaluation de différentes armes à feu et de munitions utilisées sur des têtes de bovins isolés. Les auteurs ont trouvé peu de différences entre les deux modèles de pistolets à percussion utilisés à l'abattoir. Parmi les armes à feu et les munitions, le « Ruger Mini-14 » et le « Core-Shot », un projectile préfragmenté, ont été les plus performants. Les auteurs concluent que dans une situation où un grand nombre de troupeaux devraient être anéantis et qu'il ne serait pas pratique d'utiliser des méthodes de contention nécessaires lors de l'utilisation des pistolets à percussion, il existe des armes à feu commerciales et des munitions adéquates à cette fin.

(Traduit par Docteure Thérèse Lanthier)

Can Vet J 1995; 36: 160-165

Agriculture and Agri-Food Canada, Food Production and Inspection Branch, c/o 2 Tecumseth Street, Toronto, Ontario M5V 2R5 (Baker); 174 Stone Road West, Guelph, Ontario N1G 4S9 (Scrimgeour).

Reprints not available.

Introduction

Agriculture and Agri-Food Canada has formed Regional Emergency Response Teams (RERTs) in each of its six administrative regions (Atlantic, Quebec, Ontario, Mid-West, Alberta, and British Columbia), in preparation for a possible foreign animal disease (FAD) outbreak in Canada. Depending on the particular disease entity involved, depopulation of affected premises might be carried out to prevent further spread and, ultimately, to eradicate the disease. In the event of an outbreak, the RERTs would have responsibility for planning and carrying out the euthanasia and disposal of affected animals.

The 1984 RERT protocol for slaughter and disposal recommends the use of captive bolt stunners in the euthanasia of large animals affected with a foreign animal disease.

There has been some criticism of the captive bolt stunner for this purpose. Captive bolt stunners are used in abattoirs precisely because they do not cause immediate death of the animal (thus allowing cardiac function to aid in exsanguination). Since captive bolt stunners do not necessarily cause immediate death, questions arise about the humaneness of immediate burial after shooting. Except when a long bolt and a heavier load are used, captive bolt stunners give different penetrations for different thicknesses of skull bone. The need to closely approach each animal raises concern regarding the physical safety of the operator, and in some cases, exposure of the operator to the disease agent. The need for restraint of each animal requires a restraint chute and alleyways, which must be constructed on each affected farm, at a cost which may be in the thousands of dollars for each site. Movement of the animals through the restraint facility for individual euthanasia, and subsequent removal of the carcasses, requires numerous experienced handlers.

Methods that do not require close approach or individual restraint (i.e., firearms) may be appropriate for euthanasia of large numbers of mammals (1). Indeed, the avoidance of close approach and confinement of the animals can make the handling more humane (2). The Canadian Veterinary Medical Association (CVMA) has recently developed a policy on the use of firearms for euthanasia, which deals with restraint and points of aim (3). Similar guidelines have been published by other veterinary associations (1,4). However, little research has been done on the selection of appropriate firearms and calibers for this purpose, and most researchers have assumed that small numbers of animals will be shot at short range (5,6). We therefore conducted an evaluation of these factors with regard to cattle.

Materials and methods

The experiment was conducted in two phases. In phase I, the captive bolt gun (.25 caliber (cal) Stunner, Accles and Shelvoke, Birmingham, England) in use at a local

Table 1. Summary of firearms and ammunition evaluated

Firearm	Ammunition	Range	Number of heads
.22 caliber rifle, Ruger 10/22, with 4 × 15 scope	Remington .22LR standard velocity	25 m	1
	Remington .22LR high velocity	25 m	1
	Omark .22 shotshell	2 m 10 cm	1 1
.223 caliber rifle, Ruger Mini-14, iron sights	American Eagle .223 FMJ ammunition	25 m	2
	Core-Shot .223 prefragmented ammunition	25 m	2
.30-06 rifle, Remington Model 721	Gevelot .30-06 softnose	25 m	2
.410 gauge shotgun, El Faisan of Spain	#4 birdshot	1 m	1
	#6 birdshot	1 m	1
12 gauge shotgun, Remington 870 pump	Winchester 1 oz rifled slug	25 m	1
	Remington #7 1/2 birdshot	2 m	1
12 gauge shotgun, Velpa	1 1/4 oz rifled slug	25 m	1

FMJ: Full metal jacket
LR: Long rifle

slaughter plant was compared to a more powerful model (.25 cal Magnum Stunner, Accles and Shelvoke), which was provided to us by the manufacturer for evaluation.

In phase II, intact heads of steers and heifers slaughtered by the kosher method, thus preserving the integrity of the skull, were taken to a military small arms range. Single heads were placed on a sandbag resting on a wooden trestle at a height of 1 m. Each head was shot once, at a distance appropriate to the type of firearm and ammunition. In each case, rounds were fired from directly in front of the head, and aimed to penetrate through the frontal bone into the brain, as recommended in the CVMA protocol (3). We considered that this would be the orientation normally encountered during herd depopulations, as animals tend to orient toward activity that takes place nearby but outside their flight zone (2). Table 1 lists the firearms and ammunition that were evaluated. It should be noted that the second phase primarily evaluated the terminal ballistics of various types of ammunition. The selection of firearms does not much influence this, but will influence such factors as accuracy and perceived recoil. Following are brief descriptions of the captive bolt stunners and firearms.

.25 cal Stunner (Accles and Shelvoke)

Accles and Shelvoke's standard captive bolt stunner is in routine use at a packing plant in Ontario. It uses a

blank cartridge to propel a steel rod. When the device has been fired, the rod protrudes 12 cm.

.25 cal Magnum Stunner (Accles and Shelvoke)

This device is mechanically very similar to the company's standard unit, but it has a heavier breech, permitting the use of more powerful charges.

Ruger Model 10/22 (Sturm, Ruger and Company, Southport, Connecticut, USA)

This is a popular, well-constructed, semi-automatic rifle designed for .22 cal Long Rifle (.22LR) ammunition. It normally accepts a 10-round rotary magazine, although larger capacity magazines are available from third party manufacturers. Our test firearm was equipped with a 4 × 15 power telescopic sight. Some individuals in the meat packing industry believe that this caliber can be used for euthanasia.

Ruger Mini-14 (Sturm, Ruger and Company)

This is a popular and readily available small-caliber rifle, which is semi-automatic and gas-operated. It is chambered for the .223 Remington round (also known as 5.56 mm NATO). Magazines are available in 5, 10, 20 and 30 round capacities. Our test rifle was equipped with a rear aperture sight and a front blade sight, but it is capable of being fitted with a telescopic sight.

**.30-06 rifle, Remington Model 721
(Remington Arms Company, Inc.,
Wilmington, Delaware, USA)**

This is a bolt-action rifle, which was manufactured between 1948 and 1962. It is typical of many modern large-caliber hunting rifles.

.410 gauge shotgun (El Faisan, Eibar, Spain)

This is a single-shot break-action shotgun. While this obscure make was selected solely on the basis of availability, it is of a conventional design, and demonstrates the performance of the round. Firearms in this caliber are available from several manufacturers.

**Remington 870 12 gauge shotgun
(Remington Arms Company, Inc.)**

This is a popular pump-action shotgun, which is available in several models and gauges. The test firearm was a Remington 870 Express, chambered for 12 gauge and equipped with a 28 in smooth bore, an improved cylinder choke, and a vent rail and front bead for sighting. The standard magazine holds 4 rounds, although magazine extensions that can increase this to 8 rounds are available.

Velpa 12 gauge Over/Under Shotgun

This shotgun, manufactured in Finland, is a double-barrel, over/under design, with a full choke on the upper barrel and a cylinder choke on the lower. Information on the manufacturer could not be obtained, but the design is conventional, and similar models are available from various sources.

Brief descriptions of the ammunition used are as follows:

**Remington .22LR standard velocity
(Remington Arms Company, Inc.)**

This round fires a 40 grain lead bullet with a nominal muzzle velocity of 350 m/s. The designation "LR" denotes a casing 17 mm in length.

**Remington .22LR high velocity
(Remington Arms Company, Inc.)**

This round propels a 40 grain lead bullet with a nominal muzzle velocity of 382 m/s.

**CCI .22LR Shotshell
(Omark Industries, Lewiston, Idaho, USA)**

This round has a .22LR casing and a projectile consisting of a plastic capsule containing 1/15 oz of #12 birdshot. The round was developed for use in hunting small birds.

**American Eagle .223 FMJ ammunition (Federal
Cartridge Company, Anoka, Minnesota, USA)**

This round is a 55 grain, boat-tailed bullet with a full metal jacket (FMJ). Nominal muzzle velocity is 853 m/s.

**Core-Shot .223 prefragmented ammunition
(Buffalo Bullet Company, Whittier, California, USA)**

This round is another version of the prefragmented round originally demonstrated in the Glaser Safety Slug (Glaser Corporation, Foster City, California, USA) (7). The latter was developed as a police round, and was designed to minimize the risks associated with ricochet and over-penetration. Both Core-Shot and Glaser ammunition are available in various calibers. The Core-Shot round consists of a hollow-nosed, copper jacket, filled with fine

lead shot. It is designed to come apart on impact with a target, resulting in immediate "dumping" of energy.

**Gevelot SP-CEB .30-06 softnose
(Gevelot SA, Paris, France)**

This is designed for use by hunters. The 180 grain projectile consists of a lead core partially encased in a copper jacket, which leaves the lead exposed at the nose of the round to produce enhanced, controlled expansion. The manufacturer's designation SP-CEB stands for Soft Point, Controlled Expansion Bullet. Nominal muzzle velocity is 823 m/s.

**Remington .410 gauge #4 and #6 birdshot
(Remington Arms Company, Inc.)**

The Remington "Express" Extra Long Range that we used in our tests is a 2 1/2 in casing in .410 gauge with a maximum load of propellant and 1/2 oz of #4 or #6 birdshot. Birdshot rounds must be used at relatively close range, as the shot disperses over distance.

**Winchester Super-X 1 oz rifled slug
(Winchester Group, Olin Corporation, East Alton,
Illinois, USA)**

This round is a 12 gauge 2 3/4 in casing with a maximum load of propellant. The projectile in this round consists of a single, round-nosed, piece of lead. A shallow hollow at the tip facilitates expansion. Grooves around the sides of the round cause it to spin after leaving the barrel, conferring some aerodynamic stability. Nominal muzzle velocity is 488 m/s.

**Federal Magnum Hi-Shok Slug Magnum Hollow
Point (Federal Cartridge Company, Anoka,
Minnesota, USA)**

This round is similar to the Winchester Super-X round, but the projectile weighs 1 1/4 oz.

**Remington #7 1/2 Game Load
(Remington Arms Company, Inc.)**

This is a 12 gauge round with a 2 3/4 in case, loaded with 3 1/4 dram equivalent of powder and 1 oz of #7 1/2 birdshot.

Heads from both phases of the experiment were taken to the postmortem facility at the Ontario Veterinary College, Guelph. The entrance wound was examined; then heads were sagittally sectioned, using a bandsaw, and the amount of tissue destruction was assessed. Photographs were taken of the entrance wounds and of each sectioned head as a permanent record of observations.

An assessment was made of penetration, tissue damage, and ease of use.

Results

Standard Captive Bolt Gun

We found that the typical entrance wound in the skull had an oval or "figure-8" appearance, which seemed to imply that the bolt rebounds on initial impact before penetrating the skull.

Unconsciousness was readily achieved in all cases, although the depth of bolt penetration varied from 5 to 8 cm.

Magnum Stunner

Unconsciousness was readily achieved in all cases. The skull wound was perfectly round and clean. Penetration depth was variable, ranging from 4 to 10 cm.

Ruger Model 10/22 with Remington .22LR standard velocity

In each case, the round penetrated the skin cleanly, struck the frontal bone at an oblique angle, and deflected, lodging between the bone and dermis about 6 cm caudal to the entrance wound. An oval defect approximately 20 × 5 mm was created in the external plate of the frontal bone, and bone chips were knocked into the frontal sinus. The bullet fragmented, leaving small particles of lead around the rim of the fracture.

Accuracy was excellent, but penetration was totally unsatisfactory.

Ruger Model 10/22 with Remington .22LR high velocity

The bullet path was identical to the standard velocity round, but there was greater fragmentation. Particles of lead and fragments of jacket were scattered around the defect in the frontal bone, and into the frontal sinus. On one of the shots, a chip of bone 5 mm in diameter was knocked from the internal plate of the frontal bone and travelled 5 cm into the cerebrum. A few small fragments of lead were also found between the calvarial defect and the chip.

Accuracy was excellent, but penetration was inadequate.

Ruger 10/22 with CCI .22 Shotshell

At a range of 2 m, the round produced no visible effect. At a range of 10 cm, the round produced blackening of the hair and skin. On dissection, one of the pellets was found to have penetrated to the subcutaneous tissues. The remaining pellets were at various depths in the dermis.

Ruger Mini-14 with American Eagle .223 FMJ ammunition

At a range of 25 m, the rounds produced a clean, roughly circular entrance hole, and a corresponding hole in the internal plate of the frontal bone. Disruption of the brain was extensive. The internal plate of the frontal bone was ruptured laterally, and brain tissue was ejected into the caudal part of the frontal sinus on both sides. The squamous part of the occipital bone was extensively fractured. In one of the test shots, the round was found in the subcutaneous tissue of the occiput as a 2 cm diameter mass comprised of fragments of lead, jacket, and bone.

Accuracy was excellent, but the round showed considerable potential for overpenetration.

Ruger Mini-14 with Core-Shot .223 prefragmented ammunition

At a range of 25 m, the rounds produced a skin wound that appeared only slightly larger than the .223 FMJ round. However, there was an irregular, roughly circular, defect in the external plate of the frontal bone, 3 cm in diameter, with fracturing of the surrounding bone; on one head, a fracture line radiated caudally for 9 cm. On each head, there was a 2 cm defect in the internal plate. Fragments of jacket and lead shot were found in the frontal sinus and throughout the brain. The occiput was intact.

Accuracy was excellent, as were penetration and destruction of the brain.

.30-06 rifle, Remington Model 721 with Gevelot SP-CEB .30-06 softnose

Two heads were tested with this ammunition. One round struck slightly rostral, in the caudal half of the

nasal bone. A large oval defect was produced in the frontal bone, and there was total destruction of the nasal turbinates. Fragments of lead and jacket were found in the caudal nasal passage as far as the cribriform plate, but the plate itself was not fractured or penetrated. The second shot was more accurate, and shattered the right side of the internal plate of the frontal bone, leaving fragments of bone and jacket near the occipital bone.

.410 gauge shotgun, El Faisan with Remington #4 and #6 birdshot

At a range of 30 cm, the round produced a ragged defect 2.5 × 4 cm in the external plate of the frontal bone. There was a corresponding defect in the internal plate, and shot was scattered throughout the brain. Performance was identical for the two sizes of shot.

Accuracy was easily achieved because of the short range involved, and brain damage was excellent.

Remington 870 12 gauge Shotgun with Winchester Super-X 1 oz rifled slug

Recoil with the solid slug is considerable. The projectile passed through the nasal passage and lodged against the basisphenoid bone. The projectile disintegrated on impact, leaving pieces of lead of various sizes, mostly near the end of the track.

Velpa 12 gauge Over/Under Shotgun with Federal Magnum Hi-Shok 1 1/4 oz slug round

Results were similar to those obtained with the Remington 870 and 1 oz slug.

Remington 870 with Remington #7 1/2 Game Load

At a range of 2 m, this round produced a defect roughly 5 cm in diameter in the frontal bone. There was extensive fracturing of the occipital bone with displacement of the fragments.

Discussion

In assessing the suitability of the various rounds and firearms for use during a foreign animal disease eradication, it was considered that three objectives must be met.

First, euthanasia must be humane. Not only are humane considerations important to regulatory veterinarians in their own right, but depopulation during a foreign animal disease outbreak can be expected to attract considerable media attention and public scrutiny. We felt that this required that the brain be hit and that sufficient damage be done to result in instant death. To achieve this, the firearm must have sufficient accuracy to permit a moderately skilled operator to fire a 10 cm group, and the round must have sufficient power to penetrate into the brain and extensively damage the brain tissue.

Second, the round must not over-penetrate. A projectile which exits from the skull may strike and injure another animal behind the first, which is unacceptable for humane reasons. Such a projectile may also ricochet, posing a hazard to operators, bystanders, and people at a considerable distance from the site. An exiting projectile will also scatter potentially infectious material.

Finally, the firearm must be comfortable to use for extended periods, mechanically reliable, and easy to reload.

Standard captive bolt stunner

While the captive bolt stunner should be in solid contact with the skull when fired, this is not always possible, as the animal frequently moves its head. Proper placement of the stunner and timing of the shot require considerable skill and experience on the part of the operator.

The operator at the abattoir we visited uses four captive bolt stunners at his station, rotating among them after 10 shots or so, to reduce overheating. This would be awkward under field conditions, since a rack of some sort would be required.

Magnum stunner

The operator reported that perceived recoil was higher with the heavier load, and that heating of the breech area was noticeably greater. The shape of the entrance wound suggested that more reliable penetration had occurred.

Performance of the magnum stunner was not much different from that of the regular stunner under our test conditions, although differences in performance might become more apparent in animals with thicker frontal bones, such as large bulls.

Although both of the captive bolt guns tested produced immediate and lasting unconsciousness, their use requires close restraint of each animal, with its attendant costs and hazards.

Ruger Model 10/22 with Remington .22LR standard velocity

Because the projectile deflects from the outer plate of the frontal bone, there is no mechanism for energy transfer to the brain. This round would produce a painful wound without causing unconsciousness.

Ruger Model 10/22 with Remington .22LR high velocity

Since the projectile deflects on impact with the outer plate of the frontal bone, energy transfer is inadequate. The penetrating bone chip on one of the shots was considered fortuitous. Furthermore, while penetration of this chip might have caused unconsciousness in a living animal, it could not have been depended on to do so.

Ruger 10/22 with CCI .22 Shotshell

Even at close range, pellets failed to penetrate the skin. This round is totally unsatisfactory for the purpose.

Ruger Mini-14 with Core-Shot .223 prefragmented ammunition

The round evidently began to fragment on contact with the external plate of the frontal bone, dissipating some of its energy between that and the internal plate, which permitted brain penetration without overpenetration. The disaggregation of the shot assured widely distributed tissue disruption.

.30-06 rifle, Remington Model 721 with Gevelot SP-CEB .30-06 softnose

While the rifle is theoretically capable of sufficient accuracy, either improper sight adjustment or operator error resulted in poorly placed shots, which made direct comparison of penetrations difficult. The rounds did not over-penetrate, and the round that struck the brain did sufficient damage. This result emphasizes the importance of operator skill to ensure correct bullet placement. The rifle has considerable recoil, and could be unpleasant to fire for an extended period.

.410 gauge shotgun, El Faisan with Remington #4 and #6 birdshot

This shotgun caused sufficient brain damage and had a mild recoil. However, when shot is used for euthanasia, it must be used at close range to prevent excessive dispersion of the shot before impact. In addition, this shotgun must be reloaded after every shot. It therefore offers only slight benefit over a captive bolt gun.

Remington 870 12 gauge Shotgun with Winchester Super-X 1 oz rifled slug

At ranges of 25 m, the rail sighting system is not sufficiently accurate. Although the slug failed to penetrate the brain, the round is quite powerful, and the shockwave from impact would likely have been sufficient to produce unconsciousness. The recoil is sufficiently unpleasant that an operator could not reasonably be expected to euthanize large numbers of animals with this firearm.

Remington 870 with Remington #7 1/2 Game Load

Accuracy is readily achieved at this range, and brain destruction is total, but the round is much more powerful than required, and the short range confers little advantage over the captive bolt stunner.

Conclusion

The best results were obtained with the Ruger Mini-14 using the .223 Core-Shot round. Due to the complexity of manufacture of these prefragmented rounds, the ammunition usually costs about three times as much as conventional rounds, but the added cost may be justified by the desirable terminal ballistics and the reduced risk of ricochet.

Recoil is relatively low with the .223 rounds compared to the larger calibers, so operator fatigue is minimized. A moderately experienced operator can achieve the required accuracy with iron sights, although a telescopic sight may be helpful.

The rifle currently in use by the Canadian Armed Forces, the C-7 (Diemaco, Kitchener, Ontario), is chambered for the same .223 in (5.56 mm) round. The Canadian Armed Forces may therefore be able to serve as a source of both firearms and marksmen in the event of a major outbreak.

It should be noted that the standard .223 military round is the 5.56 mm Penetrator M855 round (Olin Corporation, East Alton, Illinois, USA), which contains a steel core to enhance penetration of hard targets. Based on the performance of the .223 FMJ round that we evaluated, military ammunition is likely to overpenetrate.

Results with the 12 gauge slug and .30-06 rounds indicate that, in order to ensure brain penetration, the round must pass through the internal and external plates of the frontal bone, which are fairly thin. Rounds placed too low strike the cribriform plate or the presphenoid bone, which are thick enough to stop them.

As correct placement of rounds is crucial, it is important that operators selected for this task demonstrate the ability to consistently group under 10 cm at working distances.

As even skilled operators will occasionally place a poor shot, particularly on a target that may move as the operator fires, it is important for humane reasons to be able to place a second shot accurately and quickly.

Recent federal regulations have limited magazine capacities for center-fire semi-automatic rifles to 5 rounds, which may hamper operations. However, a skilled operator should be able to change magazines in under 3 s, so this requirement should result in only slight, albeit frequent, delays.

Additional regulations or Orders in Council may restrict or prohibit the possession of various firearms and types of ammunition, without prior warning and based on criteria that are often obscure. This too must be taken into account when selecting loads for euthanasia.

The ability to euthanize animals from a distance of 25 m makes it feasible to place the animals in a fenced enclosure or, if the animals are to be disposed of by burial, to prepare a burial pit with a ramped entrance on one side. In either case, care must be taken in the selection of a backstop and firing point to ensure that any round that misses or overpenetrates will strike soft earth in a short distance and, therefore, not pose a hazard.

One of us (HJB) has had the opportunity to observe the use of firearms in depopulations and has found, contrary to expectation, that domesticated or semidomesticated animals do not flee from the sound of the shot. The use of a suppressor might reduce agitation among the animals, and would certainly be beneficial in protecting the hearing of the operator; however, the possession of such devices is prohibited in Canada.

Acknowledgments

We thank Capt. R. Cunningham of the Department of National Defense for the use of the department's small arms range; the Ontario Veterinary College, University of Guelph, for the use of its postmortem facility; and Mr. Kevin Dockery for reviewing the firearms information and for technical assistance. CVJ

Glossary

The field of firearms design and manufacture, like that of veterinary medicine, has its own specialized vocabulary. Following are some of the terms and abbreviations used in this article.

Caliber: The internal diameter of the barrel. This is sometimes expressed in millimeters and sometimes in fractions of an inch. In the latter case, the value may be expressed as a numerical value alone, or followed by the abbreviation for caliber, for example .22 cal.

Charge: The quantity of propellant contained in a round. This is usually measured in grains. One grain equals 64.7989 mg.

Choke: A constriction of the last few inches of the bore of a shotgun for the purpose of retarding the spread of shot. The terms cylinder, improved cylinder, modified, and full denote progressively increasing constrictions.

FMJ: Full metal jacket, a designation indicating that the jacket covers the entire bullet, as opposed to "soft nose", in which the lead core is exposed at the point.

Jacket: a layer of metal alloy applied to the outside of a lead bullet. This serves to prevent the buildup of lead in the barrel, and to control or prevent the deformation or fragmentation of the bullet on impact.

Group: If several rounds are fired at a target in succession while aiming at a single point, the points of impact are termed a group. If the sights are adjusted correctly, the group should be centered on the point of aim. The diameter of the group depends, among other things, on the inherent accuracy of the firearm and the skill of the operator.

Load: The charge, bullet type, and bullet weight to achieve a given velocity and energy level.

Muzzle: The extreme front end of the barrel, from which the projectiles emerge.

Muzzle velocity: The velocity at which projectiles are travelling at the moment they emerge from the muzzle. As this is the maximum velocity attained by the projectile, it is a convenient point of reference. This velocity depends on the charge, the mass of the bullet, and the length of the barrel. Ammunition manufacturers publish tables giving the average muzzle velocity of their ammunition when fired from a test barrel of a specified length. This is the "nominal" muzzle velocity, because the velocity actually obtained when using this ammunition with a particular firearm invariably deviates to some extent from this test value.

Overpenetration: The penetration of the bullet beyond the target.

Rifle: A firearm whose bore bears a series of spiral grooves, termed rifling, which serve to impart a spin to the projectile (see shotgun).

Round: The fundamental unit of ammunition, consisting of a casing, a primer, a quantity of propellant, and a projectile. A shotgun round may contain multiple projectiles.

Shotgun: A firearm with a smooth bore (see rifle). It may fire a single projectile, termed a slug; multiple large projectiles, termed buckshot; or multiple small projectiles, termed birdshot.

Suppressor: A device that attaches to the muzzle of a firearm and contains a series of baffles or expansion chambers. It serves to reduce the noise of firing by reducing the velocity of the propellant gas that emerges from the barrel behind the bullet. Sometimes referred to as a silencer.

References

1. American Veterinary Medical Association. Report of the AVMA panel on euthanasia. *J Am Vet Med Assoc* 1993; 202: 229-249.
2. Grandin T. Recommended animal handling guidelines for meat packers. Washington: American Meat Institute, 1991.
3. Longair J, Finley GG, Laniel M-A, *et al*. Guidelines to euthanasia of domestic animals by shooting. *Can Vet J* 1991; 32: 724-726.
4. Australian Veterinary Association. Guidelines on humane slaughter and euthanasia. *Aust Vet J* 1987; 84: 4-7.
5. Dodd K. Humane euthanasia I, shooting a horse. *Irish Vet J* 1985; 39: 150-151.
6. Blackmore DK. Energy requirements for the penetration of heads of domestic stock and the development of a multiple projectile. *Vet Rec* 1985; 116: 36-40.
7. Sanow E. Glaser safety slug. *Petersen's Handguns* 1989; 3(3, May): 44-45.