



Question raised by requestor

How to best stun water buffalo for slaughter?

We have one slaughterhouse that slaughters a small number of water buffalo, but a good stun seems difficult to achieve. We allow the occipital shooting position in this case, because of the structure of the skull, but we still see problems with insufficient stunning. Are there any recommendations regarding the stunning method or the equipment in order to achieve the best possible stun?



Answer

EURCAW *Ruminants & Equines* is responding to a query in relation to the best stunning practices for water buffalo at slaughter, with special regard to the choice of stunning method and equipment to achieve an effective stun.

Short answer

Effective stunning to achieve unconsciousness is required to ensure welfare during slaughter. The frontal stunning position recommended for cattle using the conventional penetrating 9 cm or even 12 cm captive bolts may be barely adequate in buffaloes, due to their distinct skull structure (Schwenk et al., 2016). To stun water buffaloes, the best position of the captive bolt is reported to be **8 cm dorsal with respect to the recommended site for cattle** (position above the intersection point of the imaginary lines from the middle base of the horns and the external corner of the opposite eye), **and 2 cm lateral from the midline** with the device held perpendicular to the head. A high pressure pneumatic (200-220 psi) penetrating device must be used with a protruding bolt length of at least 9 cm (Molnar Fernández et al., 2023). This method was effective across different breeds, ages and body weights and achieved immediate collapse, absence of rhythmic breathing and absence of ocular reflexes in 95.1% of animals after the first shot (Molnar Fernández et al., 2023).

Alternatively, an **occipital position** can be used. The shot should be directed carefully towards the base of the tongue in buffaloes younger than 30 months and towards the nose in those older than 30 months (Gregory et al., 2009). The protruding bolt length should be at least 9 cm (Schwenk et al., 2016). However, this method presents serious disadvantages. First, a considerable percentage of the animals presented signs of risk of consciousness (Gregory et al., 2009). Second, indicators used to assess the effectiveness of a frontal shot cannot be applied when using occipital shots as an incorrect positioning of the device may damage the spinal cord, resulting in collapse of the animal and respiratory arrest, but without inducing unconsciousness.

In countries allowing the use of firearms, a large calibre rifle (e.g. approx. 9 mm bullet) with deformative bullets is also an option. It should be noted that shot positions defined relative to external landmarks may vary depending on head morphology, which differs across breeds and individuals. Thus, the orientation of the shot must be carefully adapted to the animal's head shape to ensure that the trajectory reaches the target brain structures.

Explanations are provided below. To understand why conventional mechanical methods may fail in this species, we first examine the standard stunning principles applied to cattle.

Legal framework

The legal framework applicable to water buffalo stunning is the Council Regulation (EC) No 1099/2009 on the protection of animals at the time of killing, which lays down the rules for stunning and slaughter of animals in the EU.

Answer

Stunning of cattle

Using a captive bolt gun is the usual method for mechanical stunning of bovine animals (EFSA, 2020). This method aims to damage a specific area of the brain, which includes the thalamus, hypothalamus, midbrain and rostral part of the pons (Terlouw, 2020; Figure 1). Damage to parts of this area disrupts their activating effect of the cortex, resulting in immediate unconsciousness. In cattle, the optimal shot position is 1 cm below a point on the midline, halfway between the top of the poll and a line drawn between the lateral canthus of each eye (Gilliam et al., 2016; Demota et al., 2024; Figure 2A). An alternative is to use the top of the head and the internal canthus of the eye while adding 2 to 3 cm toward the top of the head (Demota et al., 2024, Figure 2B). A final option is to draw 2 imaginary lines between the internal canthus of each eye and the upper side of the base of the contralateral horn, while adding 2 to 3 cm toward the top of the head (Demota et al., 2024; Figure 2C).



Correct positioning must be combined with the appropriate mechanical force delivered by the equipment. The energy required to propel the captive bolt is provided either by compressed air (pneumatic guns) or by a blank cartridge-type primer (cartridge guns). Consequently, the operating pressure (for pneumatic guns) and the cartridge power (for cartridge guns) must be adapted to the size of the animals being slaughtered (Kamenik et al., 2019; Gibson et al., 2015). Regardless of the propulsion system, a bolt exit velocity of 54 m/s and an impact energy release of 400 Joules ($\pm 10\%$) are recommended for effective stunning of adult cattle (Daly et al., 1987; Oliveira et al., 2017; Gibson et al., 2015; Grist et al., 2020). For bulls, a higher bolt velocity (72 m/s; 600 J) may be necessary (Gregory et al., 2007; Gibson et al., 2015).



Figure 1: Optimal placement of the captive bolt gun in cattle such that the target zone (blue) is damaged (Photo reproduced from Terlouw et al., 2021a).

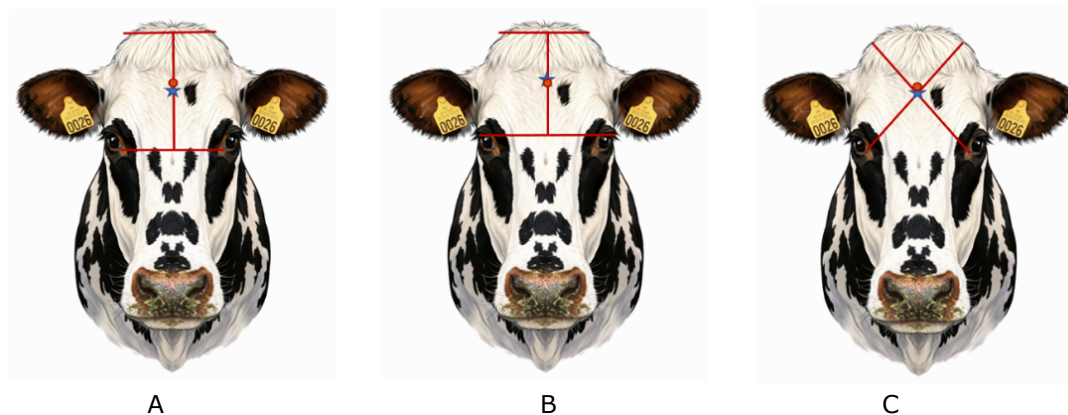


Figure 2: Optimal placement of the captive bolt gun in cattle, indicated by a red dot. A. Use of the top of the head and internal canthi of the eyes, adding about 2-3 cm from the midpoint toward the top of the head; B. Use of the top of the head and the lateral canthus of the eye while lowering the gun by about 1 cm from the midpoint; C. Use of 2 imaginary lines between the internal canthus of each eye and the upper side of the base of the contralateral horn, while adding 2 to 3 cm toward the top of the head from the crosspoint. The blue asterisks indicate the mid- and crosspoints that still need to be adjusted, the red dots indicate the optimal, adjusted placement (AI generated graphs by Claudia Terlouw).

Following the application of these mechanical parameters, it is necessary to evaluate the effectiveness of the procedure. To assess the animal's state of unconsciousness, the absence of signs of consciousness is verified and the animal is monitored to ensure there is no return to consciousness. These signs are controlled by structures near the target zone described above. The rationale is that when this zone is damaged, these nearby structures are also affected. In addition to the standing posture, other indicators of consciousness are controlled by brain areas positioned caudally with respect to the target zone. The standing posture requires that the midbrain, but also the pons and medulla oblongata are functional. Hence, if an occipital position is used (Figure 4), damaging the caudal pons or medulla oblongata, without damaging the target zone, would result in a fully conscious animal, that is incapable to stand or breathe and may not show a corneal reflex (Figure 3).



Figure 3: Median cut of a sheep brain. The brain anatomy is similar across ruminant species, and this diagram serves to demonstrate the relevant structures. A. The grey areas are those involved in consciousness. If the thalamus/hypothalamus, midbrain or rostral part of the pons are damaged (target zone), the animal is unconscious, because the cortex is no longer stimulated. B. The areas involved in the control of standing posture (red: midbrain, pons and medulla oblongata), corneal reflex (green: caudal pons, rostral medulla) and breathing (blue: caudal medulla, spinal cord). If an occipital shot is performed in such a way that the caudal part of the pons and/or the medulla are damaged, but not the target zone, the animal will collapse, may present no corneal reflex nor breathe, but it will be conscious (Photos adapted from Terlouw et al., 2021a, b).

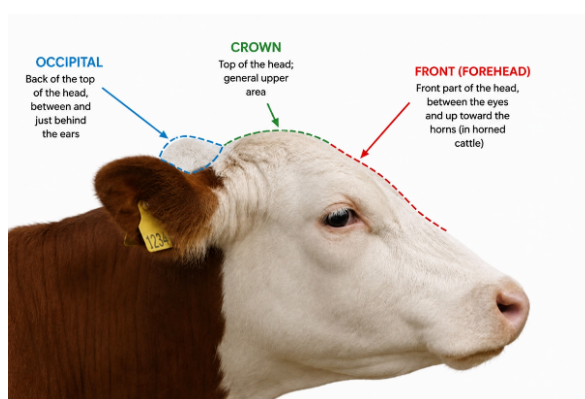


Figure 4: Key regions of the bovine head (AI generated graph by Claudia Terlouw)

Stunning of water buffaloes

Adult water buffaloes are more difficult to stun with a captive bolt in the frontal position than cattle (de la Cruz-Cruz et al., 2018; Gregory et al., 2009; Glardon et al., 2018; Grandin et al., 2023). This is caused by their anatomical characteristics, including their greater skin thickness, thicker frontal bones, and extensive frontal sinuses, with a highly developed median interfrontal septum compared to cattle (Schwenk et al., 2016). In addition, the distance between the frontal position of the gun and the target zone is much greater in buffaloes than in cattle. If the shot site recommended for cattle is used, the standard bolt length will be too short to reach the target zone in most cases (Schwenk et al., 2016; Figure 5), leaving the animal conscious. For this reason, alternative positions have been explored for stunning water buffaloes.

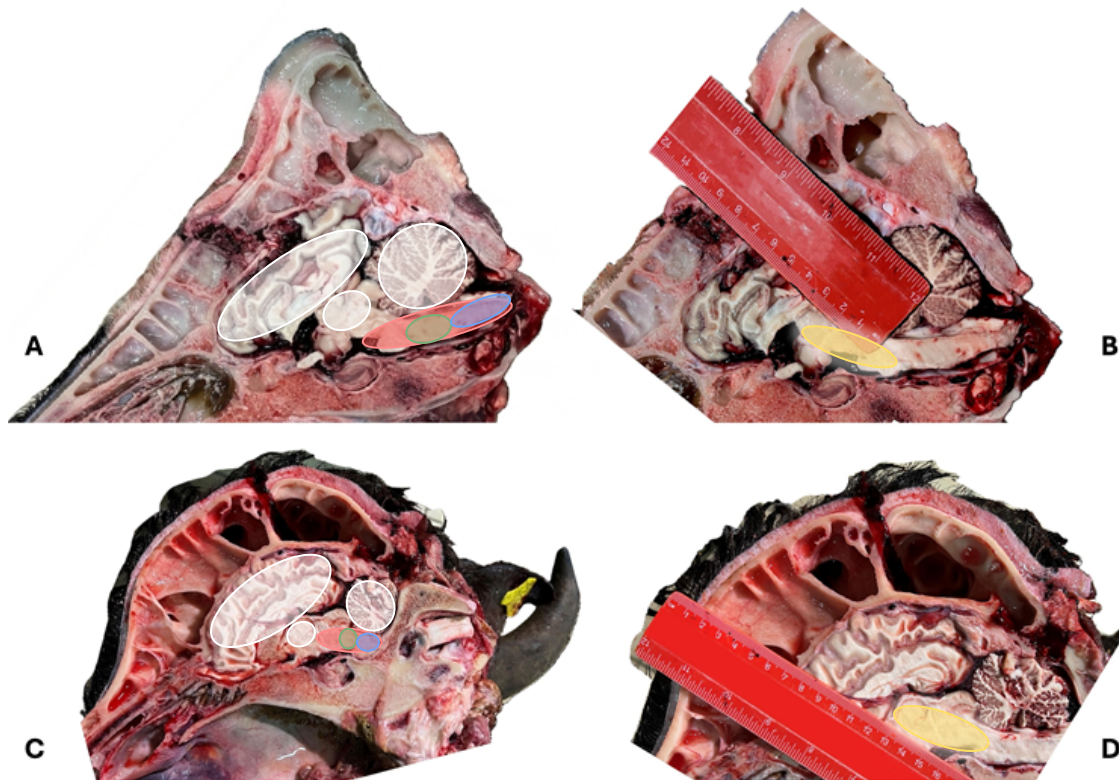


Figure 5: Skull of a 600 kg bovine (A and B) and a 800 kg buffalo (C and D). Same colours have been used as in Figure 3 to show brain anatomy. Using the traditional reference point and same penetration route as for the cattle, the captive bolt must travel approximately 10 cm in cattle (B) but 14 cm in buffalo (D) is needed, resulting in ineffective stunning under standard protocols. The yellow zone (B and D) indicates target zone to reach (Photo of Damiano Gioia).

In a study on alternative shot sites, the **crown** position (top of the head) located 16-19 cm from foramen magnum (Figure 6) did not induce an adequate unconsciousness in the 3 buffaloes that were tested (Gregory et al., 2009). The occipital position, located 1-4 cm from the foramen magnum, was tested in 14 young animals (< 30 months, approximately 400 kg liveweight) and 16 old ones (> 30 months). Although this position induced immediate collapse in most animals, a considerable percentage of them showed signs of risk of consciousness (rhythmic breathing movements, eyeball rotation, positive corneal reflex, positive palpebral reflex and nystagmus).

Adopting an **occipital** position would considerably reduce the distance between the bolt entry point and the thalamus and could therefore be anatomically effective (Schwenk et al., 2016). Shots in this position should use the depression below the intercornual protuberance and above the points of attachment of the nuchal ligament and should be directed towards the base of the tongue in young water buffaloes (<30 months) and towards the nose in older ones (> 30 months) (Gregory et al., 2009; HSA, 2018). However, achieving routinely adequate stunning of water buffaloes using the occipital position is considered to be complicated, because it increases the risk of animals recovering consciousness during bleeding. In addition, indicators used for the evaluation of unconsciousness for frontal shots are not valid for occipital shots as the occipital position may only damage the caudal parts of the brain stem, thereby disrupting standing posture, eye function, and breathing, without inducing unconsciousness (Gregory et al., 2009) (Figure 7).

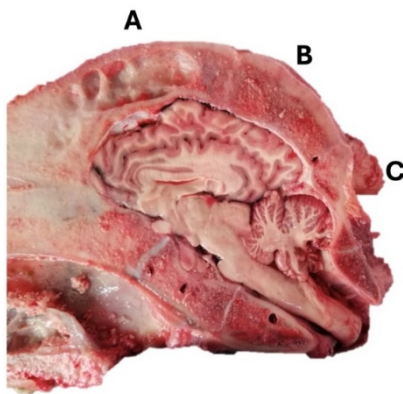


Figure 6: Various anatomical regions evaluated for the stunning of water buffalo. A, the frontal position (analogous to that used in cattle), which presents anatomical limitations in adult buffaloes; B, the crown position (top of the head) and C, the occipital position. While the occipital position may be effective, if it is oriented towards the mid brain, it carries a significant risk of missing the mid brain and only severing the part of the caudal part of the brain stem resulting in an animal that is fully conscious but unable to stand or to breathe (Figure 3) (Photo of Gustavo Araya-Rodríguez).

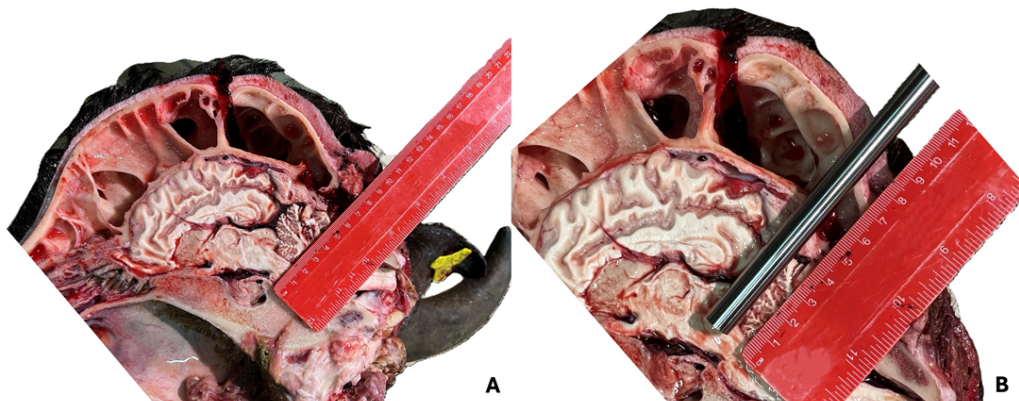


Figure 7: Skull of a 800 kg adult buffalo (A and B) using the occipital position. The tip of the bolt is in the target zone. The ruler indicates that the bolt length must be at least 10cm (Photo of Damiano Gioia).

Recent work has focused on high-pressure pneumatic devices and on bullet-based systems designed specifically for buffaloes (Molnar-Fernández et al., 2023; Gasho et al., 2022; Glardon et al., 2018). The study by Molnar-Fernández et al. (2023), showing that a high-pressure pneumatic penetrating captive bolt at 200–220 psi placed approximately 8 cm dorsal to the recommended position for cattle and 2 cm lateral to the midline with the captive bolt positioned perpendicular to the head, was effective across 534 buffaloes of Murrah, crossbred and Mediterranean breeds with different sexes and skull thickness (Figure 8). Using this position, 95.1% of buffaloes showed immediate collapse, absence of rhythmic breathing, and absence of ocular reflexes after the first shot, suggesting effective stunning. Macroscopic brainstem damage was observed in only 27.5% of examined heads from effectively stunned animals, but other traumatic lesions, including haemorrhage and bone fragments in the thalamus, were reported (Figure 9). In addition to direct tissue damage, the rapid intracranial acceleration induced by the bolt likely contributes to a contrecoup effect and haemorrhages resulting in a loss of consciousness. Therefore, unconsciousness can be achieved through the combined effects of cerebral concussion and physical damage using the position described above, and the correct orientation. Since this approach targets the frontal-dorsal region rather than the occipital route, if the shot is correctly oriented, there is less risk of localised damage to the caudal brain stem or spinal cord that could merely immobilise the animal without inducing unconsciousness.

Gasho et al. (2022) developed a double-barrel bullet-shooting stunner that allowed effective stunning with .357 Magnum ammunition while minimising the risk of over-penetration. Glardon et al. (2018) also reported that bullet deformation has a major influence on performance and that heavier deformative ammunition (e.g. .357 Magnum) may be preferable to light ammunition for larger animals. Finally, WOA (2024) indicates that water buffaloes should be stunned with a penetrative captive bolt in the occipital position using a heavy-duty contact-fired device directed towards the nose, or with large-calibre firearms and deformative ammunition such as .357 Magnum.

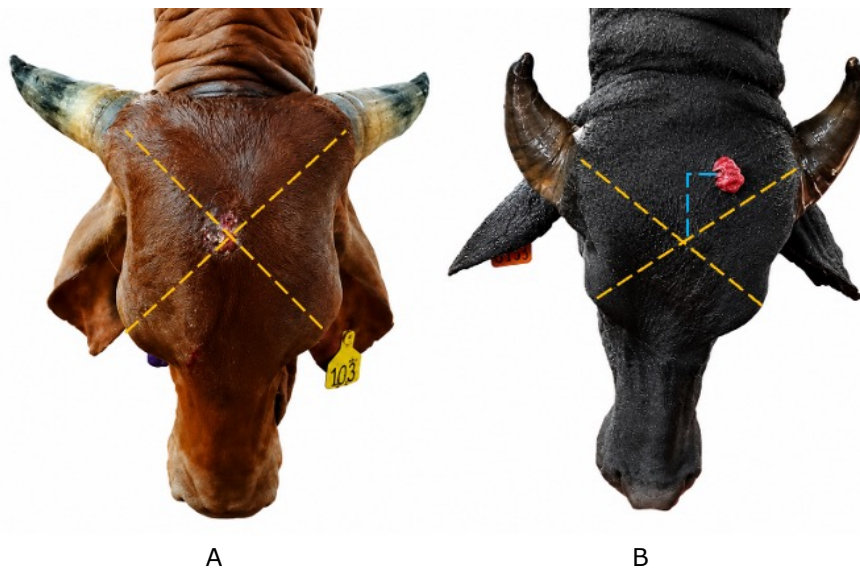


Figure 8: Optimal positioning of the captive bolt gun for stunning buffaloes (B) compared to cattle (A). The captive bolt should be positioned 8 cm above the site recommended for cattle and 2 cm laterally (B). This is due to the greater thickness of the frontal bone and the presence of a highly developed interfrontal septum, unlike that observed in cattle (Photos of Gustavo Araya-Rodríguez).

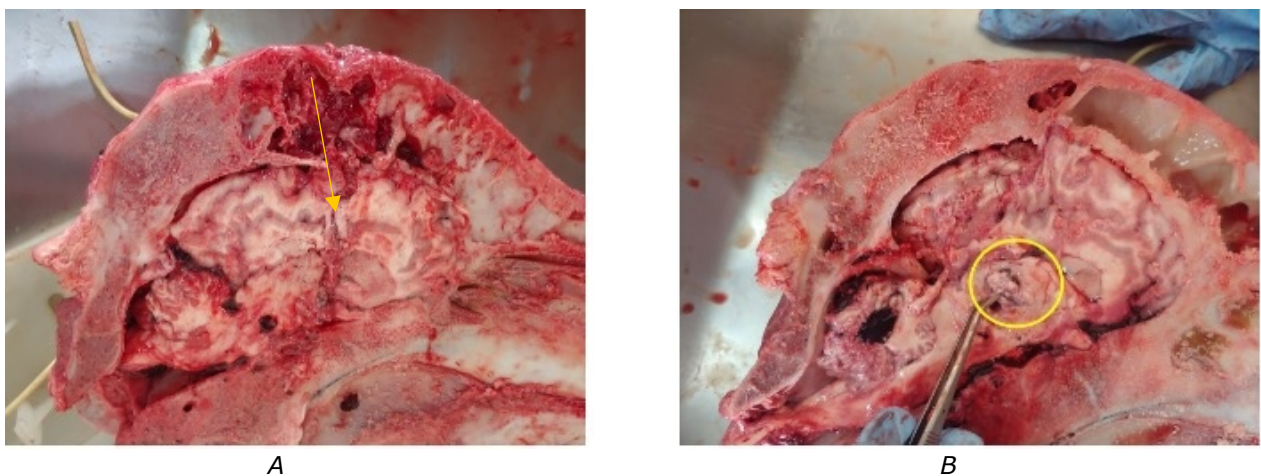


Figure 9: Macroscopic findings in the brain following penetrating captive bolt stunning (200–220 psi). (A) Brain tissue disruption along the trajectory generated by the impact of the penetrating captive bolt (indicated by the arrow). As the bolt length was limited to approximately 9 cm, the lesion extended beyond this depth due to secondary damage caused by displaced cranial bone fragments. (B) Bone fragment (circled) lodged within the thalamus, acting as a secondary projectile and causing additional brain tissue disruption (Photos of Gustavo Araya-Rodríguez).

Table 1 presents technical characteristics of some devices used and proposed for stunning water buffaloes in which only penetrating methods have been tested (extracted from Grandin et al., 2023).



Table 1: Technical characteristics of some devices used and proposed for stunning water buffaloes in which only penetrating methods have been tested (extracted and adapted from Grandin et al., 2023).

Bolt gun	Cash Magnum 9000S	Schermer KL	EFA VB 215	BigBovid	Jarvis USSS-1
Type	Bolt gun	Penetrating bolt gun	Air operated penetrating bolt gun	Bullet-shooting stunner	Pneumatic penetrating captive bolt with high air pressure
Position	Frontal	Frontal	Frontal	Frontal	Frontal
Damage to	Frontal lobe, diencephalon	Frontal lobe, diencephalon	Frontal lobe, diencephalon, rhombencephalon	Diencephalon, rhombencephalon	Telencephalon, diencephalon
Bolt length (mm)	121	125	135	280	90
Cartridge caliber (mm)	6.35	6.86	-	-	-
Bullet size (mm)	-	-	-	9	-
Barrel length (mm)	-	425	-	195 mm	-
Penetration depth (cm)	14.5	12.7	13.14	9.37-21.25	6-11
Pressure (PSI) (normal operating pressure)	-	-	174	-	160-175 (max 250)



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