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Animal Welfare 2009, 18: 171-175
ISSN 0962-7286

Assessment of the efficiency of captive-bolt stunning in cattle and feasibility of associated behavioural signs

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Abstract

Efficient stunning is essential for the welfare of animals destined for slaughter. Several studies have dictated certain signs as reliable for the assessment of stunning efficiency in cattle. However, there is still a lack of data concerning the viability of these signs. The aim of the following study was to assess stunning efficiency at a slaughterhouse, studying the relationship between age, sex and breed of cattle and the efficiency of stunning and determining the feasibility of the following signs in assessing stunning efficiency: immediate collapse, muscle spasms, rhythmic breathing, rotation of the eyeballs, painful response to ear or nose pinch, vocalisation and muscle tone of the ears. Cattle were observed immediately after stunning and hoisting onto the bleed rail. Results showed that stunning efficiency decreased with age, was greater in females than males (for animals greater than 12 months of age) and was superior in 'dairy' compared to 'beef' cattle at all age ranges. Presence of ear muscle tone, absence of muscular spasms, presence of rhythmic breathing, and vocalisation were the most common signs of inefficient stunning recorded in the present study. Recognition of the most frequently occurring signs associated with inefficient stunning will point out the need for re-stunning, preventing animals from regaining sensibility.

Keywords: *animal welfare, behavioural signs, captive-bolt stunning, cattle, EFSA report, stunning efficiency*

Introduction

The purpose of any stunning method is to render an animal insensible prior to slaughter (Gregory 1998). Captive-bolt stunning is one of the most efficient and commonly used methods for stunning cattle (Gracey *et al* 1999; EFSA 2004). According to Finnie (1996), this method induces an efficient stun when an adequately severe lesion is induced to the brain stem and caudal portion of the cerebral hemispheres.

Previous studies have recommended certain parameters for assessing the efficiency of stunning methods by means of the observation of behavioural patterns and responses to certain stimuli (Grandin 1994; Gracey *et al* 1999; Grandin 2001, 2002). According to the EFSA, efficient captive-bolt stunning produces the following effects: immediate collapse, muscle spasms of the dorsum and legs, immediate and sustained absence of rhythmic breathing, a blank stare, absence of righting reflex, absence of painful responses (ear or nose pinch) and of vocalisation. Inefficient stunning, therefore, produces the following: rhythmic breathing, constricted pupils, attempts to raise the head, vocalisation during stunning, presence of corneal reflexes, rotation of the eyeballs, response to painful stimuli and presence of ear muscle tone (EFSA 2004). However, a degree of controversy exists as to the signs that should be considered most reliable to measure stunning efficiency. Gracey *et al* (1999) considers the absence of rhythmic breathing to be the most consistent sign of unconsciousness whereas Grandin (2002) believes that insensibility is achieved when a limp head, extended tongue and a blank stare are present.

Stunning efficiency not only impacts on animal welfare but also greatly influences meat quality (Velarde *et al* 2003). Stress reduces the glycogen content of muscle fibres; an essential component of the meat maturation process (Devine *et al* 1993; Immonen 2000). Subsequently, improved texture, taste and preservability are achieved when animals are handled and stunned humanely.

The aim of this study was to assess stunning efficiency in a slaughterhouse, determining whether there was a relationship between stunning efficiency and age, sex and breed of cattle. Additionally, we examined the feasibility of the signs proposed by the EFSA report (2004) to assess stunning efficiency.

Table 1 General data of study cattle.

Variables	Female	Male	Total
Age (months)			
< 12	103 (20.7%)	127 (36.1%)	230 (27.1%)
12–30	89 (17.9%)	201 (57.1%)	290 (34.1%)
> 30	306 (61.4%)	24 (6.8%)	330 (38.8%)
Breed			
Dairy	208 (41.8%)	213 (60.5%)	421 (49.5%)
Beef	290 (58.8%)	139 (39.5%)	429 (50.5%)
Total	498 (58.6%)	352 (41.4%)	850 (100%)

Materials and methods

Sample collection

This study was carried out during routine stunning and slaughter at a beef abattoir, in Braga, Portugal, between January and April, 2007. During this period, a total of 850 animals were examined, corresponding to 30% of the total number of cattle slaughtered each day. Stunning was performed in a conventional stunning box (2.98 × 1.12 × 1.60 m; length × width × height) without head or body mechanical restrainers. When the animal head was presented in a suitable position it was shot with a contact-firing, captive-bolt gun (Cash® Cowpuncher 8000 Model, Accles & Shelvoke Ltd, UK), fitted with blank, 0.22 calibre cartridges. All animals were shot by the same slaughterman, who had received specific training in the technique of shooting cattle, at the crossover point between imaginary lines drawn between the base of the horns and the opposite eyes. The stunned animal was then ejected from the side of the stunning pen and a second slaughterman shackled one hindleg and hoisted the animal onto a bleeding rail where it was stuck by inserting a knife into the thoracic cavity. The following features, based on the EFSA (2004) report for assessing stunning efficiency, were recorded after the shot animal had rolled out of the pen by an individual standing beneath the stunning pen: gender, age range, breed, eyeball rotation, rhythmic breathing, muscle spasms, vocalisation, painful response to ear and nose pinch and muscle tonus of the ears. Tremor was evident in the underside of the animal, originating in the muscles of the limbs and belly. Eyeball rotation was assessed from the presence of the whites of the eye (sclera). Rhythmic breathing excluded spasmodic gasping and gagging. Pinching was carried out with the tips of index finger and thumb, along the inner surface of the apex of the ear and dorsal aspect of the nose (above the nostrils). In order to assess stunning efficiency, the following signs of recovery of sensibility were observed in each animal once it had been hoisted onto the bleed rail: resumption of rhythmic breathing, attempts to raise head (both lateral and dorsal) and return of stiffness (muscle tone) of the ears. Therefore, an animal that presented at least one of the previously mentioned signs was considered inefficiently stunned; otherwise, stunning was registered as having been efficient. Depending on line speed, every third, fourth, fifth or sixth animal was examined. A total of 2,800 animals were included in this study. Cleaning and maintenance records of captive bolts were consulted on a daily basis throughout the study.

For the purposes of the study, cattle were grouped into 'beef' and 'dairy' breeds; dairy cattle consisting mainly of Holstein Friesian and Jersey and respective crossbreeds whereas beef cattle were mainly traditional Portuguese breeds (eg Barrosã, Alentejana, Maronesa) or Charolais, Limousin, Belgian Blue along with respective crossbreeds. All male cattle included in the study were entire (Table 1).

Data analysis

Statistical analysis was performed via Chi-squared tests, using SPSS version 11.0 for Windows®. Investigations were carried out to study the relationship between stunning efficiency, age, sex and breed (dairy or beef) and associations with the following parameters: immediate collapse, muscle spasms, rhythmic breathing, rotation of eyeballs, muscle tonus of the ears, painful response to ear or nose pinch and vocalisation. All the parameters were analysed on an individual basis, regardless of their simultaneous occurrence in the same animal.

Results

The overall efficiency of captive-bolt stunning in this study was 68.2%. Statistical differences were found between stunning efficiency and age of cattle ($P < 0.001$). The efficiency of stunning decreased substantially with age, ranging from 89.1%, in cattle younger than 12 months of age, to 50.3% in animals with ages greater than 30 months. Associations were also found between stunning efficiency and sex, such that in females the efficiency was reduced (63.1%) compared to males (75.6%) ($P < 0.001$) (Table 2). In cattle older than 12 months of age, stunning efficiency was greater for females than for males. Specifically, between the ages of 12–30 months, stunning efficiency was 69.7 and 77.5% for males and females, respectively, while for cattle older than 30 months it was 45.8 and 50.7% (Table 2). Stunning efficiency also had a breed association. It was greater in dairy (74.3%) compared to beef (62.2%) cattle ($P < 0.001$) (Table 2). This finding was observed for all age groups considered (Table 2).

The most frequent indicators of inefficient stunning we found were as follows: presence of muscle tone of the ears (17.8%), absence of muscle spasms (11.5%), presence of rhythmic breathing (9.4%), and vocalisation (7.9%). However, the parameters indicative of inefficient stunning that appeared more commonly among animals that presented signs of recovery of sensibility were: absence of an immediate collapse (100%), presence of rotated eyeballs (91.3%), presence of rhythmic breathing (91%), and painful

https://doi.org/10.1017/S0962728600000312 Published online by Cambridge University Press

Table 2 Differences in stunning efficiency between breed, sex and age of cattle.

Variables	Efficient stunning	Inefficient stunning	Total	*P*-value
Breed				
Dairy				< 0.001
Age (months)				
< 12	115 (90.6%)	12 (9.4)	127 (30.2%)	
12–30	119 (73.5%)	43 (26.5%)	162 (38.5%)	
> 30	79 (59.8%)	53 (40.2%)	132 (31.4%)	
Total	313 (74.3%)	108 (25.7%)	421 (100%)	
Beef				< 0.001
Age (months)				
< 12	90 (87.4%)	13 (12.6%)	103 (24.0%)	
12–30	90 (70.3%)	38 (29.7%)	128 (29.8%)	
> 30	87 (43.9%)	111 (56.1%)	198 (46.2%)	
Total	267 (62.2%)	162 (37.8%)	429 (100%)	
Sex				
Male				< 0.001
Age (months)				
< 12	115 (90.6%)	12 (9.4%)	127 (36.1%)	
12–30	140 (69.7%)	61 (30.3%)	201 (57.1%)	
> 30	11 (45.8%)	13 (54.2%)	24 (6.8%)	
Total	266 (75.6%)	86 (24.4%)	352 (100%)	
Female				< 0.001
Age (months)				
< 12	90 (87.4%)	13 (12.6%)	103 (20.7%)	
12–30	69 (77.5%)	20 (22.5%)	89 (17.9%)	
> 30	155 (50.7%)	151 (49.3%)	306 (61.4%)	
Total	314 (63.1%)	184 (36.9%)	498 (100%)	
Age (months)				< 0.001
< 12	205 (89.1%)	25 (10.9%)		
12–30	209 (72.1%)	81 (27.9%)		
> 30	166 (50.3%)	164 (49.7%)		
Total	580 (68.2%)	270 (31.8%)		

response to ear and nose pinch (84.6%). With the exception of rhythmic breathing, these signs were otherwise observed infrequently (less than 3.8%) and therefore considered of rare occurrence (Table 3).

Significant differences were found regarding the incidence of vocalisation subsequent to inefficient stunning between breeds, such that dairy animals vocalised more often (69.7%) than their beef counterparts (55.9%) ($P < 0.05$) (Table 4).

Discussion

The results of this study revealed that under these study conditions, captive-bolt stunning resulted in the recovery of approximately one-third of the animals stunned. Common causes of stunning inefficiency reported elsewhere that could have interfered in our study, include, a lack of a proper head restraint system (Grandin 1996), a lack of shooting accuracy (Cockrum & Corley 1991; Grandin 1996) and poor gun

https://doi.org/10.1017/S0962728600000312 Published online by Cambridge University Press

Table 3 Stunning efficiency regarding the variables studied that indicate ineffective stunning.

Variables that indicate inefficient stunning		Without recovery*	With recovery**	Total	*P*-value
Absence of immediate collapse	No	577 (68.8%)	262 (31.2%)	839 (98.7%)	0.006
	Yes	0 (0%)	11 (100%)	11 (1.3%)	
Absence of muscle spasms	No	510 (73.6%)	183 (26.4%)	693 (88.5%)	< 0.001
	Yes	31 (34.4%)	59 (65.6%)	90 (11.5%)	
Presence of rhythmic breathing	Yes	7 (9.0%)	71 (91.0%)	78 (9.4%)	< 0.001
	No	564 (74.9%)	189 (25.1%)	753 (90.6%)	
Presence of rotated eyeballs	Yes	3 (9.7%)	28 (90.3%)	31 (3.7%)	< 0.001
	No	577 (70.6%)	240 (29.4%)	817 (96.3%)	
Presence of ear muscle tonus	Yes	47 (31.3%)	103 (68.7%)	150 (17.8%)	< 0.001
	No	532 (76.5%)	163 (23.5%)	695 (82.2%)	
Presence of painful response to ear or nose pinch	Yes	2 (15.4%)	11 (84.6%)	13 (1.5%)	< 0.001
	No	578 (69.3%)	256 (30.7%)	834 (98.5%)	
Presence of vocalisation	Yes	25 (37.3%)	42 (62.7%)	67 (7.9%)	< 0.001
	No	555 (71.0%)	227 (29.0%)	782 (92.1%)	

* Independent of presence or absence of the sign, continued observation of the animal revealed absence of signs of recovery of sensibility as specified by the EFSA (2004).
** Independent of presence or absence of the sign, continued observation of the animal revealed presence of signs of recovery of sensibility as specified by the EFSA (2004).

Table 4 Differences in incidence of vocalisation between breeds of studied cattle.

Breed	Vocalisation	Stunning without recovery	Stunning with recovery	Total	*P*-value
Beef	Yes	15 (44.1%)	19 (55.9%)	34 (7.9%)	
	No	252 (64.0%)	142 (36.0%)	394 (92.1%)	0.019
	Total	267 (62.4%)	161 (37.6%)	428 (100%)	
Dairy	Yes	10 (30.3%)	23 (69.7%)	33 (7.8%)	
	No	303 (78.1%)	85 (21.9%)	388 (92.2%)	< 0.001
	Total	313 (74.3%)	108 (25.7%)	421 (100%)	

maintenance (Grandin 1994; Gracey *et al* 1999; EFSA 2004). However, during this study, all trials were performed under the same working conditions, therefore minimising their interference on the results obtained.

Stunning efficiency decreased with the age of the cattle. Certain anatomical changes are known to occur in the bovine skull during growth that could possibly explain this finding. The frontal sinuses are less developed in calves compared to adult cattle and this development tends to follow the growth of the animal, invading the dorsal aspects of the skull (Dyce 1997). In adult cattle, the frontal sinuses occupy the majority of the frontal bone and caudal aspect of the skull (Sisson 1986). It is expected that as adult cattle present a larger and thicker frontal bone, in some animals the brain might be beyond the normal reach of the bolt.

Skull structure is variable not only with age but also breed (Dyce 1997). Thus, the differences in stunning efficiency found between breeds may be associated with head conformation. This is supported by the observed relationship between the efficiency of stunning and the cattle breed in all three age ranges.

Overall, females had a higher percentage of inefficient stuns compared to males. However, this finding is probably due to a higher percentage of females greater than 30 months of age, compared to males. Nevertheless, in animals greater than 12 months old, the incidence of inefficient stunning was higher for males than females. It is possible that differences in skull structure between sexes might only become established after cattle's first year of life, increasing the difficulty of an efficient stun in males. Accordingly, Gracey

https://doi.org/10.1017/S0962728600000312 Published online by Cambridge University Press

et al (1999) stated that, as a probable result of having a larger frontal bone, stunning efficiency is poorer in males compared to young cattle and females.

The signs indicative of inefficient stunning that appeared most commonly throughout this study (presence of muscle tone of the ears, absence of muscle spasms, presence of rhythmic breathing and vocalisation) might be of great use when assessing stunning efficiency. In a previous study by Grandin (1998), vocalisation was considered a feasible sign for assessing welfare as 98.2% of the animals that vocalised during her study, did so as a consequence of an aversive event during handling, restraining and stunning, namely: excessive electric prodding, extreme pressure by restraint systems and missed stuns. According to Grandin (1998), certain breeds, namely Aberdeen Angus and Holstein Friesian, have a genetic predisposition for vocalisation. In this study, dairy cattle vocalised more frequently as a consequence of inefficient stunning, when compared to beef cattle which might imply a greater use when assessing stunning efficiency of dairy cattle.

In conclusion, the present study has revealed that more than one sign should be considered when assessing stunning efficiency as it will increase the likelihood of differentiating between efficient and inefficient stunning. As certain signs occurred more frequently than others, it might be worthwhile considering these first when assessing stunning efficiency. Upon their occurrence and from a welfare perspective, they indeed justify re-stunning to avoid unnecessary suffering.

Animal welfare implications

The welfare of cattle is influenced greatly by stunning efficiency. An animal that regains sensibility on the bleed rail is almost certain to experience a tremendous amount of pain, not only due to the missed stun and the neck cut, but also from being suspended on the rail, exerting all its bodyweight onto one limb. This is of particular concern when we consider that cattle can achieve extremely heavy weights. It is essential, therefore, from the point of view of welfare, to prevent cattle from returning to sensibility.

Preventing animals from regaining sensibility at slaughter may also present other potential advantages, such as an improvement in meat quality as a consequence of a more peaceful death. Nonetheless, these parameters could be taught to employees as they are easily assessed as well as providing better safety at work. It would also promote a healthier public opinion regarding farm animal slaughter methods, as the knowledge of poor welfare of farm animals creates much public disgust and disagreement, which is of increasing concern to the meat industry.

The authors believe that specific European legislation regarding this procedure would help decrease the high number of inefficient stuns observed under the technical conditions that this study was carried out.

Acknowledgments

We would like to thank Francisco Rosário who made this project possible. Also, Rui Magalhães for technical support.

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