Assessment of stun quality after gunshot used on cattle: a pilot study on effects of diverse ammunition on physical signs displayed after the shot, brain tissue damage and brain haemorrhages

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Abstract
Moving the slaughter process from the abattoir to the animals’ familiar environment has the potential to reduce pre-mortal stressors to a minimum and contribute considerably to improved animal welfare at slaughter. On-farm stunning and killing of free-range cattle via gunshot became legal in Germany in November 2011, including for commercial sale of the meat. As an effective stun is essential for maintaining animal welfare until the animal dies, the goal of this study was to assess the feasibility of delivering an instantaneous and deep stun by an accurate frontal gunshot at cattle. Thirty free-range cattle (Galloway, German Angus) were shot with five different combinations of rifles and bullets. A stun-quality protocol was developed to assess musculoskeletal, optical and respiratory signs displayed after the shot. Key signs, such as failure to collapse, corneal reflex, spontaneous blinking, eyeball rotation or eyeball movement, distinct vocalisation and rhythmic breathing were not evident in 29 of the 30 cattle. Dissections of the heads were used to detect penetration depth of the projectile as well as evaluate brain tissue damage and brain haemorrhage caused by the shot. Tissue damage was marginal and not related to the ascertained level of stun quality. Brain haemorrhages assumed to be sufficient for causing a deep stun were detected in 25 out of 30 cattle. Accurate shot placement turned out to be more important than the application of a certain calibre. However, it was considered crucial for safety reasons that the projectile should remain within the cranial cavity. As long as there are high levels of accuracy, gunshot was considered to be an effective stunning method with the potential of maintaining high standards of animal welfare until death occurs.

Keywords: animal welfare, brain haemorrhage, cattle, gunshot, physical signs, stun quality

Introduction
In response to societal as well as scientific demands, animal welfare at commercial slaughter has improved over recent decades, but remains a matter of concern in many places. Psychological and physical pre-mortem stressors still occur in cattle during loading or transport as well as at the abattoir itself (Grandin 1998a, 2006, 2012; Terlouw et al 2012; Atkinson et al 2013). Frequently, transport-related bruises and lacerations lead to carcass downgrading. Each year, significant losses to the meat industry are caused by stress-induced dark-firm-dry (DFD) meat (Jarvis et al 1996; Ferguson & Warner 2008; Algers et al 2009; Shen et al 2009). Pre-slaughter stunning via captive-bolt gun is the most common method at commercial cattle abattoirs (Algers & Atkinson 2007; Troeger & Moje 2012) and many slaughter-related studies focus on efficiency and/or optimal shot placement of captive-bolt guns (Lambooy & Spanjaard 1981; Ilgert 1985; Daly et al 1987; Finnie 1993a; Grandin 2002; Gregory et al 2007; Gouveia et al 2009; Kohlen 2011; Gilliam et al 2012; Atkinson et al 2013). Depending on the size of the animal, captive-bolt guns are usually operated with energies between 300 and 600 J and a relatively low speed of < 100 m s\(^{-1}\) for stunning cattle (Algers & Atkinson 2007; Anil & Lambooij 2009). The technical design of stun-related slaughterhouse facilities and stunning devices varies considerably. Service-related problems with the stunning apparatus (unclean devices, worn out parts, use of damp ammunition) are still common, despite the fact they require to be regularly well serviced to ensure a proper stunning (Atkinson et al 2013). A lack of shooting accuracy, due to unrestrained animals or disability or fatigue of the shooter, can lead to failed shots or poor stun quality (Grandin 1998a). A field study at German, Swiss and Austrian abattoirs revealed that the overall number of cattle improperly stunned via a captive-bolt gun was approximately 9% (von Wenzlawowicz et al 2012), while a Swedish investigation found 12.5% of the cattle insufficiently stunned, of which 16.7% were bulls compared to 6.5% other cattle (Atkinson et al 2013). Gregory et al (2007) reported a higher prevalence of poorly stunned bulls (14.0–16.3%) compared to steers (5.2–7.4%) and heifers (4.7–6.1%). Even well-