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Effect of neck cut position on time to collapse in halal slaughtered cattle without stunning

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ABSTRACT

This study examined the effect of neck cut position on the time to physical collapse in upright restrained halal slaughtered cattle ($n = 644$). Time to collapse was used as an indirect indicator of the early stages of onset of unconsciousness. Cattle were slaughtered with either a conventional low (LNC) ($n = 561$) or a high neck cut (HNC) ($n = 83$). Mean time to final collapse was higher in the LNC compared to HNC group (18.9 ± 1.1 s and 13.5 ± 1.3 s respectively ($P < 0.01$)). The mean false aneurysm scores were higher in the LNC cattle (0.8 ± 0.0) compared to the HNC (0.6 ± 0.1) ($P < 0.01$). Animals that took >20 s to final collapse had larger false aneurysms. In summary, the HNC reduced the mean time to final collapse and the frequency of animals that took longer than 20 s to collapse.

1. Introduction

When cattle are slaughtered without stunning, any delay between the cut to the neck and the onset of unconsciousness could result in suffering from: stress and pain associated with restraint (hyperextension of the neck, excessive pressure from the restraining systems) (Berg & Jakobsson, 2007; Grandin, 1998; Grandin & Regenstein, 1994; Velarde et al., 2014); pain associated with the cut and stimulation of nociceptors in the wound (Gibson, Johnson, Murrell, Chambers, et al., 2009; Gibson, Johnson, Murrell, Hulls, et al., 2009; Zulkifli et al., 2014); distress associated with delays in the time to loss of consciousness (Daly, Kallweit, & Ellendorf, 1988; Gregory, Fielding, Von Wenzlawowicz, & Von Holleben, 2010); and distress associated with aspiration of blood into the respiratory tract (Grandin & Regenstein, 1994; Gregory, von Wenzlawowicz, & von Holleben, 2009).

Previous research has shown that when upright restrained or cast cattle are slaughtered, the ends of the severed carotid arteries (cephalic and cardiac ends) can develop false aneurysms, which can impede or stop exsanguination (Gregory et al., 2008). A false aneurysm is thought to form when the severed carotid artery retracts within its surrounding connective tissue sheath. Blood from the severed vessel impregnates and swells the adventitia (Gregory, Shaw, Whitford, & Patterson-Kane, 2006). The swelling of the adventitia impedes and can block the flow of blood from the artery (Gregory, Schuster, Mirabito, Kolesar, & McManus, 2012; Gregory et al., 2010). When animals have not been stunned prior to neck incision this is a welfare concern, as the aneurysm can obstruct the flow of blood, and if blood continues to flow to the brain via the vertebral arteries (which are not cut during slaughter), there can be delays in loss of consciousness (Gregory, Schuster, et al., 2012; Gregory, von Wenzlawowicz, et al., 2012). It has been shown that cutting the neck at a position corresponding to the first cervical vertebra (C1) compared to the conventional C2 + will almost eliminate false aneurysm development, thereby minimising the risk of arrested exsanguination (Gregory, Schuster, et al., 2012; Gregory, von Wenzlawowicz, et al., 2012). It is proposed that delays in the onset of unconsciousness can be reduced by performing the neck cut at the higher position on the neck, and this would minimise subsequent distress. The aim of the study was to examine the effect of neck cut position on time to collapse, indices of brainstem function and false aneurysm formation in halal slaughtered cattle. Time to collapse was used as an indicator of the early stages of onset of unconsciousness.

2. Materials and methods

Data was collected from 755 cattle during routine halal slaughter at a commercial Belgian slaughter plant (over 16 non-consecutive days). One hundred and eleven animals were excluded from analysis due to missing recordings (90), animals slipping in the box prior to neck incision (10), incomplete severance of the carotid arteries (8), additional cuts made to the neck following the main halal procedure (2) and a downer animal that was slaughtered when in sternal recumbency (1). The animals not excluded from the analysis were Belgian Blue (BB) and BB crosses (636) and 8 dairy cattle. Five hundred and fifty of the

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cattle were female (2 heifers; 548 mature cows) with the remaining male animals being veal calves (31), young bulls (43) and mature bulls (20). With the possible exception of the veal calves, all animals were sourced from markets and were penned in the abattoir lairage prior to slaughter.

Cattle were restrained individually, while standing in an upright position, with a back pusher, neck yoke and chin lift. Animals were either slaughtered with a conventional low (LNC) or high neck cut (HNC) by the same halal slaughterman. The soft tissues of the ventral aspect of the neck were severed in a continuous motion. Cuts were defined as a change in the direction of movement of the knife (i.e. the forward movement of the knife would count as one cut, while the corresponding reverse movement would be recorded as a second cut). A number of knives were used by the slaughterman during data collection. Their use was rotated depending on their level of sharpness. The knives were sharpened with a steel at intervals throughout a work period. The knife blades ranged in length from 20 to 25 cm, with a straight edge (14–16 cm) that curved upwards at the end of the knife. Immediately after the cut the head and neck were released from the chin lift and head yoke, allowing the animal to bleed while standing unrestrained in an upright position in the pen. Time to physical collapse after the start of blood flow from the neck wound was used as an indicator of the early stages of loss of consciousness (Gregory et al., 2010). The number of cuts, time to collapse (no longer standing on all four feet), regaining upright posture (on all four feet) after collapse, eye rotation/dilatation/fixation, general eye reflexes, cut position relative to the trachea rings (TR) and false aneurysm formation of the cardiac ends of the carotid arteries were recorded by three researchers working at different positions along the slaughter line. Each researcher was individually responsible for the collection and assessment of a specific set of parameters for all animals. False aneurysm score was estimated by palpating the severed ends of the carotid arteries. Increasing false aneurysm score (0 to 5) corresponded to increasing outer diameter of the artery. Gregory et al. (2006) reported that the subjective assessment of aneurysm score was highly correlated with the objective measurement of the diameter with a ruler (correlation coefficient = 0.96; $P < 0.001$). The generalised eye response was a combination of the corneal and palpebral reflexes.

Cut position was assessed in relation to the number of TR situated cranially to the cut (the first 112 animals were also assessed in relation to the cervical vertebra), by palpating at midlevel on the inner lateral aspect of the cephalic segment of the severed trachea. The TR were counted from the arytenoid cartilage onwards, but not including the cricoid cartilage. The cuts were categorised as either LNC with ≥2.5 TR, or HNC with ≤2 TR. All HNC were below the level of the thyroid cartilage.

Statistical analysis was performed with SPSS 20.0 (IBM Corporation, Chicago, IL, USA) and Prism 6.0 (GraphPad Software Incorporated, San Diego, CA, USA). Where appropriate the Kolmogorov–Smirnov test was used to test the distribution of the data. The mean number of cuts; time to collapse; false aneurysm score; time to loss of eyeball rotation; time to loss of a generalised eye response; time to assessing false aneurysm formation were examined for differences between the LNC and HNC groups with the non-parametric Mann–Whitney test. Time to collapse, neck cut position and false aneurysm score were examined for associations with the Fishers Exact test. Correlations between data were performed with Pearson product–moment coefficient or the spearman rank–order correlation where appropriate.

3. Results

Time to collapse was assessed by two independent observers on the first 112 animals to determine whether there might be any observer bias. It was found that the observations for time to collapse were significantly correlated between the observers, with $r = 0.90$ (95% CI 0.87–0.94) $P < 0.001$. Thereafter one operator performed all subsequent recordings of time to collapse. Furthermore, to test for sampling drift the results were analysed for sample day effects, and no significant associations were found ($P < 0.564$). There were no significant interactions between animal breed, age or gender on the time to collapse or other recorded parameters.

Six hundred and forty four cattle were slaughtered without stunning. The mean time to final collapse for all animals was 18.2 ± standard error (SE) 0.9 s (s) (range 1–257 s). Eighty one percent of all animals collapsed in the initial 20 s after the cut. In total 26 (4%) animals took 60 s or more to achieve final collapse. There was a significant correlation between TR and cervical vertebral position, with $r = 0.76$ (95% CI 0.73–0.79) $P < 0.001$. To simplify analysis of neck cut position, the cuts were grouped as either low neck cut (LNC) (TR ≥ 2.5, ≈C2–C3+) or high neck cut (HNC) (TR ≤ 2, ≈C1). In total, data was collected from 561 and 83 cattle that received a LNC and HNC respectively.

Fig. 1 is the frequency distribution for time to final collapse for animals in the LNC and HNC groups. Final collapse in the majority of animals occurred within 20 s (LNC 79%; HNC 89%). There was a significant difference in the mean time to final collapse (Table 1), with animals receiving the HNC (13.5 ± 1.3; range 4–86 s) collapsing sooner than those in the LNC group (18.9 ± 1.1; range 1–257 s) ($P < 0.01$). The mean number of cuts ($P < 0.001$) was significantly higher in animals slaughtered with the HNC (2.0 ± 0.1) compared to the LNC (1.7 ± 0.0).

The mean false aneurysm score was significantly higher in the LNC (0.8 ± 0.0) compared to the HNC (0.6 ± 0.1) group ($P < 0.01$). There was a significant difference in the mean time to assessing false aneurysm formation between the LNC (74.1 ± 2.0 s) and HNC (62.8 ± 3.2 s) group ($P < 0.05$). There was a weak ($r = 0.34$ (CI 0.27–0.41)) but significant correlation ($P < 0.001$) between the time of assessment of false aneurysms and time to final collapse.

The time to onset of eyeball rotation was assessed in 68 (LNC 59; HNC 9) cattle. There was no significant difference in the mean time to onset of eyeball rotation in the LNC (29.0 ± 1.5 s) compared to HNC (19.6 ± 2.8 s) group ($P = 0.200$). However, there was a significant correlation between time of eyeball rotation and time to final collapse ($r = 0.60$ (CI 0.41–0.73); $P < 0.001$). The time to the last recorded period of generalised eye response was significantly different between the LNC (117.9 ± 2.5 s) and HNC (99.2 ± 3.8 s) groups ($P < 0.05$).

There were 71 (11%) attempts/successes by cattle to regain posture on all 4 feet. Of these, the mean number of attempts/successes was 1.3 ± 0.1 (range 1–4). However, care must be taken in interpreting this data, as it was difficult in some cases to distinguish between a conscious attempt to regain posture from a convulsion episode. More reliable is the assessment of the frequency of animals that regained posture on all 4 feet after the initial collapse. Fifty-two (8%) cattle that collapsed, temporarily regained posture on all 4 feet. The mean number of episodes where animals regained posture into the standing position was 1.4 ± 0.10 (range 1–4). Forty-eight animals (9%) in the LNC

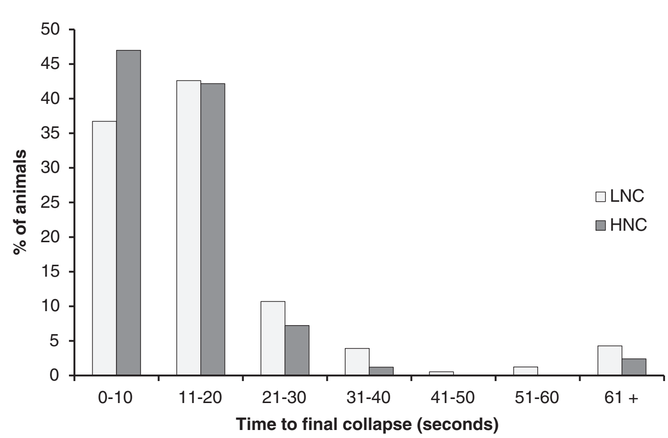

Fig. 1. Distribution (%) of cattle in LNC (light grey) and HNC (dark grey) groups according to time to final collapse following slaughter without stunning.

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Table 1
Effect of neck cut position (low (LNC) or high (HNC) neck cut) on the mean number of cuts, time to final collapse, time to false aneurysm assessment, aneurysm score, time to onset of eyeball rotation, last recorded time of generalised eye response, and frequency of animals that regained posture in cattle slaughtered without stunning.

	Neck cut position		*P* value
	LNC (≥2.5 trachea rings)	HNC (≤2 trachea rings)	
Number of animals	561	83	
Mean number of cuts (± SE)	1.7 ± 0.0	2.0 ± 0.1	<0.001
Mean time to final collapse (s) (±SE)	18.9 ± 1.1	13.5 ± 1.3	<0.01
Mean false aneurysm score (±SE)	0.8 ± 0.0	0.6 ± 0.1	<0.01
Mean time to onset of eyeball rotation (s) (±SE)[a]	29.0 ± 1.5	19.6 ± 2.8	0.200
Mean of last recorded time of generalised eye response (s) (±SE)[b]	117.9 ± 2.5	99.2 ± 3.8	<0.05
Number of animals that regained posture on all 4 feet (%)	48 (9%)	4 (5%)	0.288

[a] Note that data for eyeball rotation was collected from 68 (LNC 59; HNC 9) cattle.
[b] Note that generalised eye response was a combination of the corneal and palpebral reflexes. Data was collected from 394 (LNC 347; HNC 47) cattle.

group regained full posture, with a mean number of episodes of 1.4 ± 0.1 (range 1–4). Meanwhile, only 4 (5%) animals that received the HNC regained posture on all 4 feet with a mean number of episodes of 1.5 ± 0.2 (range 1–2). There was no significant association between cut position and regaining posture ($P = 0.288$).

Table 2 shows the frequency of false aneurysm scores for carotids arteries according to cut position. There was a significant association between neck cut position and false aneurysm score ($P < 0.01$). Significantly more animals had false aneurysm scores of 0 (no false aneurysms) in the HNC (62%) compared to the LNC (53%) group ($P < 0.05$). In aneurysm scores 1 and 2 there was no significant difference between the LNC and HNC groups. However, there was a significantly higher frequency of cattle with aneurysm scores of 3+ in the LNC (11%) compared to HNC (3%) group ($P < 0.05$).

There was no direct association between final collapse at >60 s and aneurysm score ($P = 0.617$). However, there was a significant association between final collapse >20 s and aneurysm score ($P = 0.01$). There was no interaction between neck cut position and false aneurysm score on the mean time to final collapse (Table 3). It was found that neck cut position ($P < 0.05$) significantly influenced the mean time to final collapse, while false aneurysm score did not have a significant influence ($P = 0.104$). Furthermore, of the two animals in the HNC group that took greater than 60 s to final collapse neither had a carotid artery aneurysm score greater than 2.

Table 4 shows the frequency of delayed time to final collapse in relation to neck cut position. Twenty-four (4%) of the cattle in the LNC group took >60 s to final collapse compared to 2 (2%) in the HNC group. There was no significant association between final collapse >60 s and neck cut position ($P = 0.560$). If late collapse is classified as taking >20 s to lose posture (based on 81% of all cattle collapsing within 20 s), there was a significant association between final collapse >20 s and neck cut position ($P = 0.037$). One hundred and sixteen animals (21%) in the LNC group took >20 s, compared to 9 (11%) in the HNC group.

4. Discussion

Performing a HNC significantly reduced (LNC 18.9 ± 1.1 s; HNC 13.5 ± 1.3 s) the time to final collapse in halal slaughtered cattle without stunning compared to the conventional LNC. Furthermore, it significantly reduced the proportion of animals that took >20 s to final collapse. The time to collapse was used as an indirect indicator of the early stages of unconsciousness. Collapse is one of the first signs of onset of unconsciousness and can be assessed without direct manipulation of the animal. Delays in the interval between the cut and onset of insensibility/unconsciousness could be associated with pain and distress. Using a HNC reduces the frequency of animals that have a prolonged time to unconsciousness and could lessen such suffering. This is further supported by anecdotal observations by Grandin (1994), that if a rapid deep cut is performed close to the jawbone (HNC position), 95% of cattle rapidly collapsed. It is well recognised that there is increased branching of the common carotid arteries at the HNC position (TR ≤ 2) (Dyce, Sack, & Wensing, 2002; Pasquini, 2005), and it is proposed that this prevents or minimises retraction of the carotid within the connective tissue sheath, thereby reducing the likelihood of false aneurysm formation. Furthermore, the risk of false aneurysms sealing all severed branches may be lower than the occlusion of the single common carotid at the LNC position (TR ≥ 2.5). The HNC used in the current study was similar in position to the cut recommended by Grandin (1992).

There were a significantly higher number of cuts in the HNC (2.0 ± 0.1) compared to the LNC (1.7 ± 0.0) group. The higher number of cuts in the HNC group could have increased the level of damage to the carotids, potentially resulting in improved bleedout. However, this is unlikely as although significant, the number of cuts was very similar with overlapping between the groups. Velarde et al., 2014 in a study of 10 halal non-stun abattoirs, reported significant variation in the number of cuts, between operators and restraint systems, with more cuts performed on cattle restrained in the upright position (9 cuts) compared to inversion at 180° (5 cuts) and 90° (3 cuts).

In the study, 48 (9%) and 4 (5%) cattle that received a LNC and HNC regained posture on all 4 feet respectively. Although not statistically significant, using the HNC compared to the conventional LNC reduced the proportion of animals that regained full posture. The regaining of posture could indicate a phasic return of consciousness in some animals (Gregory et al., 2010). Newhook and Blackmore (1982) and Blackmore, Newhook, and Grandin (1983) reported resurgence of sensibility in some animals, based on analysis of the activity of the spontaneous electroencephalogram (EEG) after slaughter without stunning. Blackmore (1984) reported possible resurgence of sensibility in a calf 323 s after bilateral severance of the carotid arteries and jugular veins from its coordinated attempts to rise. The results of the current study are similar

Table 2
Frequency of false aneurysm scores from the cardiac ends of both carotid arteries when severed at either low (≥2.5 trachea rings) (LNC) or high (≤2 trachea rings) (HNC) neck cut positions during slaughter without stunning.

False aneurysm scores	LNC (≥2.5 trachea rings)	HNC (≤2 trachea rings)
0	599 (53%)[a]	103 (62%)[b]
1	268 (24%)[a]	42 (25%)[a]
2	132 (12%)[a]	16 (10%)[a]
3+	122 (11%)[a]	5 (3%)[b]

Values in rows with different superscript letters are significantly different at $P < 0.05$.

Table 3
Effect of cut position (low (LNC) or high (HNC) neck cut) and false aneurysm score on the mean time to final collapse in cattle slaughtered without stunning (seconds).

	False aneurysm score			
	0	1	2	3+
Cut position				
LNC (≥2.5 trachea rings)	18.9 ± 1.0	21.4 ± 1.8	16.9 ± 1.7	15.4 ± 1.6
HNC (≤2 trachea rings)	13.2 ± 1.1	14.1 ± 1.8	14.7 ± 4.8	10.8 ± 1.4

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Table 4
Frequency of time of final collapse (seconds) following slaughter without stunning in relation to neck cut position (low (LNC) or high (HNC) neck cut).

	Time to final collapse after the cut (seconds)			
Cut position	≤60	>60	≤20	>20
LNC (≥2.5 trachea rings)	537 (96%)	24 (4%)	445 (79%)	116 (21%)
HNC (≤2 trachea rings)	81 (98%)	2 (2%)	74 (89%)	9 (11%)

to those of Gregory et al. (2010), who reported that 14% of cattle were able to temporarily recover to the standing position after slaughter by ventral neck incision. These results and those of the current study suggest that for some animals the initial collapse does not signify the complete loss of consciousness. Rather these animals can repeatedly drift in and out of consciousness until irrecoverable unconsciousness sets in. Furthermore, the results suggest that a HNC reduces the proportion of animals that have a phasic return of consciousness.

In addition to the assessment of time to collapse, the time to onset of eyeball rotation and the last recorded time of a generalised eye response were also recorded in the study as indices of loss of brain function. Due to the design of the restraining pen and slaughter line it was difficult to record these indices. There was no significant difference between the LNC and HNC in the time to onset of eyeball rotation. This could have been due to the low sample size, with data only collected from 68 (LNC 59; HNC 9) cattle. However, there was a significant correlation between time of onset of eyeball rotation and time to final collapse. Eyeball rotation has been previously used as a sign of presence of brainstem function following slaughter without stunning (Bourguet, Deiss, Tannugi, & Terlouw, 2011; Limon, Guitian, & Gregory, 2009, 2010). During the study it was difficult to separate positive corneal and palpebral reflexes during testing on the slaughter line. Instead a generalised eye response was recorded, which was a combination of the corneal and palpebral reflexes. The time to the last recorded period of generalised eye response was significantly different between the LNC (117.9 ± 2.5 s) and HNC (99.2 ± 3.8 s) groups. These values differ from those of Levinger (1995), who reported the loss of the corneal reflex in shechita slaughtered cattle at a mean time of 38.8 ± (standard deviation) 25.5 s. A generalised eye response, like the corneal and palpebral reflexes, is an indicator of brainstem function, the absence of which can be used as a sign of brainstem death.

A potential limitation of the study was the limited number of animals in the HNC group. At the start of the study there was an agreement with the plant management and the slaughterman that an equal number of animals would be slaughtered at the two different neck positions. However, due to customer wishes and the design of the chin lift it was not always possible to perform a HNC. Despite the imbalance in the sample sizes of the two groups, there were statistically significant differences between the groups in the results. In some cases when a HNC was attempted, the design of the chin lift limited access to the neck and resulted in the knife contacting the metal of the restraining system. This could have contributed to the higher frequency of cuts in the HNC compared to the LNC group. This emphasises the importance of chin lift design in ensuring that there are no obstructions to the neck cut region.

In the current study there was a similar skew in the distribution and large variation between animals (range 1–257 s) for time to final collapse as that reported by Gregory et al. (2010) in the same abattoir with the same slaughterman. However, despite the similar distributions, the frequency of animals that took >60 s to final collapse was less (4%) than that reported by Gregory et al. (2010) (8%). Furthermore, in that study there was a significant association between final collapse ≥60 s following the neck incision and the aneurysm scores of 3+ (Gregory et al., 2010). Meanwhile, in the current study there was no significant association between final collapse >60 s and aneurysm score. There are a number of theoretical explanations for the variation between the studies. Firstly, in the 2010 study all 174 cattle were slaughtered with a LNC. In the current project the cattle were slaughtered with either a LNC (561) or HNC (83). The results from the HNC group could have reduced the overall frequency of animals that took >60 s to final collapse. Secondly, the 2010 study had a limited sample size, potentially if this was increased the results could have been similar. Thirdly, there could have been improvement in the skill of the slaughterman between the studies. However, in the 2010 study the same slaughterman was still considered by the researchers as skilled and experienced. Fourthly, there could have been variation in the characteristics of the animals. This explanation is considered unlikely, as the populations investigated in both studies were similar (i.e. principally BB beef cattle). Finally, in conjunction with aneurysm formation (Gregory et al., 2008; Gregory, Schuster, et al., 2012) and the continued supply of blood to the brain by the undamaged vertebral arteries (Baldwin & Bell, 1963a,b,c; Blackman, Cheetham, & Blackmore, 1986), there may be additional mechanisms that are associated with the delay in the time to unconsciousness during slaughter without stunning in some cattle. Potential mechanisms could include: (1) retraction of the carotids without occlusion. The retraction of the vessels within the carotid sheath could provide resistance to blood loss that could retard bleeding. (2) Carotid retraction during respiratory movements. In some animals it was observed that during inhalation respiratory movements (including gasps) the carotid arteries retracted and bleeding was reduced or momentarily interrupted, and following exhalation bleeding resumed. (3) Physical occlusion of the vessels of the neck, either due to the position of the head relative to the body or to physical pressure on the neck from the metal work of the pen restricting blood loss. This has been observed in a different plant where physical pressure from the lower structures of the neck yoke reduced blood flow from the severed carotid arteries.

In conclusion, the findings of the study showed that the performance of the HNC compared to the conventional LNC significantly reduced the time to loss of posture in halal slaughtered cattle. The adoption of a HNC could reduce the welfare compromise associated with the delayed time to loss of consciousness during slaughter without stunning.

Conflict of interest

There is no conflict of interest.

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