

**Assessment of a specifically developed bullet casing gun for  
the stunning of water buffaloes**

Carmen Meichtry<sup>1</sup>, Urs Glauser<sup>2</sup>, Matthieu Glardon<sup>3</sup>, Steffen G. Ross<sup>4</sup>, Isabel Lechner<sup>5</sup>,  
Beat Kneubühl<sup>3</sup>, Dominic Gascho<sup>4</sup>, Claudia Spadavecchia<sup>6</sup>, Alois von Rotz<sup>1</sup>,  
Ana Stojiljkovic<sup>1</sup>, Michael H. Stoffel<sup>1</sup>

<sup>1</sup> Division of Veterinary Anatomy, University of Berne, Berne, Switzerland

<sup>2</sup> Waffen Glauser AG, Aarberg, Switzerland

<sup>3</sup> Institute of Forensic Medicine, University of Berne, Berne, Switzerland

<sup>4</sup> Department of Forensic Medicine and Radiology, Institute of Forensic Medicine,  
University of Zurich, Zurich, Switzerland

<sup>5</sup> Veterinary Public Health Institute, University of Berne, Berne, Switzerland

<sup>6</sup> Division of Veterinary Anaesthesiology, University of Berne, Berne, Switzerland

**Corresponding Author:**

Michael H. Stoffel, Prof. Dr. med. vet.  
Division of Veterinary Anatomy, University of Berne  
Länggassstrasse 120, POB 8466  
CH - 3001 Bern, Switzerland  
Tel: +41 (0)31 631 22 05  
Fax: +41 (0)31 631 26 15  
Email: michael.stoffel@vetsuisse.unibe.ch

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## **Abstract**

To meet the demand for genuine mozzarella and meet, keeping of water buffaloes has become increasingly popular in Switzerland. Concomitantly, close to 400 buffaloes are being slaughtered every year. Irrespective of their close relatedness, anatomical characteristics of the heads of water buffaloes and cattle differ considerably. As a result, standard captive bolt stunners fail to reliably produce adequate loss of consciousness in water buffaloes and, thus, do not fulfill animal welfare requirements. The goal of the present study, therefore, was to develop a new stunning device for water buffaloes meeting all animal welfare and occupational safety requirements and to pave the way for corresponding regulations. This newly designed bullet casing gun was assessed under practical conditions in an abattoir as based on widely accepted criteria. Stunning resulted in deep unconsciousness in all the water buffaloes slaughtered but for one male individual over 9 years of age. Excepted for old bulls, the device presented herewith provides a means to stun water buffaloes of both sexes effectively and reliably while keeping occupational hazards to a minimum.

**Keywords:** *water buffalo, skull anatomy, stunning assessment, bullet casing gun*

## 1. Introduction

Water buffaloes were first introduced into Switzerland in 1996 to allow for the domestic production of genuine mozzarella. Since then, the number of animals has increased continuously with the result that approximately 360 animals are slaughtered every year for stock management and meat production (Dr. A. Briner, Federal Food Safety and Veterinary Office FSVO, personal communication).

Animal welfare legislation (Tierschutzgesetz, 2014; Verordnung des BLV über den Tierschutz beim Schlachten, 2014) stipulates deep concussion as a prerequisite for bleeding and further slaughtering. Concussion is usually accomplished by producing severe brain damage with penetrating devices in order to produce deep unconsciousness. Conscious perception is linked to the cerebral cortex. Prior to reaching the primary cortex areas, however, all the sensory information but olfaction is relayed in the thalamus. Damage to the thalamus thus is an effective way to prevent conscious perception making this region of the diencephalon an effective target for stunning.

Irrespective of the close relatedness of the two species, water buffaloes have distinctive anatomical head features compared to cattle (Schwenk, 2014). Therefore, standard captive bolt stunners fail to produce loss of consciousness and, consequently, stunning procedures commonly used for cattle may not be applied to water buffaloes. This is basically due to the width of the frontal sinus, the skin thickness and the hardness of the bone plates which together prevent captive bolts from reaching the cranial cavity (Alsafy, El-Gendy, & El Sharaby, 2013; Kamel & Moustafa, 1966; Moustafa & Kamel, 1971; Saigal & Khatra, 1977). Attempts to improve the situation by increasing the bolt length and using stronger propellant charges have failed to resolve the issue satisfactorily. For these reasons, various handguns are currently being used by butchers. Though they are dependable and effective in many cases, stunning with free bullets from a distance of 5 to 15 centimeters does not

meet other requirements such as occupational safety, applicability and affordability. Thus, a legally underpinned standard procedure for the stunning of water buffaloes taking into account the exigencies of both animal welfare and work safety is urgently needed.

The goal of the present study, therefore, was to develop a new stunning device for water buffaloes meeting all animal welfare and occupational safety requirements and to pave the way for corresponding regulations. After in-depth analysis of ballistic parameters, usability, effectiveness and reliability of a newly designed bullet casing gun were assessed under practical conditions in an abattoir. Assessment of widely accepted criteria (Anonymous, 2013b; Grandin, 2002; Gregory, Lee, & Widdicombe, 2007; Verhoeven, Gerritzen, Hellebrekers, & Kemp, 2014) showed that stunning resulted in deep unconsciousness in all the water buffaloes but for one male individual over 9 years of age. Except for old bulls, the device presented herewith provides a means to stun water buffaloes of both sexes effectively and reliably while keeping occupational hazards to a minimum.

## **2. Materials and Methods**

All the experiments were performed with a bullet casing gun which was specifically designed and built for stunning water buffaloes (Fig. 1). The device was made of two 9 mm-bore rifled gun barrels with a barrel length of 150 mm, both of which were loaded with .357 Magnum 10.2g Hollow Point (.357 Mag./10.2g HP) ammunition from Geco (Ruag Ammotec Group, Germany) to provide a backup means for an immediate second shot in case of failure of the first attempt. As a safeguard, the device needs to be unlocked ahead of firing. The contact point was slightly lateral to the intersection of two lines connecting the upper and contralateral lower edges of the horn base.

The heads of six water buffaloes were collected after regular slaughtering to conduct preliminary ballistic experiments prior to assessing the bullet casing gun on live animals in an abattoir. The unskinned heads were numbered from 1 to 6 according to the animals' ages. Five heads (h1-h5) were from bulls aged 26, 28, 30, 35 and 107 months. Head six (h6) originated from a 114 month-old female water buffalo. In four out of the six heads (h1-h4), the base of the skull was cut away with a band saw and the brains were removed thus yielding front plates.

Up to four shots were fired on any given head (h1-h4) and four different ammunitions were tested in order to assess whether the projectiles reached the cranial cavity. Ammunitions tested on front plates included

- the .357 Mag. 10.2g Hollow Point (.357 Mag./10.2g HP) bullets from Geco (Ruag Ammotec Group, Germany),
- the .357 Mag. 8g Semi Jacketed Hollow Point (.357 Mag./8g SJHP) bullets from Remington (Madison, North Carolina, USA),
- the .357 Mag. 8g Semi Jacketed Soft Point bullets (.357 Mag./8g SJSP) from Union Metallic Cartridges (UMC, Madison, North Carolina, USA) and
- the .38 Special 10.2g Semi Jacketed Soft Point (.38 Spl./10.2g SJSP) from Geco (Ruag Ammotec Group, Germany).

After every shot, the front plates were inspected from the inside to determine whether the bullet had completely penetrated the skull. The two best suited ammunitions, i.e. .38 Spl./10.2g SJSP and the .357 Mag./10.2g HP, were then tested on the two intact heads h5 and h6. The .38 Spl./10.2g SJSP was fired to the right half and the .357 Mag./10.2g HP ammunition to the left half of the head, respectively. Both heads underwent computed tomography with a dual-source CT scanner with 2x128 slices (SOMATOM FlashDefinition, Siemens, Forchheim, Germany) to track the projectile's pathway through

the brain. Data reconstruction was performed with 0.6 mm slice thickness in a soft (B30) and a hard (B70) reconstruction algorithm. Multiplanar and 3-dimensional reconstructions were performed at a multimodality workstation (LEONARDO, SynGo, Siemens Medical Solutions, Forchheim, Germany). Data were analyzed with the Osirix® software (Pixmeo, Bernex, Switzerland).

Thereafter, the effectiveness of the bullet casing gun loaded with .357 Mag./10.2g HP bullets was assessed on 20 water buffaloes in a standard slaughtering environment with the approval of the [State Veterinary Office Aargau](#) (permit 75661). All the animals were stunned by the same butcher and in the same setting. To record the entire slaughtering process from stunning to exsanguination, a High Definition Video Camera (Panasonic, HC-V727, Rotkreuz, Switzerland) was used. Depth of concussion was judged at the abattoir during routine slaughtering according to a detailed checklist including a broad spectrum of established criteria (Anonymous, 2013b; Grandin, 2002; Gregory, Lee, & Widdicombe, 2007; Panel on Euthanasia, 2013) as given in Table 1. Every single criterion was graded with 1 when it was indicative of loss of consciousness and with 0 when it was not compatible with concussion. On-site evaluation was double-checked by viewing the video recordings upon return from the slaughterhouse. To ensure proper handling of the bullet casing gun, computer tomograms from two heads (Nr 10 and 16, Table 1) were produced as reported above in order to track the bullet's pathway and to review the brain lesions produced (Schwenk, 2014). As a backup, the butcher always had his "Ruger GP 100 Double Action" Revolver at hand in case of failure of the first shot. The revolver was loaded with .357 Magnum 10.2g Semi Jacketed Soft Point Flat Nose ammunition (.357 Mag./10.2g SJSP-FN). The decision to rely on the previously used stunning method as a backup was part of the approval from the Swiss Federal Food Safety and Veterinary Office. Immediate collapse, instant onset of apnoea and of spontaneous blinking as well as

the absence of any vocalisation (during the entire slaughtering process) were considered as main criteria for loss of consciousness (Anonymous, 2013a, 2013b; Grandin, 2012; Verhoeven, Gerritzen, Hellebrekers, & Kemp, 2014). These criteria were complemented with additional benchmarks. Tonic and clonic spasms were considered normal immediately after stunning (Gregory et al., 2007). Their presence was graded with 1 and specified as being mild or vigorous. A fully relaxed, atonic state, in turn, was rated with 0 as being anomalous. Adequate stunning was expected to abolish nystagmus as well as evoked corneal and palpebral reflexes. Furthermore, eyes were required to have a wide blank stare and not to be rotated (Grandin, 2002). In addition, absence of the nasal septum reflex was assessed with forceps. Agonal breathing, defined as gasping, was graded with 0 when present and with 1 when absent. As soon as the animal was hanging on the bleeding rail, the tongue was assessed with respect to both its position (straight) and its tone (limp). A clearly protruding tongue hanging straight and limp was considered indicative of loss of consciousness and assessed with 1. In contrast, a stiff or curled tongue as well as active tongue movements were interpreted as a sign of possible return to sensitivity and assessed with 0 (Grandin, 2002; Gregory, Lee, & Widdicombe, 2007). When the tongue was concealed within the oral cavity, assessment of corresponding parameters obviously was not feasible. The head, the ears, the tail and the back were expected to hang straight and without targeted or directed motility or righting reflexes. A general loss of muscle tone in the second phase, i.e. prior to bleeding, was judged as based on head, ears, back and tail hanging straight and limp and was also considered a required sign of adequate stunning.

### **3. Results**

In the preliminary ballistic experiments with front plates and two complete heads, the .357 Mag./10.2g HP bullets infallibly punched through both bone plates and reached the

cranial cavity. Analysis of CT data sets from the two whole heads (h5 and h6) confirmed the destruction of the thalamus (data not shown). The .38 Spl./10.2g SJSP ammunition produced penetrating shots as well, but CT images revealed only limited brain damage as the bulk of the projectile fragments were absorbed in the frontal sinus prior to reaching the brain. The preliminary experiments revealed that fragmentation was less and the penetration considerably better for the heavier projectiles (.357 Mag./10.2g HP and .38 Spl./10.2g SJSP) than for the lighter ones (.357 Mag./8g SJSP and the .357 Mag./8g SJHP). The .357 Mag./8g SJSP produced an unwanted blowback.

Assessment of the stunning effectiveness of the bullet casing gun used with the .357 Mag./10.2g HP ammunition is summarized in Table 1. Stunning was considered effective in 19 of 20 animals and complete loss of consciousness resulted from a single shot. Analysis of CT data from the animals Nr. 10 and 16 revealed the point of contact to be perfectly adequate as the target region was precisely hit. Notwithstanding, animal Nr. 10, a 161 months old female water buffalo, did not collapse immediately but with some delay. However, all the other indicators of deep concussion were fully met.

Only a 118 month old male water buffalo (Table 1, Nr. 20) had to be reshot because he did not collapse after the first shot. The animal was immediately stunned again with the “Ruger GP 100 Double Action” Revolver. Because of limited accessibility to the head, the second shot had to be fired with an occipital contact point. Thereafter, the bull collapsed hesitantly. Breathing, gasping, vocalization, spontaneous blinking, eye movements and the nasal septum reflex were absent. The corneal as well as the palpebral reflex were absent but the eyeballs were rotated downwards (as under general anesthesia). When hanging on the rail, the animal’s back was straight, muscle tone was lost but for the stiff ears. The head and tail were hanging loose and limp. The tongue was not visible and, thus, could not be assessed. The animal did not react to the bleeding. Careful analysis of the CT data set



revealed that the brain had essentially been spared. Neither of the two bullets had reached the cranial cavity and brain damage was limited to minor hemorrhagic lesions.

After the stunning, tonic and clonic spasms were observed in 16 water buffaloes. In 13 cases out of these, the spasms were mild while the remaining 3 animals showed vigorous spasms. Four out of the 20 buffaloes did not exhibit any spasms and were assessed with score 0. In these cases, assessment of spasm intensity was not applicable and entered as x (Table 1). A mere tail switch from one side of the body to the other or vigorous tail movements were noted in 3 animals. In one out of the three, tail movements were combined with vigorous spasms. In 16 animals, the tongue was protruding and was invariably hanging out straight and limp. Thus, no curling or tongue movements were ever observed. In 4 animals, the tongue was not visible and could not be assessed. Neither of these 20 animals showed positive eye and nasal septum reflexes or a response to a nose pinch. Similarly, gasping, spontaneous blinking, nystagmus as well as vocalisation were absent in all the water buffaloes including the old bull.

#### **4. Discussion**

This study provides a detailed description of a newly designed bullet casing gun to stun water buffaloes as well as a thorough assesement of its usability under practical conditions. We recommend this method to be used in regular slaughterhouses as it is effective, reliable and safe to handle.

Conventional captive bolt stunning devices (Schermer KL, Cash Magnum 9000S) comply with standard safety requirements but because of their inadequate penetration power and insufficient bolt length, even the high-performance systems (Schermer KL) do not ensure a dependable stunning effectiveness in water buffaloes. In addition to the mere width of the frontal sinus, the skin and the bone thicknesses add to restrict the effectiveness of such

systems in this species. In order to shorten the distance to the brain, captive bolt devices were assessed from an occipital contact point. Irrespective of a sufficient bolt length and lesser resistance of the occipital bone as shown in ballistic tests (results not shown), further assessment revealed that the occipital approach is not suitable for practical reasons. The animals' interest in the stunner inevitably prevented a dependable positioning of the captive bolt device. Therefore, such an approach would require a complete immobilization of the head in a bent position which is not feasible with water buffaloes in a standard setting without unwanted considerable stress for the animal.

Notwithstanding, regulation to come into effect by August 2015 requires slaughter cattle to be confined in such a way as to allow a stunning device to be placed to the forehead reliably and accurately (Dr. A. Briner, Federal Food Safety and Veterinary Office FSVO, personal communication). Although this will definitely facilitate the use of stunning devices in a frontal position, this is not enough to allow their use in an occipital position.

The attempt to develop a specialized and more powerful captive bolt stunner with an adequate penetrating bolt length of 18 cm to be used in a frontal position was abandoned due to the prohibitive energy consumption of the return system. An increase of the propulsive energy would not solve the issue as the recoil would dislodge the device from the head at the expense of propelling the bolt towards the brain. Therefore, a device with a free projectile was developed.

The custom-built bullet casing gun presented herewith combines the advantages of handguns and captive bolt stunners. The bullet casing gun may be pressed against the forehead like a captive-bolt stunner. Besides providing a standard handling, this further minimizes operational hazards. However, the bullet casing gun may also be fired from a distance of five to ten centimeters should the animal not tolerate physical contact. The .357 Mag./10.2g HP provides a deformable bullet which delivers its energy in the target

tissues. It was expected, therefore, to provide an effective and reliable stunning impact without bearing the risk of through and through shots.

Eighteen criteria were used to evaluate the loss of consciousness in 20 animals from a one year old male calf up to a thirteen years old cow including a ten years old breeding bull. In order to come to a final judgment on the stunning effectiveness, several criteria were taken into account. “Failure to collapse or delayed collapse”, “regaining posture”, “active breathing”, spontaneous blinking or “vocalisation” were considered crucial elements (Anonymous, 2013b; Grandin, 2012; Gregory, Lee, & Widdicombe, 2007; Verhoeven, Gerritzen, Hellebrekers, & Kemp, 2014). Other criteria such as “nystagmus”, “positive eye reflexes” or “rigid muscle tone of the animal’s body” were seen as being less compelling as single features and, thus, were assessed within a broader context. But for the breeding bull which had to be reshot, all the animals were ascertained to have been stunned properly. This also applies to the 13 year old cow which did not fully collapse immediately. When reviewing the video tape, it became obvious that the animal had become wedged within the stun box due to its mere size. Although the animal was not stunned again, all the other criteria were fully met, thus indicating complete loss of consciousness. CT further corroborated that the brain target had been hit by the bullet.

Tonic and clonic spasms are expected after captive bolt stunning (Gregory et al., 2007) whereas a fully relaxed physical state raises concerns about a potential resumption of consciousness (Gregory et al., 2007). Absence of muscle spasms was noted in 4 animals. In two out of these, all the other indicators of deep concussion were met. In one of the remaining animals, the tongue was not protruding and could not be assessed. As for the fourth animal, it was the old breeding bull which did not collapse immediately and in which the tongue was not protruding. It also showed rotated eyeballs and stiff ears.

Variable tail movements were observed in 3 animals during lifting but could not clearly be

differentiated from general spasms in all the instances. However, when suspended to the bleeding rail, the tail was hanging limp in all the 3 animals. Whereas a stiff and curled tongue is a sign of possible return to sensitivity (Grandin, 2002), a protruding tongue hanging straight and limp closely depends on a completely relaxed jaw and, thus, is considered a reliable sign of deep unconsciousness (Grandin, 2002). The latter was the case in all the animals in which the tongue was visible. On the other hand, failure of the tongue to protrude is not an indicator of residual consciousness (Grandin, 2002) and, thus, was not taken into account. This applied to 4 animals. As for the old breeding bull, it collapsed slowly after the second shot only. Although the majority of the other criteria indicating loss of consciousness were met, some parameters were indicative of a shallow concussion. These included rotated eyeballs, lack of spasms and stiff ears. This is in agreement with the computer tomography findings of the head which revealed that the brain had been spared. Therefore, one must part on the assumption that stunning was shallow only.

Taken together, the assessment of the loss of consciousness clearly supports the contention that the bullet casing gun is an adequate means for stunning water buffaloes. In congruence with the ballistic studies (Schwenk, unpublished results), no through and through shots were observed in live animals, nary in the youngest calves. On the other hand, the bullet casing gun reliably and reproducibly provided a complete loss of consciousness but for the old breeding bull. Thus, particular solutions should be considered for old males. Our data show that the bullet casing gun provides an adequate stunning for male buffaloes up to 5 years and is likely to work for somewhat older males as well. This is corroborated by the preliminary experiments which were conducted to test the ammunition. One of the heads used originated from a bull that was almost 9 years old and all the bullets regularly reached the cranial cavity. However, for lack of more bulls between 5 and 10 years of age, the

threshold age may not be defined more accurately. But for the exception of very old bulls, the bullet casing gun presented herewith provides a highly reliable stunning device in combination with .357 Mag./10.2g HP ammunition both from an animal welfare as from an occupational safety point of view.

## **5. Acknowledgments**

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**Table 1:** *Assessment of the loss of consciousness in 20 water buffaloes stunned with the bullet casing gun loaded with .357 Mag./10.2g HP ammunition.*

The table provides a compilation of the criteria used to assess the concussion and their rating for every single animal. All the animals were fully stunned but for the bull Nr. 20 which did not collapse immediately and which was reshot with a handgun loaded with .357 Mag./10.2g SJSP-FN. Nonetheless, concussion was shallow only. BCG: bullet casing gun; HG: handgun (Ruger GP 100 Double Action Revolver); shaded cells: main criteria; 1: the criterion was met; 0: the criterion was not met, x: not applicable; v: vigorous; m: mild.

Nr.	Sex	Age		Stunning device	Ammunition	Immediate collapse	Spasms		Instant onset of apnoea	Absence of gasping	Absence of spontaneous blinking	Absence of nystagmus	Wide blank stare	Absence of palpebral reflex	Absence of corneal reflex	Absence of nasal septum reflex	Loss of muscle tone (on bleeding rail)	Tongue		Head hanging straight and limp	Ears hanging straight and limp	Back straight, no righting reflex	Tail hanging straight and limp	Absence of any vocalisation	Number of shots fired	Deep concussion (overall assessment)	
		Months	Days				Tonic and clonic	Intensity										Protruding	Straight and limp								
1	Females	16	508	BCG	.357 Mag/10.2g HP	1	1	m	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1		
2		17	537			1	0	x	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1		
3		18	567			1	0	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
4		19	590			1	1	m	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	
5		19	592			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
6		22	689			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
7		38	1162			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8		58	1789			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9		113	3467			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10		161	4898			0	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	Males	13	418	BCG	.357 Mag/10.2g HP	1	1	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	
12		21	659			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
13		21	669			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
14		31	963			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
15		33	1008			1	1	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16		35	1090			1	0	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17		36	1106			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18		39	1201			1	1	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19		53	1617			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20		117	3576			BCG	.357 Mag/10.2g HP	0	0	x	1	1	1	1	0	1	1	1	1	1	0	x	1	0	1	1	2
			HG	.357 Mag/10.2g SJSP-FN																							



**Figure 1**      *The bullet casing gun prototype with its two 9 mm-bore rifled gun barrels and protected trigger.*

Both barrels are loaded with .357 Mag./10.2g HP to provide a backup means for an immediate second shot in case of failure of the first attempt. A shifter allows for a rapid switch between the barrels. The safety lever locks both barrels and needs to be released ahead of firing. 1: Trigger; 2 Safety lever.

