

How to use a penetrating captive bolt gun

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Introduction

Ownership of penetrating captive bolt guns for euthanasia of livestock is increasing among Australian farmers. This is because they are considered safer and have fewer restrictions than firearms, cheaper models are now readily available and animal welfare guidelines restrict use of traditional methods such as blunt trauma and cutting the throat.

Because more farmers may seek advice from veterinarians on which type to purchase for their operation and how to use them, the purpose of this paper is to provide some information on how to choose and use penetrating captive bolt guns for euthanasia of farm livestock.

From here on, the terms captive bolts and captive bolt guns refers to penetrating captive bolt guns designed to penetrate the skull. Not discussed are non-penetrating captive bolt guns where the bolt has a mushroom-shaped end designed to only strike the outside of the skull and render the animal unconscious rather than kill it.

Captive bolts versus firearms

A captive bolt gun is like a rifle or a pistol except that it uses blanks to propel a retractable bolt rather than bullets. Although still dangerous, they are considerably safer than rifles and pistols. The requirement for close approach of the animal is the important disadvantage of captive bolts compared to rifles and pistols. Close approach within the animal's flight distance usually comes with the requirement for restraint of the animal and its head for operator safety and proper placement of the shot.

Unlike firearms, a licence is not required to own or operate a captive bolt except in WA and Tasmania, nor are there special storage conditions for the gun or the blank rounds. It has been a common misconception among farmers and veterinarians in the non-licence-requiring states that captive bolt guns require a licence. As awareness increases, farmers in the non-licence requiring states are opting for captive bolts over rifles because of the reduced restrictions. They enjoy the freedom of carrying them in their vehicles making them readily accessible should animals require prompt euthanasia.

Concerns that captive bolts only stun animals and require follow-up methods has been another important disadvantage of captive bolts. The general recommendation that bleeding-out or pithing must be used to complete euthanasia makes busy, cost-conscious farmers unwilling to swap their rifle for a captive bolt despite safety and licensing advantages. However there is increasing awareness that when used properly, especially with careful shot placement, captive bolts can be the sole method to achieve euthanasia without the need for bleeding or pithing.^{2,3}

Currently in the animal welfare standards and guidelines, it is a guideline, not a standard, that a follow-up method such as bleeding-out is used, hence follow-up methods are not mandatory. What is mandatory is to ensure the method used results in rapid loss of consciousness followed by death while unconscious and action is taken to ensure the animal is dead.⁴

How do they work?

Penetrating captive bolt guns are pressed firmly against the skull and a trigger pull actuates a firing pin igniting a blank round, driving a heavy rod-shaped steel bolt with a concave penetrating-end through the skull, into the brain. In most models, including the Blitz Kerner .38, the Cash Special .22 and the Matador SS 3000, the bolt penetrates a short distance, about 55 mm, until a recuperating system of springs or rubber washers causes the bolt to recoil back into the barrel of the gun. In one model, the Schermer KR, the bolt penetrates up to 85 mm and the bolt must be manually pushed back into the barrel.

The end of the bolt is recessed to maximise concussion and disruption of brain function. There is some direct physical damage from the bolt but most physical and functional disruption is believed to be caused by the shockwave from the end of the bolt striking the skull followed by the massive increase in intracranial pressure as the bolt enters the skull at high velocity. Unconsciousness is believed to be due to disruption of cerebral cortex function; death is believed to be the result of disruption to the function of the brainstem.

Disruption of the brainstem is critical for death to occur. The shockwave and increase in pressure must affect the brainstem. This requires the bolt to be of suitable diameter and the penetrating end to be directed at high velocity at the brainstem. High velocity of the bolt requires the correct strength blanks being used to propel the bolt, and the bolt and its supporting washers and springs within the gun being free of velocity-reducing corrosion and carbon deposits. For the bolt to be directed at the brainstem depends on the correct anatomical landmarks and direction of aim to be known and used, the animal and its head being still, and any parallax error to be corrected for.

How should captive bolts be used?

In the author's experience, penetrating captive bolt guns are a safe and effective sole method for euthanasia of farm livestock as long as one is set-up-for-success in a series of critically important areas:

1. the animals must be well restrained,
2. operators must know the correct anatomical landmarks and how to confidently handle and operate the captive bolt.
3. captive bolts must be well maintained so that the velocity of the bolt is not slowed by corrosion or carbon build-up in the barrel.
4. the correct strength blanks must be used appropriate to the size of the animal (the blanks for each model of captive bolt are colour-coded according to the amount of propellant in them. The manufacturers' recommendations on the colour-code for the size of the animal must be followed.)
5. the blanks must have been stored properly so the propellant doesn't deteriorate.

From this list one can see there is considerable margin for error hence it is also critical to know what to do if the shot goes wrong and how to confirm the death. To just give a captive bolt gun to a farmer without providing some basic instructions is likely to create a bad experience and give an undeserved bad reputation to a tool that is potentially very useful.

Anatomical landmarks

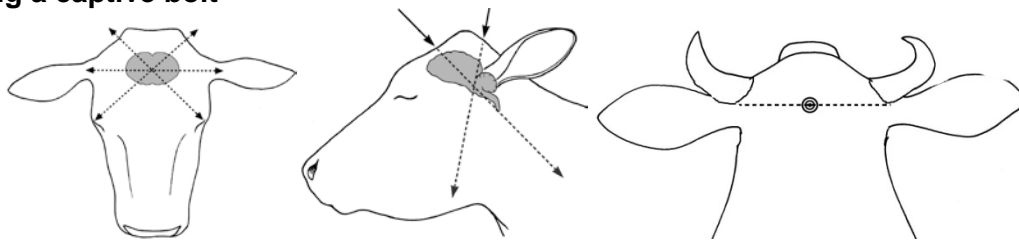
Most critical is the placement of a well-directed shot appropriate for the species and its size if follow-up methods are to be avoided. The most consistently effective killing shots are those directed at the brainstem which in most species lies between the ears. This applies to frontal shots, poll shots and behind the ear shots – they should be directed at the brainstem.

In cattle, sheep, goats and pigs the brainstem consistently lies between the ears, or more specifically, between the ear canals which are usually at the base of the ears. This appears to be true regardless of age, size or shape of the head and hugely simplifies describing to farmers where to shoot and in which direction. For veterinarians, targets are easy to remember regardless of species encountered.

Cattle

In cattle, the target for frontal shots is the midline of the forehead on an imaginary horizontal line drawn between the base of the ears (Figure 1). This matches the intersection of imaginary lines from the lateral canthus of the eye to the opposite side horn-base which has been shown to be a better target than the intersection of lines drawn from the medial canthus to the base of the opposite horns.²

Figure 1: Schematic diagrams of bovine head showing anatomical landmarks for using a captive bolt



There is a natural tendency when using the frontal shot to aim too low. Even a slight lowering of the frontal shot from the recommended target above results in a greater depth of bone and sinus having to be penetrated by the bolt (reducing its velocity) and the shockwave not being directed at the brainstem. This may be the explanation for the poor results of Appelt and Sperry¹ where five of 12 cattle were not killed by a penetrating captive bolt shot administered low on the forehead. This tendency to shoot too low occurs even among experienced captive bolt users, usually when concentration lapses.

Some operators recommend that frontal shots in bulls should be slightly off centre because the bone is thinner either side of centre. This is incorrect as there is no thicker ridge of bone running vertically down the middle of the forehead of bulls. Frontal bones thicken and sinuses enlarge with increasing distance from the midline in both sexes of cattle, sheep, goats and pigs.

The poll shot in cattle should enter a point in the middle of a horizontal line drawn between the base of the horns (or where they were or should be) (Figure 1). The direction of aim should be down, midway between the ears. This is in the vicinity of the base of the tongue which has sometimes been the recommended direction of aim for poll shots in ruminants.

Poll shots aimed at the nose have been recommended but these will completely miss the brainstem. Such shots will usually stun the animal but not always kill it. Nose-directed poll shots have been used for sampling brains of animals for Transmissible Spongiform Encephalopathy surveillance programs to preserve the brainstem for laboratory examination. Follow-up bleeding of the stunned animal is required.

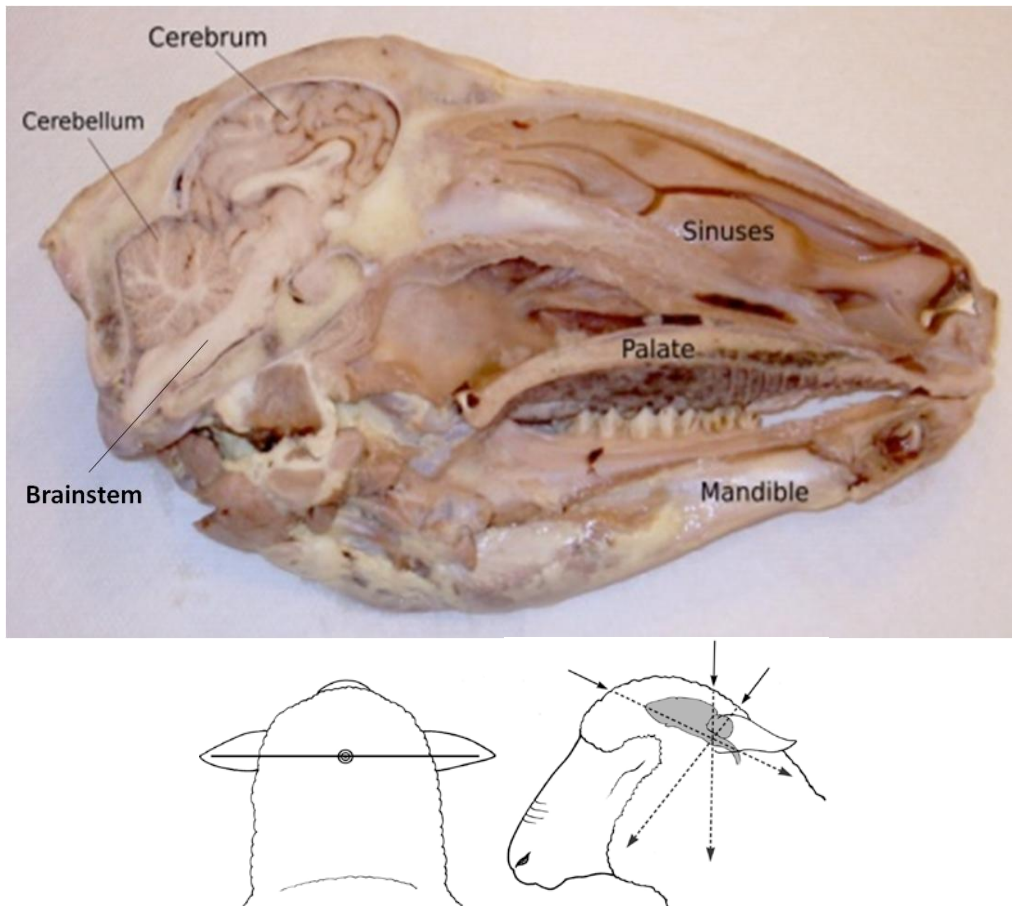
Because the depth of penetration of captive bolts is usually relatively shallow, the frontal shot is preferred in larger cattle. The poll shot should be limited to where frontal shots are awkward or where cattle are best approached from behind such as a downer cow in a pen with the head in the corner.

Temporal shots aimed between the eye and ear canal have sometimes been recommended. They simply don't work with captive bolts or firearms, even heavy calibre firearms. The zygomatic arch and ramus of the mandible shield the cranium in this area, slowing bolts and deflecting bullets, and the depth from the skin surface to the inside of the cranium in the temporal region is considerable, usually beyond the depth most bolts can penetrate.

Sheep and goats

The remarkable feature of sheep and goats is how far caudally positioned are the base of the ears and brainstem compared to other species (Figure 2). This makes the poll shot the preferred shot in sheep goats and explains why the frontal shot has a reputation for being inconsistent. The poll shot is however not a typical poll shot – it is probably best described as a nape-of-the-neck shot because of how far the ears (and brainstem) are positioned caudally.

Figure 2: Picture showing the very caudal location of the brainstem in the ovine skull and schematic diagrams of the ovine head showing anatomical landmarks for using a captive bolt



Crown shots aiming vertically downward have sometimes been recommended for sheep and goats. Unless directed between the ears, these will miss the brainstem. In some male and/or horned sheep and goats, the crown area has very thick bone and fibrous tissue which can be difficult to penetrate.

The skull and fibrous tissue overlying the more caudally positioned brainstem between the ears in sheep and goats is considerably less than over the crown and much more

easily penetrated. The author believes that frontal and crown shots should be discouraged in sheep and goats and only the poll shot, directed between the ears, should be recommended.

Pigs

For pigs the recommended target for the frontal shot has often been a specific distance such as one or two finger-width's above the middle of a line drawn between the eyes. The problem with this approach is the considerable variability in size and shape of pigs' heads. As with the brainstem in cattle, sheep and goats, the brainstem of pigs lies between the ear canals so a frontal shot directed between the base of the ears is most likely to give consistently good results. Because the ears of some pigs are so large, care has to be taken to judge the base of the ears to ensure the shot is correctly placed.

Because most pig breeds usually have such thick necks running into the crown of the head, poll shots won't work well. However, a back-of-the ear shot aimed diagonally across to a point just forward of the base of the opposite ear will pass through the brainstem. This is a useful follow-up shot in pigs that are down and laterally recumbent from a frontal shot.

Early signs of effective and ineffective shots

A consistent indication of a successful killing shot is the series of events of immediate collapse followed by rigidity (generalised muscle contractions), followed by muscle relaxation and periodic bouts of reflex kicking and development of a glazed appearance of the eyes.³ If there are deliberate attempts to rise, vocalization, blinking or breathing, the animal is still alive³ and the animal must be shot again or bled or pithed.

In adult cattle, the duration of rigidity is usually 10 to 20 seconds with a good shot. Relaxation follows and reflex kicking of the hind legs is intermittent over the next 3 to 4 minutes. This makes it very dangerous for people applying ropes or chains to the hind legs to remove the carcass. In neonates, the reflex kicking of the hind legs is sometimes violent and prolonged.

The kicking movements of the hind legs is presumed to occur because the dying brainstem prevents central nervous system control over the hind limb reflexes. There is also a phase of hyperexcitability of muscles and nerves as they are deprived of oxygen and die. Grabbing the legs to put a rope or chain on invariably stimulates a period of reflex kicking. The kicking is not an indication that the animal is still alive but rather, the animal is dying, a fact that should be explained to onlookers.

An animal that is conscious after an unsuccessful attempt to kill it, may after collapse, raise its head, blink, look around, try to stand or vocalise. These deliberate attempts to move are signs the animal is conscious. It is a matter of urgency to repeat the shot correctly as soon as possible. Unconscious animals if they don't die, eventually breathe. Breathing is the all important sign to look for.

Follow-up methods

Follow-up methods are necessary if the captive bolt shot doesn't instigate the cycle of collapse -> rigidity-> relaxation->kicking or if the animal continues to breathe, blink, vocalise or try to stand up.³ The choice of follow-up methods for farmers is limited to repeating the shot, bleeding out, or pithing. It is the author's view that bleeding or pithing is unlikely to be implemented by many farmers for a range of reasons including aesthetics or absence of an adequate knife or pithing instrument.

For example, bleeding by neck cut requires a sharp knife, it is particularly confronting for many people, it causes heavy blood loss lasting up to two minutes, the large amount of blood spilled is messy, animals smelling the blood become agitated, in diseased animals there is the potential risk of spreading pathogens in the spilt blood, and the knackery may refuse to remove the carcass because of knife damage to the skin.

Pithing is where the brain and brainstem are physically disrupted using an instrument such as a long screw driver passed through the hole made by the penetrating captive bolt after the animal has been rendered unconscious. It sometimes stimulates a transient but violent kicking reaction and a disturbing rolling of the eyes, even if the animal is dead. It can be difficult to perform if the animal is moving.

The cause of an ineffective shot can determine the follow up method. Most causes fall into the two main categories of misdirected shots or inadequate bolt velocity. The main causes of misdirected shots are head movement because of inadequate restraint, and parallax error, usually from awkward positioning of animal or operator or ignorance of the correct anatomical landmarks. The main causes of inadequate bolt velocity are deterioration of propellant in poor storage conditions; carbon build-up around the seat of the bolt near the cartridge chamber, or selection of under strength blanks.

The only practical and legal option for farmers if bleeding or pithing can't or won't be performed is to repeat the shot. However, repeating the shot can only be effective if the first shot was misdirected. Repeating the shot will be ineffective if there are problems with the gun or the blanks (the inadequate bolt velocity problems mentioned above). Hence the importance of impressing upon farmers that if cutting throats or pithing are to be avoided, the gun and blanks must be properly cared for.

Repeat shots

Repeat shots should be administered by concentrating on correcting the position and angle of the shot if a misdirected shot is suspected. The same hole must not be used. Some operators recommend plugging the first hole with a finger to achieve maximum intracranial pressure with the repeat shot.

If a frontal shot was first administered, the second shot should be a poll shot, or in pigs, a behind-the-ear shot. If a frontal shot is repeated, it is recommended the point of entry be slightly higher and off to one side than the first shot, but still directed between the ears where the brainstem lies.

Some operators perform a repeat shot routinely but this can be costly if the blanks are expensive and increases repair and maintenance requirements. Most experienced operators only repeat the shot if there is doubt the first shot has been effective. It is recommended that a suitable knife or pithing instrument is always at hand in case the captive bolt or blanks fail.

Confirming death

The aim is to create brainstem death where reflexes with pathways through the brainstem are shutdown. The brainstem is the base of the brain connecting the spinal cord with the cerebrum, cerebellum and midbrain. Animals with brainstem death lack eye reflexes, tongue, jaw and ear muscle tone, and don't breathe.

Asking farmers to use heart beat as a sign of death would be unreasonable. A weak, fast heart beat is difficult to see, feel or hear especially with well conditioned animals or with background noise of wind or machinery. And it doesn't mean much - the heart will often continue to beat for many minutes after brainstem death. For farmers, the

brainstem reflexes are adequate to determine death as long as time has passed to be confident they were not just temporarily absent.

Observation of the sequence of collapse, rigidity, relaxation, kicking is usually a sure sign of a successful kill. However, the five-finger-head check is an easily applied and remembered method of confirming death that protects the operator's reputation as well as confirming death of the animal. It tests reflexes that travel through the brainstem. Each of the fingers of one hand corresponds to one of the signs being assessed. The active placement of each finger on the anatomical point being assessed helps make for a failsafe way of confirming the animal is dead and ready for disposal.

It is a practical field method of confirming death where each finger of your hand prompts a 'hands-on' close check that the animal has:

1. absent corneal reflex
2. fixed, fully dilated pupil
3. relaxed jaw
4. flaccid tongue
5. no rhythmic breathing

Some people do a six-finger head check that includes testing for ear muscle tone.

It is best to delay performing the five-finger-head check at least three minutes and preferably five after the shot has been administered or when the animal has ceased reflex kicking and it is safe to approach. This will allow time for resumption of breathing to occur if it is going to, and for any last reflex kick of the hind legs to safely pass.

Kneel or bend down behind the animal next to its head, out of kicking danger. Take your time to perform the five checks on the upper side of the head. The order is important - assess rhythmic breathing last to give breathing some time to reappear in animals that are unconscious. In stunned animals, rhythmic breathing may reappear after a lapse of a minute or two.

If one or more of the five signs is **not** present, the animal is not brainstem dead. Resumption of regular breathing is the sign most likely to occur if the animal is not brainstem dead. A follow-up method is required and a prompt repeat shot is recommended if the gun and blanks are working properly. The shot should enter in a different position but directed between the ears at the brainstem

The reflex kicking of the hind legs can be taken as assurance that the animal is dying or is dead but does not obviate the need to perform the five finger head check to satisfy one-self and especially onlookers that death has occurred.

Choosing a captive bolt gun

There are four models of penetrating captive bolt guns available in Australia that the author is familiar with: the Cash Special .22, the Blitz-Kerner .38, the Matador Super Securit 3000 and the Schermer KR (Figure 3).

Figure 3: Four models of penetrating captive bolts. From left to right, the Blitz Kerner .38, the Cash Special .22, the Matador SS 3000, the Schermer KR.



The Blitz-Kerner .38 is made in Germany by turbocut Jopp and is imported and distributed by Shoof Australia Pty Ltd of Melbourne. It is the cheapest at ~\$400, lightweight (2.25 kg) and pipe-shaped with an easy-to-grab cocking knob on the end of the head piece. The head piece containing the firing pin and a trigger lever separates completely from the barrel containing the cartridge chamber by a lengthy unscrewing process. The spent blank must be manually removed using a hook on the end of the trigger lever. As a result they are the slowest of the captive bolt guns to load and reload. The bolt penetrates to a depth of ~55 mm and is retracted into the barrel by a long spring and rubber washer surrounding the bolt. The large powerful 9 x 17 mm centre fire blanks are the most powerful on the market but which comes at a cost - they are \$2.00 each. The blanks come in four colour-coded strengths in packets of 50 which is good for turnover.

The Cash Special .22 is made in England by Accles and Shelvoke and distributed by MPE Pty Ltd of Adelaide. It is expensive (~\$2400), heavy (3.0 kg), pistol-shaped and relatively high maintenance, but has a major advantage over other models in being quick to reload by pulling back the hammer and firing block with the thumb (like a cowboys' six gun). The spent blank is partially ejected when the hammer and firing block are pulled back making it easy to grab with fingers to complete removal. The 6 x15 mm rim fire blanks are ~30c ea but only purchasable in boxes of 1000. Bolt penetration depth is ~55 mm and is retracted into the barrel by a series of rubber washers surrounding the bolt.

The Matador Super Securit 3000 is made in France by Termet and is imported and distributed by Kentmaster Equipment (Aust) Pty Ltd of Hillcrest, Qld. It is moderately priced at ~\$1600, heavy (2.9 kg) and pipe-shaped with a difficult-to-grab might-break-one-day cord on the end of the head piece which must be pulled to cock the gun. It has a folding head design where the head piece containing the firing mechanism and side-mounted trigger button is hinged to the barrel containing the cartridge chamber. A twisting and folding action opens and closes the gun for loading and unloading. The spent blank is automatically ejected when the gun is folded open. The 6.3x12mm rim fire blanks cost about 30c each, come in three strengths that are colour coded and are available in boxes of 500. Bolt penetration depth is ~55 mm and it is retracted automatically into the barrel by a series of rubber washers surrounding the bolt.

The Schermer KR is made in Germany by Karl Schermer GmbH and Co and is imported and distributed by Jarvis ANZ Pty Ltd of Richlands, Qld. It is equally the most expensive (~\$2400) with the Cash Special, the heaviest (3.1 kg) and is pipe-shaped. An easy-to-grab spring-tensioned knob on the end of the head piece is used to cock the gun but when fired by pressing the trigger button (on the side of the head piece)

there is a risk of jamming fingers when the knob springs back into place. To expose the cartridge chamber in the barrel for loading, the head piece separates completely from the barrel using a ¼ twist action. Bolt penetration depth is ~85 mm which is ~30 mm deeper than the other models. The bolt must be manually pushed back into the barrel after each shot, an action that also ejects the spent blank. To replace the bolt the rounded end of the cocking knob is designed to press the concave end of the bolt. Because of the requirement to manually replace the bolt the Schermer KR is nearly as slow as the Blitz Kerner to reload. The 6.8 x 15 mm rim fire blanks cost about 25 cents each, come in four different strengths which are colour coded and are available in packets of 100.

The author generally recommends the Blitz-Kerner .38 for farm enterprises where euthanasia of livestock is required occasionally. The pros are that the device is cheap, simple to use, has high killing power and the blanks can be purchased in small quantities. The cons are the high cost of the blanks and the slowness to reload which is why the heavier duty models should be considered if larger numbers of animals must be euthanased.

In very large dairy enterprises, feedlots or piggeries where a captive bolt would be used on a daily or weekly basis the Cash Special .22 is probably the best because it is quick to reload, the blanks are relatively cheap, the large quantities of blanks that must be purchased can be regularly turned over, and the higher usage of the device can justify the higher purchase cost.

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