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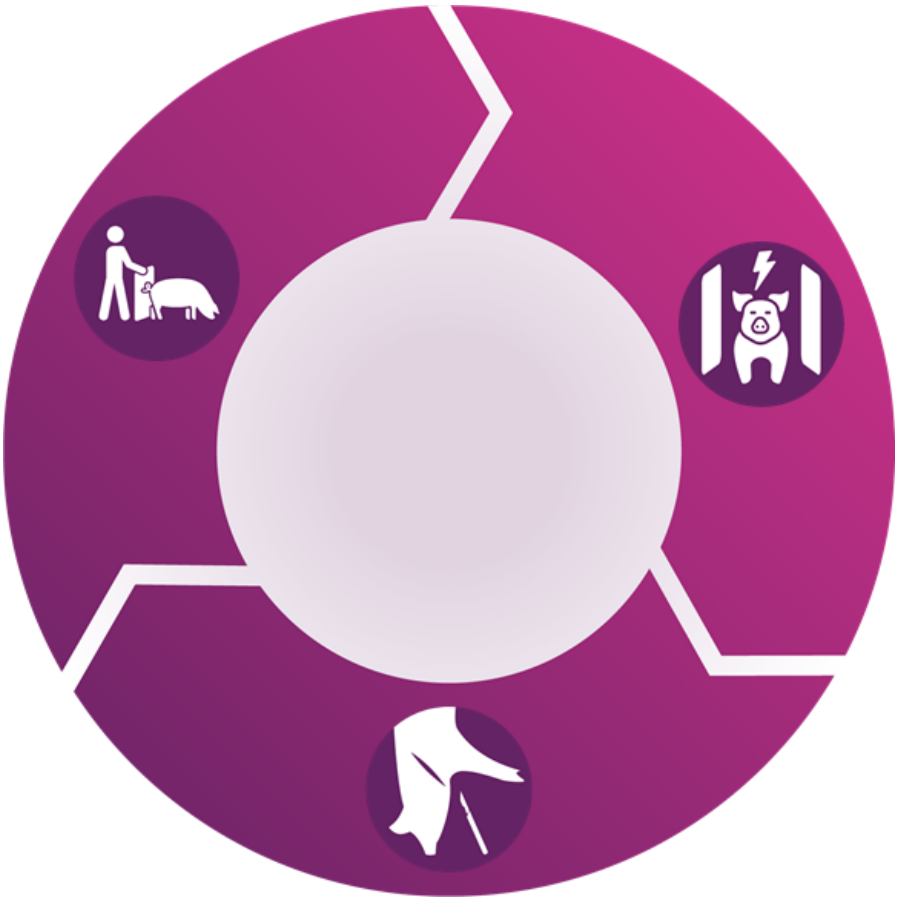

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Review of pig welfare in slaughterhouses at stunning and bleeding

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Each EURCAW-Pigs review provides background information on the biological relevance of the welfare topic. It then presents the most important key areas to focus on during welfare inspections, describes why welfare issues occur and lists specific animal-based indicators that can help official inspectors to identify these welfare issues. Finally, the review summarizes ways of good and better practices that can help to solve the previously described welfare issues, and deals with related legislative requirements.

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Contents

1 Executive Summary

The general requirement of the Council Regulation (EC) No 1099/2009 (EC, 2009) is to protect animals at the time of killing such that they are spared any avoidable pain, distress or suffering (Article 3). The regulation thus recognises that killing animals may induce pain, fear and distress even under the best available technical conditions. Therefore, any person involved in the stunning or killing of animals should take the necessary measures to avoid pain and minimise distress and suffering during the slaughtering and killing process, taking into account the best practices in the field.

This review highlights the following 3 key areas relevant for animal welfare at the time of stunning and killing, some of which have been subdivided further: handling (moving into the stunner and restraint for the purpose of stunning), stunning (electrical stunning and CO2 stunning) and killing (bleeding).

The review addresses the underlying scientific knowledge, key areas to focus on during welfare inspections around stunning, how to minimise welfare problems and facilitate improved practices, as well as the underlying legal requirements.

Slaughter must legally spare animals any avoidable pain, distress or suffering. This implies that moving animals into the stunner and holding them there for the purpose of stunning must be done without causing undue fear and distress as may be shown by animals vocalising and trying to turn back or being reluctant to move. Stunning should apply proper electric current or CO2 concentrations such that animals rapidly lose consciousness and do not recover before they have been killed by bleeding. Operators must carefully watch for signs of recovery throughout the process following stunning and perform re-stunning immediately when there is any reason for doubt such as righting responses, vocalisation, breathing movements, or responses to pain or touch (e.g. palpebral and corneal reflex). Best practices minimize stress during slaughter, during handling, stunning and bleeding.

2 Introduction

When pigs are to be slaughtered Council Regulation (EC) No 1099/2009 requires that the animals are spared any avoidable pain, distress or suffering (Article 3). In practice this implies that the killing process, which is usually done by bleeding, is preceded by a stunning procedure intended to render the animal unconscious with the least possible amount of fear, pain or distress. The two main stunning methods applied at pig slaughter are electrical stunning and gas stunning using CO_2. These stunning methods differ in important respects. Electrical stunning provides an instantaneous stun but requires individual restraint, whereas gas stunning results in a gradual loss of consciousness but can be applied to groups of pigs resulting in a reduced sense of social isolation. This review will not deal with mechanical stunning methods, such as the penetrative captive bolt or with emergency stunning or killing practices.

To evaluate compliance with the detailed requirements in Council Regulation 1099/2009 (see chapter 6), animal welfare inspectors assess resource- and/or management-based indicators, e.g. stunner settings and current-output values. However, this should always be complemented with the evaluation of a sufficient number of animal-based indicators (ABI) applying measurable and objective outcome-based criteria to

evaluate the welfare of animals at slaughterhouses as this could complement and to some extent confirm the (validity of the) welfare input-based criteria.

Animal-based indicators should be used to assess animal welfare at the time of slaughter. In this review, the following three relevant key areas and corresponding animal welfare indicators are described to assess pig welfare in the stunning and bleeding process:

1. Handling
2. Stunning
3. Bleeding

Chapter 3 presents the underlying scientific knowledge. Chapter 4 identifies key areas for inspectors to focus on during welfare inspections, in particular animal-based indicators (ABIs) to assess proper handling, stunning and bleeding. Chapter 5 describes (suggestions for) improved practices. The final chapter specifies the legal requirements in Council Regulation 1099/2009 related to the three key focus areas (handling, stunning and bleeding).

3 Scientific knowledge on stunning and bleeding, and how this relates to pig welfare

This chapter mainly deals with the effects of handling, stunning and bleeding on the welfare of pigs, and on how the stunning methods and bleeding lead to unconsciousness or death.

Stunning, in the context of EU Regulation 1099/2009 regarding killing at the time of slaughter, is any intentionally induced process which causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death (EC, 2009). The stunning phase includes both the restraint and the stunning processes itself. In this perspective 'restraint' means the application to an animal of any procedure designed to restrict its movements so as to spare it any avoidable pain, minimise fear and facilitate effective stunning and killing. Animals must be rendered unconscious and insensible by the stunning method and they must remain so until death occurs through bleeding. All three steps, i.e. moving into the stunner, restraint, stunning and killing by bleeding must be executed while minimising fear, pain and distress for the animals being slaughtered (Council Regulation 1099/2009, Article 3).

The main stunning methods employed in the slaughter of pigs are electrical stunning and CO_2 stunning. The latter falls into the category Controlled Atmosphere Stunning (CAS).

3.1 Handling

Before pigs can be restrained for stunning, they are moved from the lairage pens to the stunning area. This review will not deal with this as it is described in the EURCAW Review on "handling and moving in lairage" (Holmes et al., 2020). However, we will discuss some aspects of handling and moving of pigs that are specifically related to the stunning methods used. After arriving at the stunning area pigs are usually moved into the stunner manually in the case of electrical stunning, and using automatic pushing gates in the more recent CAS stunning systems.

Handling directly related to stunning and killing involves moving animals such that they can be restrained for stunning. This differs between the two main methods of stunning (electrical and CAS).

Handling prior to electrical stunning

Before electrical stunning, each pig has to be isolated to enter a stunning box for individual (manual) stunning, or into a single file for automated stunning. Moving pigs from a group into a single line and restraining them individually can be very stressful to the animals (Troeger, 1989). Social isolation is known to be stressful to pigs (Soler at al., 2013), but moving in a single file on a trail is a natural behaviour for pigs and does not have to be stressful (Wood-Gush and Stolba 1982). However, forcing animals from a group into a single line is often the most critical part of the process due to the high slaughter speed, and this is an important reason why many of the major slaughterhouses in Europe have moved to CAS.

The construction of the raceway leading to the stunning area (e.g. bottlenecks, corners or right angels), light management in the raceway and stunning area, the circulation of air, obstacles, slippery floors and noise may have a significant impact on the pigs' willingness to enter the raceway (Grandin, 2010). Rough handling, e.g. the use of too much pressure or force, shouting, hitting or the use of (electric) goads to force the animals from a group into a single line raceway, and unfamiliar sounds and smells including fear-related vocalisations of other pigs will lead to fear and reluctance of the animals to move in the direction of the stunner. This also applies to the use of rattles. They increase the general noise levels when used frequently, which can lead to renewed refusal to move forward. So, if used too often, rattles can lead to a counterproductive effect, reinforcing the effects of suboptimal design of, for example, drive tracks. In fully automated systems another critical factor is the ''stop-start'' motion of pigs in the raceway towards the stunner due to the flip-flop gate between two raceways allowing pigs one by one onto the restraining conveyor belt.

Figure 3.1.1. Pig on a centre-track (or breast-band) restrainer belt (© M. Marahrens, FLI)

Pigs are being carried to the point of stunning on a V-type restrainer or on a centre-track conveyor belt with their feet lifted from the ground (Figure 3.1.1). This lifting can make the transition from moving in a group to the single file in the slaughterhouse extremely stressful for the pigs (Troeger, 1989). At the point of isolation, depending on the layout and handling, pigs may attempt to back out or **turn back** or may be **reluctant to move forward** into the race while vocalising at high pitch. Also, **high pitch vocalisation** before the stunner,

due to fear or the application of electric prods or other handling devices causing pain, can be a significant indicator for assessing animal welfare issues at this point.

Figure 3.1.2. Moving pigs in lines in the raceway to the electrical stunner (© V. Michel, 2019)

Design of the raceway, like a carousel or a curved raceway, can facilitate the flow of the pigs (Jones, 1999; Grandin 1990) and therefore reduce the level of fear and stress when moving pigs from a group into a single line (Figure 3.1.2). The raceway and entrance to the restrainer or stunner should not have sharp edges and should be always clean to maintain movement of animals without the need to use force and avoid animals slipping and falling (Grandin, 2021). Reducing the loading speed and giving animals the time and opportunity to orientate themselves and to go from a group into a single line will prevent or reduce the level of fear and stress.

Handling prior to CO_2 stunning

In contrast to electrical stunning, during the CO_2 stunning process, pigs are driven in small groups into the stunner. In modern slaughterhouses groups of approximately 15 pigs are separated in the lairage area by automatically operating doors, and moved as a group to the stunner by hydraulic push gates. In the last step before entering the CAS stunner the group of pigs is split into smaller groups depending on the size of the pigs and the size of the gondola. Entering pigs into the stunner in small groups, of approximately 2-8 animals, using automatic doors is less stressful to the pigs than the isolation of pigs prior to electric stunning (European Food and Safety Authority (EFSA), 2004; Velarde et al., 2000). However, if pigs can hear other pigs screaming in the stunner or if the pressure on pigs is too high and the raceways are overloaded the advantage of moving the pigs in groups compared to handling into a single raceway will be abolished. Especially when automatic gates are lowered onto pigs' backs or limbs, or pigs are pushed forward while not walking; this may cause significant stress, pain and fear. In order to maintain a high speed of slaughter, the slaughter staff may (contrary to Regulation 1099/2009) put pressure on the pigs by using electric prods, put pressure on sensitive parts of pigs' bodies, drive them with hard devices, strike or kick the animals to encourage their movement

which will lead to pain, fear and suffering (Jones, 1999). Rough handling here, by humans or by wrong use of automatic doors and gates can provoke **high pitch vocalisation** and also lead to pigs **slipping**, **falling** or **turning back,** causing pain, injuries and fear.

In the presence of normal atmospheric air (absence of a high CO_2 concentration), the process of entering the gondola, i.e. the cage, and the gondola with the pigs being lowered into the pit causes moderate aversion a change of environment to which pigs can habituate if they are exposed to it repeatedly (Velarde et al., 2007; Dalmau et al., 2010). EU regulation states that the space allowance in the gondola shall be enough to allow the animals to lie down without being stacked even at maximum permitted throughput (EC, 2009 (Art. 8, Art. 14, and Annex II, Point 6.3); EFSA, 2020).

3.2 Stunning

Electrical stunning

Electrical stunning is based on the principle of passing an electric current of enough magnitude through the brain of the pig that induces a generalised epilepsy (see for details EFSA, 2004; EFSA, 2013) leading to immediate loss of consciousness. Electrical stunning can involve one or two cycles, but here we focus on one-cycle stunning only, as two-cycle methods (i.e. first head-to-body and then across the chest) are a risk to pig welfare. One-cycle electrical stunning can be applied as head-only stunning or as head-to-body stunning, which includes the stopping or altering of heart functionality

The neuronal basis of inducing unconsciousness and insensibility using electrical stunning is to block the normal functioning of neurons in the thalamus and cerebral cortex, which is a necessary condition for perceptual processes (i.e. nociception) and consciousness (as a prerequisite of e.g. the experience of pain). The extent to which the brain is affected causing unconsciousness and insensibility (as required by Art. 2 (f) of Regulation EC No 1099/2009) is best demonstrated using EEGs (Electro-Encephalograms) or ECoGs (Electro-Corticograms). Both record the spontaneous and induced (somatosensory, visual and auditory) evoked electrical potentials in the brain and allow trained experts to ascertain the state of consciousness and sensibility following stunning. The (patho)physiological basis of loss of consciousness and sensibility after electric stunning is a unique brain state of epileptiform activity of the Grand Mal type involving generalized depolarization of synaptic membranes, followed by a suppressed phase detectable in EEG/ECoG recordings (Raj, 2015).

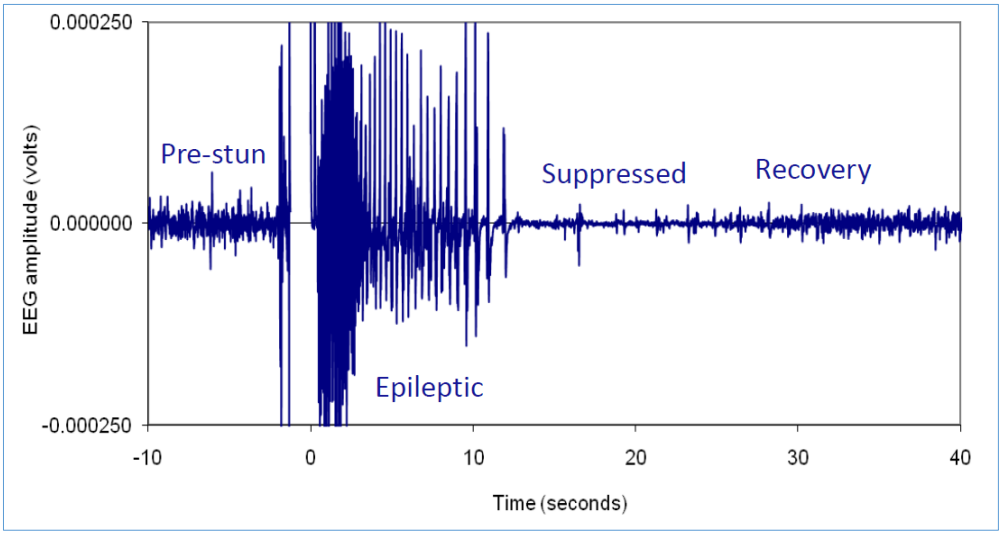


Figure 3.2.1. EEG recording in a pig before, during and after electrical stunning (Raj, 2015; © M. Raj)

According to Regulation 1099/2009, certain behavioural patterns and spontaneous or provoked physical reflexes can be used as animal-based indicators (ABIs) for effective stunning if it has been documented that these indicators are associated with altered brain states measured by EEG/ECoG. Thus, ABIs can function as proxies for unconsciousness (EFSA, 2013; see Chapter 4 for more details on the use of ABIs). Epileptic and suppressed brain states may lead, for example, to tonic rigidity or to collapse, apnoea, subsequent tonic – clonic seizures and the absence of eye reflexes, such as the cornea and eye-lid reflex, in different time frames.

Effective electrical stunning leads to a loss of consciousness and sensibility in pigs, which during the flow of current is accompanied by an immediate collapse in the hindquarters, stretched forelegs, and tonic rigidity of the entire body. Immediately after the current flow, depending on the amount of current and the applied frequency and waveform, the pigs first show a continuation of the tonic phase or a collapse of the body, which changes into a phase of tonic-clonic seizures, indicative of generalized epileptiform activity in the central nervous system. Typically, during the tonic phase pigs are in a state of tetanus with rigidly stretched front and flexed hind limbs, without showing breathing activity, and eyeballs fixed or rotated into the socket. The subsequent clonic phase is characterised by kicking, paddling or galloping movements of mostly the hind legs, but combined with a more or less rigid body trunk. Thus, effective electrical stunning is characterized also by an immediate **loss of breathing** (i.e. no effective breathing activity, i.e. apnoea with or without some ineffective gasping) lasting throughout the bleeding phase until death of the animal (Berghaus and Troeger, 1998; Gregory, 1998; EFSA, 2013). The presence of breathing indicates an ineffective electrical stun whereas stunned animals recovering consciousness will start to breath in a pattern commonly referred to as rhythmic breathing which involves respiratory cycles of inspiration and expiration, and may begin as a kind of gagging or retching. Rhythmic breathing can be recognised from the regular movements of the chest, flank and/or mouth and nostrils.

Under certain circumstances, after electrical stunning and during bleeding, gasping may occur, characterized by a drawing of the lower jaw of the opened mouth towards the thorax. It can be assumed that this is reflex-like muscular activity in the ventral part of the neck of the animal. Gasping is not to be confused with functional breathing activity, especially since the chest is not active and the lungs are not filled as happens

during inspiration. Nevertheless, gasping more than three times may indicate ineffective stunning requiring re-stunning (AG Tierschutz der Länderarbeitsgemeinschaft Verbraucherschutz (LAV), 2019).

In case of an effective electrical stun, spontaneous and directed eye movements, blinking and vocalisations are absent, as is any sign of a **righting reflex** (i.e. attempts to raise head or regain posture).

The third phase to be mentioned here, following the tonic and tonic-clonic phase, is the recovery phase. Recovery would typically occur following stunning unless prevented by immediate and adequate bleeding. The recovery phase can begin after as little as 30 seconds. If head-only stunning is applied or if ventricular fibrillation has not been triggered by the electrical current, electrical activity in the brain may normalize if the blood loss during debleeding is too low, and signs of consciousness and sensibility will return (McKinstry and Anil, 2004). During exsanguination, cerebral hypoxia occurs within 20-60 seconds after the bleeding starts. The bleeding must, therefore, have progressed to such an extent that a possible onset of a recovery of consciousness or the occurrence of related indicators is excluded beyond reasonable doubt. Sticking should happen as fast as possible, i.e. during or towards the end of the tonic phase or at the very start of clonic activity. Progressively during bleeding, the body of the properly stunned pig relaxes, as indicated by completely relaxed legs, floppy ears and tail, relaxed jaws with protruding tongue, and mainly open eyes with dilated pupils (EFSA, 2013).

Sticking during the clonic phase, or sticking more than 10 seconds after the end of stunning is a serious risk factor of poor welfare because recovery may be seen as quickly as 30 seconds after the end of stunning and it takes another 20-60 seconds for bleeding to take effect (see also below). For this reason, the carcasses should only be hoisted after bleeding, as otherwise the bleeding stitch can only be applied after a delay.

In addition to the visual inspection a range of tests are available to monitor the effectiveness of electrical stunning in individual animals. For their use it should be noted that the electrical stunning epileptiform seizure may produce false positive results (hyperreflexia) during reflex testing (Vogel et al., 2011; LAV, 2019). Brain stem reflexes such as the corneal reflex are difficult as measures of unconsciousness in electrically-stunned animals, as they may also reflect residual brain stem activity and not necessarily consciousness (Verhoeven et al., 2015). For this reason reflex tests on the eye and pain reflexes on the nasal septum are only valid after a latency period of about 40 seconds due to the possible overlap caused by tonic or clonic activity.

The first observations shall be done immediately after the ejection from the stunning box. It includes a visual check of each animal for the **presence of a tonic** state and absence of directed or voluntary movements, vocalizations, regular breathing or a spontaneous blinking of the eyes (see the toolbox figures 4.2.1 and 4.2.2 in Section 4.2). Conscious animals may show spontaneous blinking, and, therefore, this sign can be used to recognize ineffective stunning or recovery of consciousness after electrical stunning. However, not all conscious animals show spontaneous blinking (EFSA, 2013 When specific signs of ineffective stunning occur, corrective measures such as a second/repeated stunning procedure must be taken before the bleeding.

About 40 seconds after the end of the electrical stun additional reflex tests such as the “palpebral or corneal reflex” on the eye of the animal and the “**pain reflex**” at the nasal septum (e.g. by using a curved telephone tong) can be performed (Anil, 1991; EFSA, 2013). Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus.

In case these measures indicate insufficient stunning, the animal must be re-stunned immediately. This applies not only to cases where animals are conscious. It also applies when there is a high risk of regaining consciousness. It even applies to cases that are less clear, i.e. also when in (any) doubt, perform another stun immediately, and thus give the animals the benefit of the doubt. Stunning equipment must be verified to identify the cause of the problem.

Several factors can contribute to insufficient stunning such as when the electrical parameters are not set at the appropriate level (i.e., too low applied voltages or current), unable to overcome the electrical impedance/resistance in the pathway, wrong placement of the electrodes, or dirty electrodes (see e.g. EFSA, 2004; Anil and McKinstry, 1998; Stocchi et al., 2014; Nodari et al., 2014). It is therefore, important to monitor the stun quality and adjust the settings to suit different animal types (e.g. fattening pigs vs boars and sows). Furthermore, cleaning and good maintenance of the electrodes will improve stunning efficiency.

Head only

For head only electrical stunning the electrodes or stunning tongs are manually or mechanically placed on either side of the head of the pigs, between the eyes and the base of the ears, such that they span the brain. In head-only electrical stunning a minimum current of 1.30 amperes (amps) should be delivered (Council Regulation 1099/2009). The duration of the period of unconsciousness depends on the amount of current delivered to the brain and the exposure time. It is recommended to deliver the current for at least two to three seconds to produce a state of unconsciousness, which will persist until death occurs through bleeding (EFSA, 2004). Some Member States have introduced a minimum flow time in their animal welfare legislation (as the “minimum exposure time” has to be specified in the standard operating procedures depending on the stunning technique used in the slaughterhouse). With a minimum stunning time of 4 seconds for slaughter pigs (as required by TierSchlV, 2012), and a minimum current of 1.3 amps, the German animal-welfare law prescribes a minimum electrical charge of 5.2 coulombs (As) (Verband der Fleischwirtschaft (VDF), 2014). Extremely long exposure times, i.e. >10 seconds, will not further extend the duration of the stun, as depolarisation cannot be iterated during an ongoing stunning intervention. Although, the stunning depth and duration do not increase with flow times above 4 seconds, longer exposure times result in stronger/longer-lasting muscular immobilization: the bleeding stick can be placed better by the slaughterman. However, at the same time inadequate stunning is much more difficult to detect, if at all, because the animal is not able to make any defensive movements due to the paralytic effect of the electrical current on the muscles (EFSA, 2013).

A transformer supplying a constant current may also be used in stunning facilities. In automated systems this is required by Council Regulation 1099/2009, and it is preferred in manually-operated electrical stunning. The transformer ensures that the minimally-required value is reached as quickly as possible (150 – 250 msec. in practice, Troeger 1991). In this case the voltage is variable and high voltages cause the skin resistance to collapse (Troeger, 1991; Sparrey and Wotton, 1997). But the voltage required to reach the threshold current also depends on the frequency of the alternating current (EFSA, 2004; Algers et al., 2009). In the German slaughter ordinance, the minimum current values, therefore, are based on a sinusoidal or rectangular alternating current of 50 to 100 Hz (TierSchlV 2012; VDF, 2014). To reduce the transmission resistance, the electrodes should have the correct form (i.e. spikes), size (i.e. contact area), maintenance condition, and cleanliness, but the contact pressure used also plays a major role (EFSA, 2004; Sparrey and Wotton, 1997; Von Wenzlawowicz et al. 2012; VDF, 2014). By regular cleaning during a working day, e.g.

with a wire brush, the electrodes must be freed from dirt that may increase the contact resistance (Grandin, 2021).

Animal-based, and also size and age-dependent, factors for high resistance to current flow are skin condition (thickness, conductance), thickness and porosity of the skull, the proportion of brain tissue and the size, hair and shape of the head of the animals, which affects the distance between the electrodes (Troeger, 1991; Wotton and O´Callaghan, 2002). The degree of dirt and the wetness of the animals' skin may also play a role. Although the latter reduces the contact resistance between the electrodes and the skin, it also increases the risk of superficial current dissipation.

The minimum current values specified in Council Regulation 1099/2009 were generally investigated scientifically in the 1980s and 1990s. At that time the average body weight of slaughter pigs was, in many countries, about 100 to 110 kg. However, in recent years the average slaughter weights have in many cases increased to 120-130 kg or even higher, and in some regions of Europe heavy pigs may be slaughtered at a weight of 160 kg, e.g. for the production of traditional dry- cured hams (Bava et al., 2017). Therefore, the minimum values for the current to be applied in the category "slaughter pig" may not be sufficient for effective stunning in all cases. For the same reason, currents of at least 2.0 amps are recommended for adult sows and boars (where slaughter weights normally range between 200 and 350 kg) (von Wenzlawowicz, 2009; von Wenzlawowicz et al., 2012). The German guides to good practice (implementing Art. 13 of Council Regulation 1099/2009) state that pigs weighing more than 150 kg live weight must be stunned with a current of not less than 1.8 to 2.0 amps (based on a frequency of 50 to 100 Hz; VDF, 2014; Stocchi et al., 2014).

According to Art. 8 of Council Regulation 1099/2009, it is the responsibility of the device manufacturer to prepare instructions for use, and to make them available on the internet, from which it is clear which parameters are required for a sufficiently long loss of consciousness and sensibility of the animals. It is the responsibility of the operator to ensure a sufficient stunning effect until death for the animals to be slaughtered on the premises in accordance with Art. 4 (1) and Annex 1 Table 2.1 and 2.2 of Council Regulation 1099/2009. For this purpose, it is necessary to specify the level of the minimum currents suitable for the selected frequencies, the minimum voltage, the minimum exposure time and the maximum stun-to-stick interval as key parameters in the corresponding standard operating procedure.

In addition to the application of a sufficiently strong current (or more correctly: a sufficient amount of charge or electrical energy (Knöll, pers. comm. 2020), the correct placement of the electrodes on the head of the pigs plays a central role in effective electrical stunning. The general requirement is: "the electrodes shall span the brain" (Reg. EC No 1099/2009). Practical conditions must be designed to make this possible (Hoenderken, 1978; von Wenzlawowicz et al., 2012). A simulation study on current density distributions during electrical stunning performed on the bodies of slaughter pigs, supported the common practice of placing the electrodes of the stunning tongs in such a way that the brain is located on an imaginary line between the electrodes (Eike, 2003). This ensures a maximum current intensity in the brain and thus an optimised stunning efficiency, if the parameters are set correctly. On the other hand, it is clear that if the electrodes are applied more caudally, the current intensity in the brain may be insufficient (Eike, 2003), and the voltage should be increased (Hoenderken, 1978). The current makes its way via the nerves (optic nerve) and blood vessels (carotids) into the brain, leading to the recommendation to place the electrodes as close

as possible behind the eyes and not more than 5 cm behind the ears (see Figure 3.2.2.; Anil and KcKinstry, 1998; Eike, 2003).

Figure 3.2.2. Head-only electrical stunning using hand-held stunning tongs (© IRTA)

In the case of manual stunning, the operator is generally beside the pig beneath the stunning box and has to place the electrodes in a vertical movement down to the head of the pig (see Figure 3.2.2). The electrodes are sometimes placed behind the ears, because this region is easier to reach, and this results in a lower effectiveness of the current flow (see above). For this reason, and in order to solve the problem that hanging ears in certain breeds may cover the proper stunning area, a new type of semi-automatic electrical stunning tong was developed recently in Germany (Knöll et al., 2021, see Figure 3.2.3). The forceps is placed behind the ears of the animal such that the electrodes are applied rostrally to the eyes.

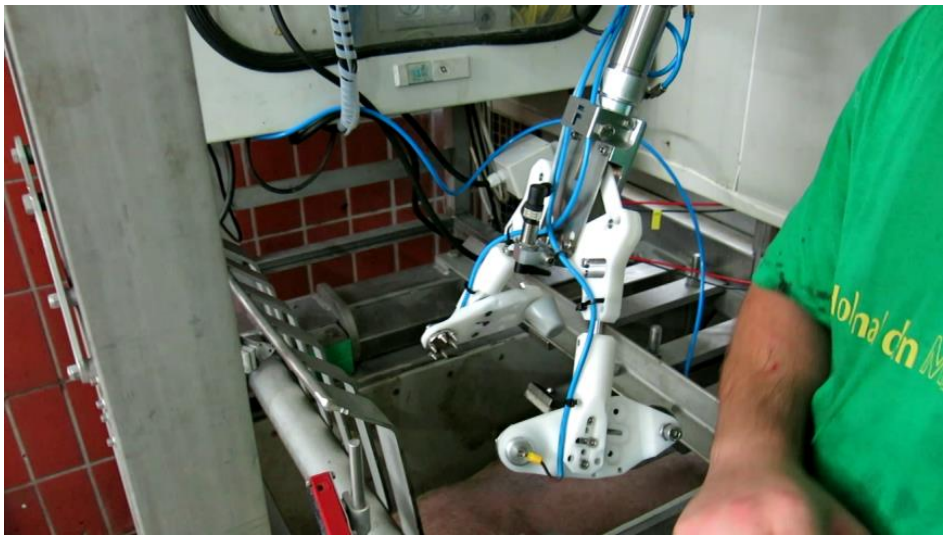


Figure 3.2.3. New semi-automatic pneumatic electrical stunning forceps © M. Marahrens, FLI; © Freund GmbH)

Head to body

Under high throughput commercial slaughter conditions head-to-body stunning is applied in an automated system were pigs are transported by a V-shaped conveyor or "riding" on a breast belt conveying restraining system to the stunning site (see Figure 3.2.4.). During head-to-body stunning, a third electrode is placed on the chest to induce ventricular fibrillation but not always, leading to cardiac arrest. This interrupts the flow of blood to the brain, reducing the risk of return to consciousness during bleeding compared to head-only electrical stunning. Like head-only, head-to-body stunning requires the killing of the animal by bleeding within a short period of time. Stunning is performed by applying a single current cycle in which electrodes are placed on either side of the head to induce unconsciousness and a third electrode placed on the chest to induce cardiac ventricular fibrillation. According to the requirements of the Reg. No. 1099/2009 as with head-only electrical stunning a minimum current of 1.3 amps shall be applied. A stun duration of 2-3 seconds, as for head-only electrical stunning, is advised. To ensure cardiac ventricular fibrillation a current should be delivered at a maximum frequency of 50Hz sine wave (AC) (EFSA, 2020).

Figure 3.2.4. Head-to-body stunning on a breast band conveyor restrainer. The electrodes are placed while the belt continues to move forwards (© A. Velarde, IRTA)

Effective head-to-body electrical stunning is as in head-only stunning characterized by tonic immobility during stunning. However, as with head-to-body stunning a part of the current may flow through the spinal cord animals may be partly paralysed or immobilized for a period of time which makes them less mobile. After the stun pigs show a tonic seizure followed by clonic convulsions comparable to those seen in head-only stunning. The convulsive movements will subsequently change to peddling movements followed by relaxation and loss of muscle tone as indicated by drooping ears and limp legs. Breathing is absent and eyes are fixed or rotated in their sockets. Corneal and palpebral reflexes are abolished, and reaction to pain stimuli are absent during the period of unconsciousness (again similar to what is seen in head-only electrical stunning).

Controlled Atmosphere Stunning using CO_2

The principle of gas stunning or Controlled Atmosphere Stunning (CAS) is that animals are exposed to a high concentration of CO_2, CO_2 mixed with inert gases, or inert gases only. High concentrations of CO_2 lead to hypercapnic hypoxia, reduced blood pH levels and rapid acidification of the cerebrospinal fluid (Verhoeven et al., 2016). This results in faster and deeper respiration in an attempt to increase pO_2 and decrease pCO_2 (Siesjö, 1972) and depression of brain activity leading to loss of consciousness and, when prolonged, death (Martoft et al., 2002). In practice, gas stunning for pigs mainly involves exposure of small groups of pigs to high levels of CO_2, which is the focus of this review.

Carbon dioxide especially at high concentrations (above 40%) is pungent and painful to inhale and leads to a highly aversive response involving very loud and high-pitched vocalisations and vigorous attempts to escape from the gondola and the exposure to the gas, including scratching other pigs vigorously with the claws of the front legs and trampling of pigs that have become recumbent. Furthermore, during the induction phase animals will show increased breathing and gasping associated with signs of breathlessness ("air hunger"). Induction of unconsciousness with CO_2 stunning does not immediately induce unconsciousness and the process is associated with fear, pain and respiratory distress (Verhoeven et al., 2016; Beausoleil and Mellor, 2015), lasting from the start of exposure to CO_2 until loss of consciousness. Depending on the gas concentration the duration of this period will typically last up to approximately 15 to 30 seconds. In recital No. 6 of Council Regulation 1099/2009 it is recommended to phase out the use of carbon dioxide for pigs for animal welfare reasons, when economical alternatives are available. Key parameters for the application of gas methods are presented in Annex 1 Table 3.1 of Council Regulation 1099/2009. For this purpose, it is necessary to specify the CO_2 concentration, the duration of exposure, the maximum stun-to-stick interval and the quality and temperature of the gas. CAS stunning equipment is fitted with devices displaying and recording the gas concentration, giving an alarm in case of insufficient gas concentration. Furthermore, the exposure time is set.

Two main CO_2 gas stunning systems exist, the dip-lift system and the paternoster system. Dip-lift designs have only one gondola in the system. In this system, groups of pigs are lowered rapidly into maximum concentrations of CO_2 at the bottom of the pit (EFSA, 2004). The paternoster designs have up to seven gondolas, rotating through the CO_2 gradient in a 3–8-m deep pit. The paternoster system stops at various intervals for loading of conscious pigs on one side and unloading unconscious pigs on the other side for sticking (EFSA, 2004). In this system, pigs are more gradually exposed to an increased concentration of CO_2 gas, as the gondola is lowered into the pit, until the CO_2 concentration reaches 80–90% at the bottom of the pit (EFSA, 2004). Under commercial conditions the concentration of CO_2 should be at least 80%, but more and more slaughterhouse use 90% or higher in an attempt to increase throughput rates (Velarde et al., 2007) and still obtain an effective stun duration after a shorter exposure time.

Figure 3.2.5. Loading of a group of pigs in a gondola of a paternoster system to apply CO_2 stunning (© A. Velarde, IRTA)

Stunning pigs using a high concentration of CO_2 can be reversible (referred to as simple stunning in Regulation 1099/2009) or irreversible (stun to kill). The depth and duration of unconsciousness achieved with CO_2 gas stunning and whether the stun is reversible or not depends on the CO_2 concentration and the duration of exposure (Raj and Gregory, 1996; Troeger and Woltersdorf, 1991; Nowak et al., 2007; Verhoeven et al., 2016). Exposure times and gas concentrations are, therefore, two crucial parameters to control during gas stunning. In case of simple stunning, bleeding must start as soon as possible after stunning to prevent resumption of consciousness (Bolanos-Lopez et al., 2014). Under batch or group stunning situations as in CO_2 stunning of pigs, the duration of unconsciousness and insensibility becomes more critical because the time interval between the end of exposure to the gas and sticking (stun-to-stick interval) is considerably longer for the last animal as compared to the first in a group (Raj, 1999; Atkinson et al., 2012). Signs of consciousness after gas stunning are **righting reflex**, presence of **breathing** (other than gasping), **corneal or palpebral reflex**, **reaction to pain stimuli** and **vocalisation.** However, the time it takes for animals to regain consciousness can be increased, either through increased exposure time to the gas (Holst, 2001; Rodriguez et al., 2008; Llonch et al., 2013) or using higher CO_2 concentrations. Exposure of pigs to a minimum of 90% by volume of CO_2 in air for 3–5 minutes results in death of most of the pigs at the exit from the gas (Llonch et al., 2013).

3.3 Killing (bleeding)

Slaughter pigs are usually killed by bleeding. Bleeding is an important step in the slaughter process as it must be done soon after stunning so as to avoid unnecessary suffering due to animals regaining consciousness before they die as a result of blood loss. Before sticking, unconsciousness of the animals should be checked (see Chapter 4 on animal-based indicators (ABIs) and the toolboxes for the different stunning methods). Signs

of return of consciousness before and during bleeding are **the righting reflex**, **recovery of breathing**, **corneal reflex** and **spontaneous blinking** of the eye lids.

Pigs are bled following a chest stick aimed at severing the common brachiocephalic trunk which gives rise to the carotid arteries that supply oxygenated blood to the brain. Chest sticking is performed by inserting a knife on the ventral aspect of the base of the neck, just in front of the sternum, towards the thoracic inlet (Figure 3.3.1). The blade of the knife should be long enough to reach the brachiocephalic trunk. The size of the incision should be large enough to allow profuse bleeding and rapid onset of death (Anil et al., 1995; Anil et al., 2000). Correct or proper bleeding can be recognized by a **profuse blood-flow** from the sticking wound. The bleeding of slaughter pigs should take place in the first few seconds in a "gush" manner, so that about 2 liters of blood flow in the first 10 seconds or 4 – 4,5 liters in 30 seconds for a 120 kg slaughter pig (Deutscher Tierschutzbund (DTB), 2021).

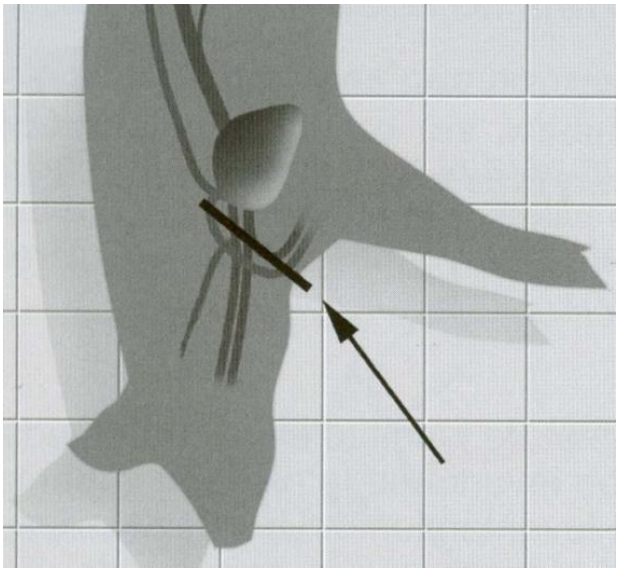


Figure 3.3.1. Illustration of chest sticking aimed at cutting the brachiocephalic trunk in a pig (Humane Slaughter Association, 2016; © HSA)

Bleeding can be performed when pigs are hoisted immediately after stunning and hanging on the slaughter line or when they are still laying in horizontal position on a bleeding table or conveyor. The latter practice is necessary to minimise the delay between stunning and bleeding.

For the execution of the bleeding stick, Regulation (EC) No 1099/2009 requires the definition of a maximum stun-to-stick interval as a key parameter after which the bleeding stick must be set when drawing up the standard operating procedure for almost every stunning method. However, it does not itself specify a stun-to-stick interval. The principle is to carry out the bleeding without any delay and thus preferably before hoisting. For example, in electrical stunning of pigs bleeding should be performed within 15s after the end of stunning (HSA, 2006). A fast bleeding rate minimises the risk of pigs regaining consciousness during the bleeding phase. This is generally only possible with the correctly placed chest stick (VDF, 2014, LAV, 2019).

b)

c)

Figure 3.3.2 and 3.3.3. b) Illustration of bleeding pigs hanging on an overhead rail (© L. Berg); c) Illustration of bleeding pigs laying on a conveyor (© EFSA)

Animals being conscious at sticking or regaining consciousness during bleeding are a serious animal welfare concern. The incision made in the chest) for the purpose of bleeding involves substantial tissue damage in areas well supplied with nociceptors and is therefore regarded as painful (EFSA, 2013).

The stun-to-stick interval should be appropriate depending on the stunning method and slaughter situation. Effective head-only electrical stunning (using the reversible "simple method") can lead to return of consciousness within 35-40 seconds (Anil, 1991). Effective head-to-body electrical stunning (which is also reversible) will prolong the duration of unconsciousness, and therefore reduce the risk of recovery of consciousness before sticking or during bleeding. However, sticking should be performed immediately or at least within 10-15 seconds after the end of stunning, depending on the performed stunning and bleeding technique. In group stunning using CO_2 the stun-to-stick interval will inevitably be longer for the last pigs of the group to be bled. In case CO_2 stunning is reversible (the "simple method") special attention should be paid to the stun-to-stick interval. Since it depends on CO_2 concentration and exposure time, no general or maximum duration of the stun-stick interval can be set. In some member states, however, the stun-to-stick interval is limited, e.g. to 10 seconds in case of bleeding on a conveyor belt, or 20 seconds after hoisting onto a rail. In such cases extended stun-to-stick intervals of animals processed in groups require approval by the competent authorities. Also in cases where the CO_2 stunning is expected to be irreversible based on the settings, this cannot be guaranteed for 100 % of the pigs. Some Member States will hence ask for a maximum stun-to-stick interval in the SOPs also for these situations, but then accepting up to 60 seconds for the last pig in the group.

To avoid recovery of consciousness due to inaccurate or delayed bleeding (prolonged stun-to-stick interval), irreversible stunning is recommended. In case of reversible stunning, it needs to be ensured that the period

of unconsciousness lasts until death occurs due to blood loss as a result of bleeding (Figure 3.3.4). The bleed-out time should be long enough to allow for death to occur in all animals. Absence of life (Terlouw et al., 2016a,b) should be confirmed in each individual animal before carcass processing begins (e.g. entering the scalding tank). Signs of absence of life as indicated by ABIs include complete **cessation of bleeding**, complete **relaxation of the body** or **absence of muscle tone** or activity, and **dilated pupils.**

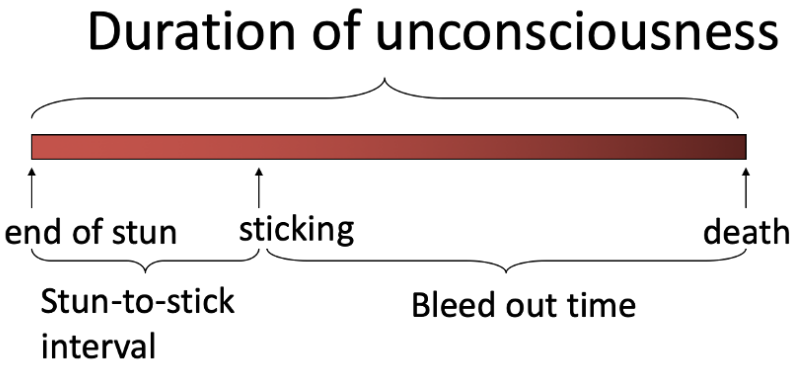


Figure 3.3.4. Period of time between stunning and death due to bleeding in case of slaughter (from EFSA, 2004; © EFSA)

4 Key areas to focus on during animal-welfare inspections by assessing animal-based indicators

In addition to the environment-based parameters required by law (Regulation 1099/2009) like electrical settings in case of electrical stunning, (records of) gas concentrations in case of CO_2 stunning and the stun-to-stick time interval, this chapter deals with animal-based indicators inspectors should use to complement their welfare assessment.

4.1 Handling

Effective handling can be checked by assessing animal movements (not turning back or being reluctant to move; not slipping or falling) and e.g. from the absence of high-pitch vocalisations (see Section 3.1 and Table A1 in the Annex of this review).

4.2 Stunning

Effective stunning can be checked by assessing consciousness or unconsciousness using ABI's. The outcomes of an ABI can indicate consciousness or the risk of return of consciousness (for example '**breathing**') or unconsciousness (for example '**apnoea**'). Some of the ABI's are specific for a stunning method whereas others applies to both electrical stunning and CAS (see also the Annex of this review).

ABIs of consciousness have to be checked through the three key stages of the slaughter process: immediately after stunning (at the end of stunning and before sticking or possible hoisting), during sticking and during bleeding (between sticking and the start of the further processing of the body). The assessment of the state

of consciousness leads to two possible outcomes: signs of consciousness and signs of unconsciousness (Terlouw, 2020). However, the presence or absence of certain ABIs can also indicate a risk of consciousness or return of consciousness. For example, vocalisations and breathing are present in conscious animals but can also be present in unconscious animals. The presence of breathing, therefore, is a sign of consciousness or of the possibility of return consciousness.

In case signs of consciousness or signs of regaining consciousness appear after stunning, appropriate back-up stunning should be applied immediately (see also Chapter 3).

Animal-based indicators (ABIs) of effective electrical stunning

Effective electrical stunning will abolish reflexes that require brain control. For example, the **palpebral** (elicited by touching the inner or outer canthus of the eye) and **corneal** (elicited by touching the cornea) **reflexes** and response to external stimuli including **pain response** (e.g. nose prick) are absent during the period of unconsciousness following electrical stunning (Anil, 1991). However, during epileptic-like seizures the presence of (only) a corneal reflex may not indicate sensibility per se and the corneal reflex can still be present or return when other signs of sensibility or consciousness are absent (Vogel et al., 2011). Brain stem reflexes such as the corneal reflex should be interpreted with caution as measures of unconsciousness in electrically stunned animals, as their presence may reflect residual brain stem activity and not necessarily consciousness (Verhoeven et al., 2015). Due to possible occurring of so called “hyperreflexia” reflex tests on the eye are only valid after a latency period of about 40 seconds due to the possible overlap caused by tonic/clonic epileptiform activity (LAV, 2019). For this reason, controls and tests of electrical stunning effectiveness shall be carried out at two different moments in time before and after the bleeding stick has been made.

For head-only electrical stunning EFSA (2013) suggested the following flowchart (Figure 4.2.1) for monitoring the state of consciousness using ABIs (blue boxes in Figure 4.2.1), to be used at three key stages. For each key stage three ABIs that are reliable in monitoring consciousness are suggested (above the dashed line), plus other two or three ABIs, which are seen as less reliable or less specific, that can be used additionally (below the dashed line), especially when occurring in combination. For example, presence of spontaneous blinking, combined with occurrence of vocalisations (both below the dashed line), is a clear sign of unsuccessful stunning and a conscious animal. On the other hand, as indicated earlier, a positive corneal reflex is, by itself, not necessarily indicative of consciousness. For each ABI, corresponding outcomes indicating consciousness or unconsciousness are reported. When shown in grey, the outcome is less specifically indicative of the state of consciousness. For example, the absence of vocalisation (shown in grey) does not necessarily mean that the animal is **un**conscious (even though an unconscious animal will not vocalise), but the presence of vocalisation (shown in black) is a clear sign of consciousness. So, the presence of vocalisation means that the animal is conscious and is therefore a relevant ABI (even though it is shown below the dashed line) but absence of vocalisation does not unambiguously indicate unconsciousness (see above and Figure 4.2.1).

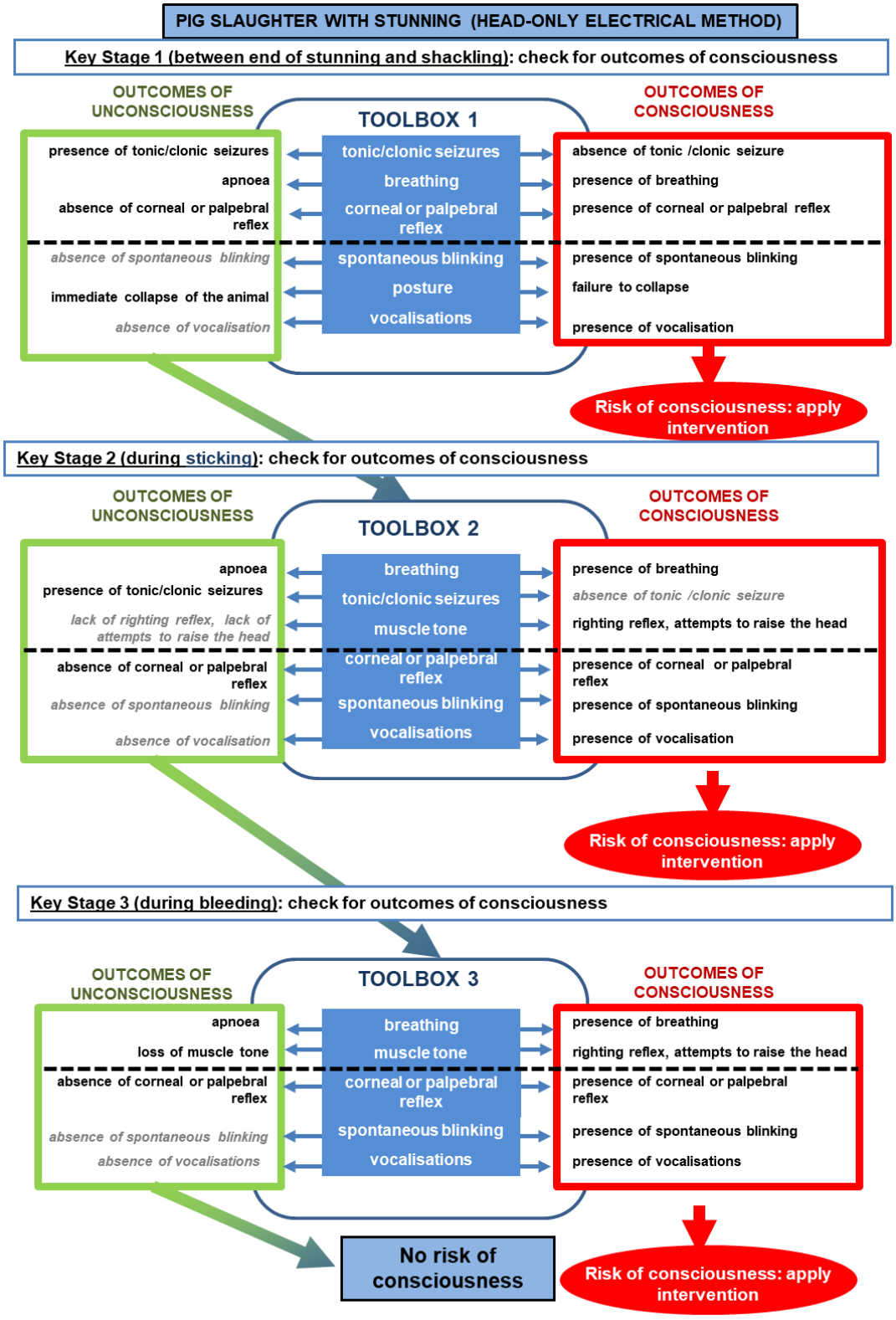


Figure 4.2.1. Flowchart including animal-based indicators (ABIs) for the monitoring of the state of consciousness. See the text for explanation of the dashed line and grey ABI outcomes (figure taken from EFSA (2013), p.46; © EFSA)

It must be emphasised that the indicators of insufficient stunning listed in the flowchart are not subject to any weighting. In particular, immediate action must be taken if spontaneous reactions occur, such as vocalisations, eye blinking or attempts to rise up. In case any of the indicators of consciousness is observed in key stage 1 then an intervention should be applied (i.e. a backup method of stunning be performed, or if it concerns only one (and not more than one) of the "less reliable indicators" after a single occurrence (possibly accidental) a thorough assessment of other indicators may be applied as an alternative, even though it is more humane and sustainable to just perform another stun to avoid any risk of an animal being conscious. After any re-stunning, the monitoring of unconsciousness, according to the flowchart, should be performed starting at the top of the chart again. Only when exclusively outcomes of unconsciousness are observed the process can continue to the next step. Following key stage 3, in case any outcome indicating consciousness is observed an intervention should be applied. When all outcomes are indicating death (including complete cessation of bleeding, complete relaxation of the body, absence of muscle tone or activity, dilated pupils and absence of breathing), the animals can be processed further.

Animal-based indicators of effective CO_2 stunning

The earliest sign of onset of unconsciousness and insensibility during exposure of pigs to high concentrations of CO_2 is the **loss of posture** (Verhoeven et al., 2016). After loss of posture convulsions may occur (Terlouw et al., 2021). However, observations of CO_2-gas stunning suggest that it may not always be possible to determine the exact time to loss of posture as pigs start to show excessive movements (excitation phase) prior to loss of posture. As exposure to the gas mixture continues, these convulsions stop, leading to a **complete loss of muscle tone**. Exposure to high levels of CO_2 leads to suppression of respiration, gasping, ending in complete cessation of respiratory activity (Raj, 1999). Other signs of unconsciousness induced by exposure to high concentrations of CO_2 include fixed eyes, dilated pupil, absence of the palpebral and corneal reflexes, and absence of response to painful stimuli such as nose prick or ear pinch (Raj, 1999; Rodriguez et al., 2008). However, Rodriguez et al. (2008) reported that 18% of the animals exposed to 90% CO_2 for 79 seconds did not lose the corneal reflex until 18 seconds after exit of the stunner. Brain stem reflexes like the corneal reflex are the last reflexes that will normally disappear in the process of inducing deep unconsciousness. When the corneal reflex is the only reflex that is still present it may not unequivocally indicate consciousness or sensibility (Verhoeven et al., 2015). This means that animals may have lost consciousness before the corneal reflex is lost. Therefore, absence of corneal reflex is a conservative but very reliable ABI to assure unconsciousness.

For CO_2 stunning EFSA (2013) suggested the following flowchart (Figure 4.2.2) for monitoring ABIs to assess the state of consciousness, to be used at three key stages. For each stage three ABIs are suggested that are reliable in monitoring consciousness (above the dashed line), plus two or three somewhat less reliable or less specific ABIs, that can be used additionally (below the dashed line). Each ABI may indicate consciousness or unconsciousness. In case any of the ABIs is indicating consciousness an intervention should be applied (i.e. a backup stunning method should be applied, and when it concerns only one less reliable ABI even then backup stunning is preferred). After any re-intervention, the monitoring of unconsciousness, as indicated in the flowchart, should be repeated. Only when unconsciousness has been ascertained the process can continue to the next step. Following key stage 3, in case any outcome indicating consciousness is observed an intervention should be applied. When all outcomes are indicating death (including complete cessation of bleeding, complete relaxation of the body, absence of muscle tone or activity, and dilated pupils, absence of breathing), the animals can be processed further.

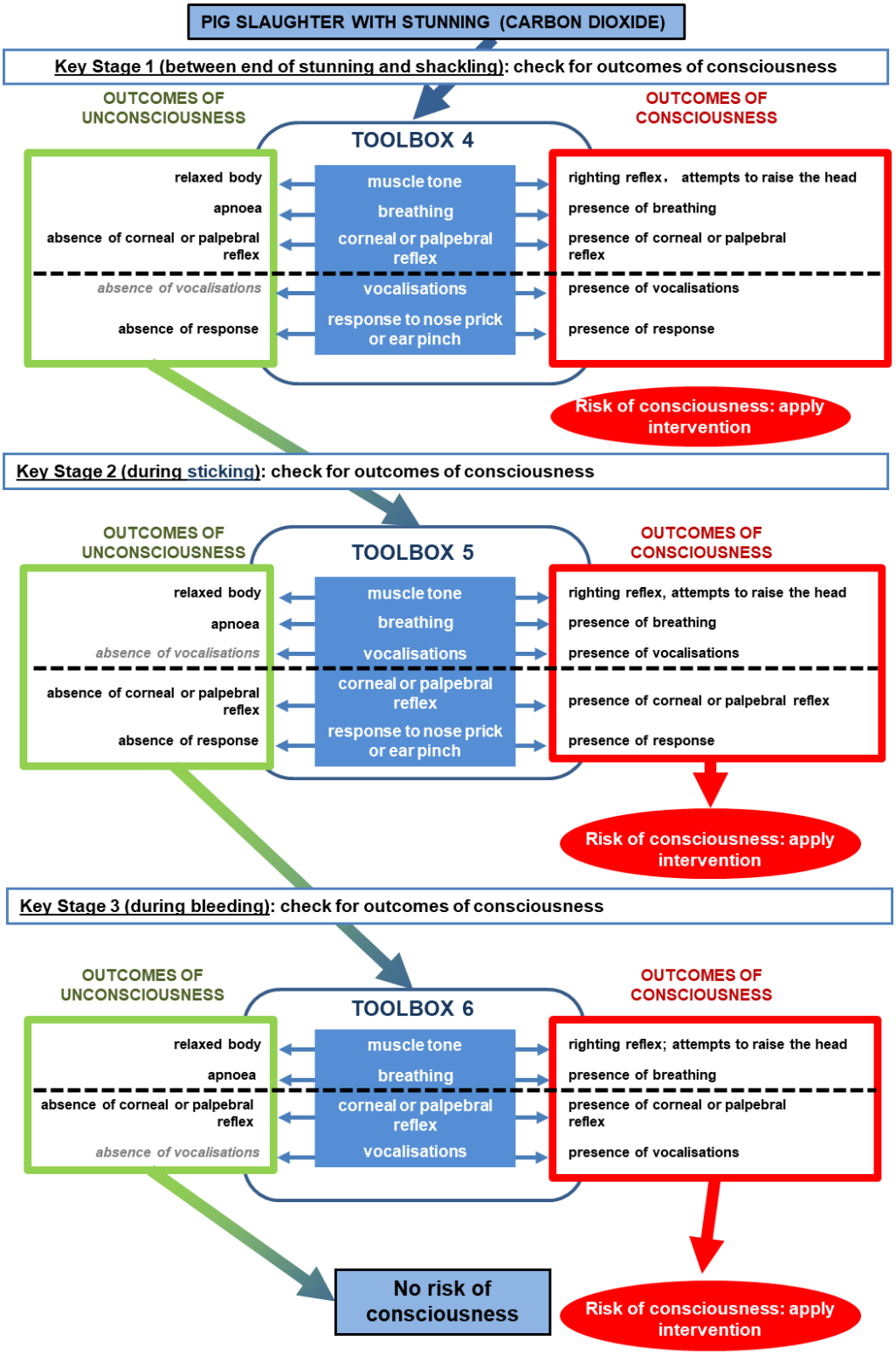


Figure 4.2.2. Flowchart of indicators for the monitoring of the state of consciousness. See the text (also in Section 4.2.1) for explanation of the dashed line and grey ABI outcomes (figure taken from EFSA (2013), p.51; © EFSA)

4.3 Killing

The key areas to focus on during welfare inspections during and after bleeding have been presented in the previous sections (key stage 3).

5 Minimising welfare problems: improved practices

This chapter aims to point out improved practices, i.e. examples of enhanced welfare where slaughterhouses or their personnel is doing more than what is minimally required by law, i.e. Council Regulation 1099/2009.

5.1 The Responsibility of the Business Operator to assure animal welfare

The **business operator (BO)** ensures that animals are protected and spared pain and suffering at the slaughterhouse. To achieve this goal the BO plans the slaughtering procedure in advance according to Art. 6 of the Council Regulation 1099/2009, drawing up and implementing **standard operation procedures (SOPs**). The SOPs define specific procedures aligned with the management of each individual slaughterhouse and handling of animals so as to maximally avoid pain, distress or suffering.

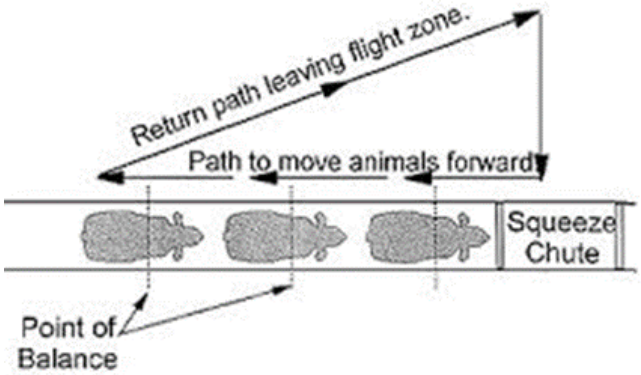
The designated **animal welfare officer (AWO)** assists the BO in ensuring compliance with the rules laid down in Council Regulation 1099/2009, defined in the SOPs for the business and holds a certificate of competence. He/she must be authorised to issue directives to persons handling live animals and to give training sessions. As mentioned before for the work and also for the competencies of the AWO a SOP document must be in place, specifying, for example, the sample size for checking animal welfare in routine operations at each stage or station of the slaughter process, handling live animals. If problems occur, the sample size must be increased until the errors have been eliminated. With a view to conflicts of interest, the BO cannot at the same time be the AWO as concerns of animal welfare may appear being opposed to the economic interests of the business. Therefore, it is advised that the AWO is protected from dismissal and holds a status similar to members of work councils. The Guideline “The Animal Welfare officer in the European Union” (EC, 2012) offers useful information on the role of the AWO in slaughterhouses.

Staff must hold **certificates of competence** according to their occupation and the species they are handling. The motivation of the employees at the slaughterhouse to comply with animal welfare provisions depends very much on their income, the working conditions and their appreciation within the business. Language barriers can be an issue and should be considered for SOPs and training. Considering staff experience and opinions regarding the SOPs can increase the motivation to comply with the provisions of Council Regulation 1099/2009, including the SOPs of the business.

5.2 Improving handling and moving pigs towards the stunning area

Pigs shall be handled in such a way as to take their natural behaviour and biology into account. During handling and moving towards the stunning area, pigs shall be handled according to their biology and to avoid pain and distress (Holmes et al., 2020). This is because the latter results in pigs hesitating and halting, causing piling up, turning back, slipping or falling, and a suboptimal slaughter process. For each stage of the slaughter process, i.e. unloading from the vehicle, lairage, moving to the stunning area, stunning, possible hoisting, and debleeding, a specified SOP must be in place and applied. This is to be monitored by the AWO.

A high prevalence of vocalisations due to the use of extensive pressure is directly linked to the design of the slaughterhouse, such as the method of separating and isolating pigs before the stunning file (Grandin, 2016). The use of excessive pressure, e.g. use of electric prods, can be significantly reduced using simple improvement measures. Pigs prefer to move into light areas and they react sensitively to head-on airflows and may be resilient to move forward into a draught. Management of light and airflow can encourage pigs to move into single files before stunning. Disturbing noises should be avoided, e.g. metal gates banging on metal (using rubber protection), noises from hydraulic slaughter apparatus and vocalisations of conspecifics. Pigs will move more easily from the crowd pen into the single-file line if the chute is partially empty and there is no risk of pigs jamming at the entrance. Walking in the opposite direction to the pigs, thus leaving their flight zone, encourages them to move forward (see Figure 5.2.1). An offset step before the chute prevents pigs from jamming (see Figure 5.2.2). If the crowd pen before the chute is not too crowded and the gates are not closed tightly, the crowding pen serves as "passing through" pen to the chute (Grandin, 2016). Groups of pigs being moved should be small. This requires more walking for the staff. Double raceways, where pigs are walking side by side, have the advantage that pigs are not isolated before the chute and walking in two parallel chutes promotes pigs' natural following behaviour. The sides in double chutes should be solid except for the middle partition which should be open such that the animals can see each other through the open partition (Grandin, 2020). A separate file for prioritised slaughter is advisable.



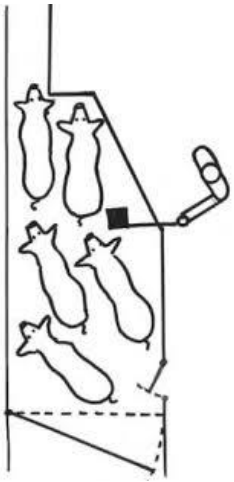


Figure 5.2.1. (Left) Flight zones (Grandin, 2016). Figure 5.2.2. (Right) Off set step before a single file race (Grandin, 2016; © Grandin)

Pigs will move or stop depending on the handler being within or outside the flight zone. Moving in the opposite direction following the arrows indicating the path, encourages pigs to move forward (Figure 5.2.1.). The handlers should avoid the blind spot behind the pigs (Grandin, 2016). Comforting pigs vocally and patting them encourages pigs to move forward.

If the electric prod is applied to a large number of animals entering the raceway, the construction of the raceway to the stunner must be reassessed and its functionality should be improved (BSI Schwarzenbek, 2013). It is important to verify that pigs have the possibility to move forward when prodded and prodding is applied only to the muscles of the hindquarters. In Germany electric prodding is allowed only at the entrance of the stunning box (TierSchlV, 2012). With optimising the environment at this point and also the handling of

the animals (limitation of the throughput rate) electric prodding can be excluded (Knöll et al, 2021). According to Regulation 1099/2009, electric prods may only be used on adult pigs, and only when they have room ahead. The term "adult" is, however, not specified in the Regulation. In some Member States like Sweden for example, any pig above the age of 9 months is considered adult, which means that electric prods cannot be used at all for fattening pigs, which are slaughtered at a lower age.

5.3 Improved stunning and killing practices

On this topic, see the sections 3.2, 3.3, 4.2 and 4.3. The main points here are to ensure proper stunner settings and maintenance, to ensure the stun-to-stick interval is as short as possible (and this depends on the stunning method), to use a range of ABIs carefully, and to give the animal the benefit of the doubt when there is any risk of animals regaining consciousness by applying a new stun.

6 Legal requirements

Council Regulation (EC) No 1099/2009 regulates legal requirements for pigs at the time of slaughter and killing. Extracts that are particularly relevant to the welfare of pigs for the key areas are listed below. Underlined phrases indicate areas given guidance and improvement measures in the review (for legislation related to handling see also Holmes et al., 2020). Regulations related to handling, stunning and bleeding, have been labelled using the terms (handle, stun, bleed) between brackets at heading level.

COUNCIL REGULATION (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing, which has been in force in the European Union since 2013, determines the animal welfare conditions under which livestock should be handled and slaughtered in abattoirs. According to Art. 26 of the regulation, Member States may have implemented stricter national rules aimed at ensuring more extensive protection of animals at the time of killing. The Member States provide mandatory guidelines for their competent authorities to ensure consistent enforcement of Council Regulation 1099/2009 and the national regulations. These Guidelines are notified to the Commission. The regulation addresses the business operator (BO) for assuring animal welfare in slaughterhouses. The BOs shall apply guides of good practice developed by his/her own organisations to facilitate the implementation of Council Regulation 1099/2009. The competent authorities assess these guides in respect to consistency with the Community guidelines.

Article 2 Definitions (handle, stun, bleed)
(a) 'killing' means any intentional induced process which causes the death of an animal;
(b) 'related operations' means operations such as handling, lairaging, restraining, stunning and bleeding of animals taking place in the context and at the location where they are to be killed;
(f) 'stunning' means any intentionally induced process which causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death;
(i) 'standard operation procedures' means a set of written instructions aimed at achieving uniformity of the performance of a specific function or standard;
(l) 'business operator' means any natural or legal person having under its control an undertaking carrying out the killing of animals or any related operations falling within the scope of this Regulation;
(p) 'restraint' means the application to an animal of any procedure designed to restrict its movements sparing any avoidable pain, fear or agitation in order to facilitate effective stunning and killing;

(q) 'competent authority' means the central authority of a Member State competent to ensure compliance with the requirements of this Regulation or any other authority to which that central authority has delegated that competence;

Article 3 (handle, stun, bleed)

1. Animals shall be spared any avoidable pain, distress or suffering during their killing and related operations.

Article 4 Stunning methods (stun, bleed)

1. Animals shall only be killed after stunning in accordance with the methods and specific requirements related to the application of those methods set out in Annex I. The loss of consciousness and sensibility shall be maintained until the death of the animal.

ANNEX I LIST OF STUNNING METHODS AND RELATED SPECIFICATIONS (as referred to in Article 4) CHAPTER I Methods Table 1 — Mechanical methods

Penetrative captive bolt device, Penetrative captive bolt device, Head-only electrical stunning, Head-to-Body electrical stunning, carbon dioxide at high concentration, in two steps or mixed with inert gases, inert gases

The methods referred to in Annex I which do not result in instantaneous death (hereinafter referred to as simple stunning) shall be followed as quickly as possible by a procedure ensuring death, such as bleeding, pithing, electrocution or prolonged exposure to anoxia.

Article 5 Checks on stunning (stun, bleed)

1. Business operators shall ensure that persons responsible for stunning or other nominated staff carry out regular checks to ensure that the animals do not present any signs of consciousness or sensibility in the period between the end of the stunning process and death.

Article 6 Standard Operating Procedures (handle, stun, bleed)

1. Business operators shall plan in advance the killing of animals and related operations and shall carry them out in accordance with standard operating procedures.

2. Business operators shall draw up and implement such standard operating procedures to ensure that killing and related operations are carried out in accordance with Article 3(1).

As regards stunning, the standard operating procedures shall:

(a) take into account the manufacturers' recommendations;

(b) define for each stunning method used, on the basis of available scientific evidence, the key parameters set out in Chapter I of Annex I ensuring their effectiveness to stun the animals;

(c) specify the measures to be taken when the checks referred to in Article 5 indicate that an animal is not properly stunned or, in the case of animals slaughtered in accordance with Article 4(4), that the animal still presents signs of life.

4. Business operators shall make available to the competent authority their standard operating procedures upon request.

Article 7 Level and certificate of competence (handle, stun, bleed)

1. Killing and related operations shall only be carried out by persons with the appropriate level of competence to do so without causing the animals any avoidable pain, distress or suffering.

2. Business operators shall ensure that the following slaughter operations are only carried out by persons holding a certificate of competence for such operations, as provided for in Article 21, demonstrating their ability to carry them out in accordance with the rules laid down in this Regulation:

(a) the handling and care of animals before they are restrained;

(b) the restraint of animals for the purpose of stunning or killing;

(c) the stunning of animals;

(d) the assessment of effective stunning;

(e) the shackling or hoisting of live animals;

(f) the bleeding of live animals;

Article 8 Instructions for the use of restraining and stunning equipment (handle, stun)

Products marketed or advertised as restraining or stunning equipment shall only be sold when accompanied by appropriate instructions concerning their use in a manner which ensures optimal conditions for the welfare of animals. Those instructions shall also be made publicly available by the manufacturers via the Internet.

Those instructions shall in particular specify:

(a) the species, categories, quantities and/or weights of animals for which the equipment is intended to be used;

(b) the recommended parameters corresponding to the different circumstances of use, including the key parameters set out in Chapter I of Annex I;

(c) for stunning equipment, a method for monitoring the efficiency of the equipment as regards compliance with the rules laid down in this Regulation;

(d) the recommendations for maintenance and, where necessary, calibration of the stunning equipment.

Article 9 Use of restraining and stunning equipment (handle, stun)

1. Business operators shall ensure that all equipment used for restraining or stunning animals is maintained and checked in accordance with the manufacturers' instructions by persons specifically trained for that purpose.

Business operators shall draw up a record of maintenance. They shall keep those records for at least one year and shall make them available to the competent authority upon request.

2. Business operators shall ensure that during stunning operations appropriate back-up equipment is immediately available on the spot and is used in the case of failure of the stunning equipment initially used. The back-up method may differ from that first used.

3. Business operators shall ensure that animals are not placed in restraining equipment, including head restraints, until the person in charge of stunning or bleeding is ready to stun or bleed them as quickly as possible.

Additional Requirements applicable to slaughterhouses

Article 14 Layout, construction and equipment of slaughterhouses (handle, stun, bleed)

Business operators shall ensure that the layout and construction of slaughterhouses and the equipment used therein comply with the rules set out in Annex II.

For the purposes of this Regulation, business operators shall, when requested, submit to the competent authority referred to in Article 4 of Regulation (EC) No 853/2004 for each slaughterhouse at least the following

a) the maximum number of animals per hour for each slaughter line;

Article 17 Animal welfare officer (handle, stun, bleed)

1. Business operators shall designate an animal welfare officer for each slaughterhouse to assist them in ensuring compliance with the rules laid down in this Regulation.

2. The animal welfare officer shall be under the direct authority of the business operator and shall report directly to him or her on matters relating to the welfare of the animals. He or she shall be in a position to require that the slaughterhouse personnel carry out any remedial actions necessary to ensure compliance with the rules laid down in this Regulation.

3. The responsibilities of the animal welfare officer shall be set out in the standard operating procedures of the slaughterhouse and effectively brought to the attention of the personnel concerned.

4. The animal welfare officer shall hold a certificate of competence as referred to in Article 21, issued for all the operations taking place in the slaughterhouses for which he or she is responsible.

5. The animal welfare officer shall keep a record of the action taken to improve animal welfare in the slaughterhouse in which he/she carries out his/her tasks. This record shall be kept for at least one year and shall be made available to the competent authority upon request.

Article 15 Handling and restraining operations at slaughterhouses (handle)

1. Business operators shall ensure that the operational rules for slaughterhouses set out in Annex III are complied with.

Article 19 Emergency killing (handle, stun, bleed)

In the case of emergency killing, the keeper of the animals concerned shall take all the necessary measures to kill the animal as soon as possible.

ANNEX 1 LIST OF STUNNING METHODS AND RELATED SPECIFICATIONS

CHAPTER I

Methods

Table 1 — Mechanical methods *(Not discussed in this review)*

Table 2 — Electrical methods (stun)

No	Name	Description	Conditions of use	Key parameters	Specific requirements of Chapter II of this Annex
1	Head-only electrical stunning	Exposure of the brain to a current generating a generalised epileptic form on the electro-encephalogram (EEG). Simple stunning.	All species. Slaughter, depopulation and other situations.	Minimum current (A or mA). Minimum voltage (V). Maximum frequency (Hz). Minimum time of exposure. Maximum stun-to-stick/kill interval(s). Frequency of calibration of the equipment. Optimisation of the current flow. Prevention of electrical shocks before stunning. Position and contact surface area of electrodes.	Point 4.
2	Head-to-Body electrical stunning	Exposure of the body to a current generating at the same time a generalized epileptic form on the EEG and the fibrillation or the stopping of the heart. Simple stunning in case of slaughter.	All species. Slaughter, depopulation and other situations.	Minimum current (A or mA). Minimum voltage (V). Maximum frequency (Hz). Minimum time of exposure. Frequency of calibration of the equipment. Optimization of the current flow. Prevention of electrical shocks before stunning. Position and contact surface area of electrodes. Maximum stun-to-stick interval(s), in case of simple stunning(s).	Point 5.

Table 3 — CAS methods (stun)

No	Name	Description	Conditions of use	Key parameters	Specific requirements of Chapter II of this Annex
1	Carbon dioxide at high concentration	Direct or progressive exposure of conscious animals to a gas mixture containing more than 40 % carbon dioxide. The method may be used in pits, tunnels, containers or building previously sealed. Simple stunning in case of slaughter of pigs.	Pigs, [...]. Slaughter only for pigs. Other situations than slaughter for [...] pigs.	Carbon dioxide concentration. Duration of exposure. Maximum stun-to-stick interval(s) in case of simple stunning. Quality of the gas. Temperature of the gas.	Point 7. Point 8.

CHAPTER II

Specific requirements for certain methods (stun)

4. *Head-only electrical stunning*

4.1. When using head-only electrical stunning, electrodes shall span the brain of the animal and be adapted to its size.

4.2. Head-only electrical stunning shall be carried out in accordance with the minimum currents set out in Table 1.

Table 1 — Minimum currents for head-only electrical stunning

Category of animals	Animals of porcine species
Minimum current	1,30 A

5. *Head-to-body electrical stunning*

5.1. Animals of the [...] porcine species.

The minimum currents for head-to-body electrical stunning shall be [...] 1,30 amperes for pigs.

7. Carbon dioxide at high concentration

In the case of pigs, [...] the minimum concentration of 80 % of carbon dioxide shall be used.

ANNEX II LAYOUT, CONSTRUCTION AND EQUIPMENT OF SLAUGHTERHOUSES (as referred to in Article 14)

3. ***Restraining equipment and facilities*** (handle)

3.1. Restraining equipment and facilities shall be designed, built and maintained to:

(a) optimise the application of the stunning or killing method;

(b) prevent injury or contusions to the animals;

(c) minimise struggle and vocalisation when animals are restrained;

(d) minimise the time of restraint.

4. ***Electrical stunning equipment (except waterbath stunning equipment)*** (stun)

4.1. Electrical stunning equipment shall be fitted with a device which displays and records the details of the electrical key parameters for each animal stunned. The device shall be placed so as to be clearly visible to the personnel and shall give a clearly visible and audible warning if the duration of exposure falls below the required level. These records shall be kept for at least one year.

4.2. Automatic electrical stunning equipment associated to a restrainer shall deliver a constant current.

6. Gas stunning equipment for pigs [...] (stun)

6.1. Gas stunners, including conveyor belts, shall be designed and built to:

(a) optimise the application of stunning by gas;

(b) prevent injury or contusions to the animals;

(c) minimise struggle and vocalisation when animals are restrained.

6.2. The gas stunner shall be equipped to measure continuously, display and record the gas concentration and the time of exposure, and to give a clearly visible and audible warning if the concentration of gas falls below the required level. The device shall be placed so as to be clearly visible to the personnel. These records shall be kept for at least one year.

6.3. The gas stunner shall be designed in a manner that, even at the maximum permitted throughput, the animals are able to lie down without being stacked on each other.

ANNEX III OPERATIONAL RULES FOR SLAUGHTERHOUSES (as referred to in Article 15)

3. Bleeding of animals (bleed)

3.1. Where one person is responsible for the stunning, shackling, hoisting and bleeding of animals, that person shall carry out all those operations consecutively on one animal before carrying out any of them on another animal.

3.2. In case of simple stunning or slaughter in accordance with Article 4(4), the two carotid arteries or the vessels from which they arise shall be systematically severed. Electrical stimulation shall only be performed

once the unconsciousness of the animal has been verified. Further dressing or scalding shall only be performed once the absence of signs of life of the animal have been verified.

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Annex. Tables of animal-based welfare indicators

Table A.1. Table of animal-welfare indicators related to handling of pigs during handling (restraint, R), stunning (s) and bleeding (b).

		Assessment of animal-welfare indicators to be used during restraint (R), stunning (S) and bleeding (B)			
	Indicator	**Key area to focus on during welfare inspections**			**Short description** .
		R	S	B	
1	**High pitch vocalisation**	x	x		Vocalisation (squeal/scream) of a pig indicating fear, pain or distress
2	**Slipping**	x			Slipping is defined as a loss of balance without (a part of) the body touching the floor. An animal slipping while it is falling will only be considered as falling and is an indicator for slippery floors, rough handling or steep ramps.
3	**Falling**	x			Falling is defined as a loss of balance in which part(s) of the body (except the legs) touch the floor. In addition, an animal is only considered as falling if it was previously standing. Falling is an indicator for slippery floors, rough handling, lameness or fatigue.
4	**Turning back**	x			Turning back is defined as when pigs facing towards the stunning area turns around and faces the lairage area. Turing back is an indicator of fear and distress.
5	**Reluctance to move**	x			Reluctance to move is defined as an animal that (for at least 2 seconds) - stops and does not explore - does not move the body - does not move the head Reluctance to move can also be addressed as freezing and is a sign of fear.

6	**Skin lesions**	x	x	x	Skin lesions are mostly the result of fighting and biting during transportation or in lairage pens. Skin lesions can also be caused by rough handling or injuries resulting from movement in raceways or restrainer, and it occurs intentionally as part of bleeding.

Table A.2. List of animal-based indicators (ABIs) that may be used to asses consciousness in animals stunned for slaughter (modified after EFSA, 2013).

ABIs	**Description**	**Reliability in indicating unconsciousness**
Tonic/clonic seizures	Tonic (rigid muscles) and clonic (jerking of muscles) phases	Applies to electrical stunning Effective head-only electrical stunning leads to the onset of tonic-clonic seizures soon after immediate collapse of the animal (for collapse, see 'Posture' in the table below). The tonic seizure, which may be recognized from the tetanus, lasts for several seconds and is followed by clonic seizures lasting for seconds and leading to loss of muscle tone (see also 'Muscle tone' in this table) (EFSA, 2013).
Breathing	Inhaling and exhaling air	Applies to: electrical and CAS stunning Ineffectively stunned animals and those regaining consciousness will start to breath in a pattern commonly referred to as rhythmic breathing which may begin as gagging (retching) and involves more or less regular respiratory cycles of inspiration and expiration. Rhythmic breathing can be recognised by observing movement of the flank and/or mouth and nostrils. Recovery of breathing, if not visible at the flank, mouth or nostrils, can also be checked by holding a small mirror in front of the nostrils or mouth to look for the appearance of condensation droplets due to expiration of moist air (EFSA, 2013).
Palpebral and/or corneal reflex	Eyelid movement following touching or tapping a finger on the inner/outer eye canthus (palpebral reflex) or cornea (corneal reflex)	Applies to: electrical and CAS stunning Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those regaining consciousness may blink in response to the stimulus. Electrically stunned conscious animals may also intermittently show a positive corneal reflex but the reflex is indicative of animals regaining consciousness

		when the reflex is positive 30 to 40 seconds after end of stunning (EFSA, 2013).
Spontaneous blinking	Eyelid movements that are not induced by touch	Applies to: Electrical and CAS stunning Conscious animals may show spontaneous blinking and therefore this sign can be used to recognize ineffective stunning or recovery of consciousness after stunning. However, not all animals that are conscious will show spontaneous blinking (EFSA, 2013).
Loss of posture/ collapse	Failure to remain standing/upright.	Applies to: Electrical and CAS stunning Effective stunning will result in immediate collapse (electrical) or loss of posture (CAS) in animals that are not restrained or prevented from doing so. Ineffectively stunned animals, on the other hand, may fail to collapse or may attempt to regain posture after collapse or after loss of posture (EFSA, 2013).
Vocalisations	Making sounds using the larynx (vocal cords)	Applies to Electrical stunning and CAS Conscious animals may vocalise, and therefore vocalisations can be used to recognise ineffective stunning or recovery of consciousness after electrical stunning. However, not all conscious animals may vocalise and not all sounds made by stunned animals may be vocalisations (e.g. gagging) or indicate consciousness (EFSA, 2013).
Muscle tone / relaxed body	Tension of muscles. Loss of muscle tone can be recognised from the completely relaxed legs, floppy ears and tail, and relaxed jaws with protruding tongue.	Applies to: electrical stunning and CAS Electrically-stunned animals will first show general loss of muscle tone after the termination of tonic–clonic seizures. Ineffectively stunned animals and those regaining consciousness will show a righting reflex and attempt to raise the head (EFSA, 2013).

EU Reference Centre for Animal Welfare *Pigs*

About EURCAW-Pigs

EURCAW-Pigs is the first European Union Reference Centre for Animal Welfare. It focuses on pig welfare and legislation, and covers the entire life cycle of pigs from birth to the end of life. EURCAW-Pigs' main objective is a harmonised compliance with EU legislation regarding welfare in EU Member States. This includes:

- for pig husbandry: Directives 98/58/EC and 2008/120/EC;
- for pig transport: Regulation (EC) No 1/2005;
- for slaughter and killing of pigs: Regulation (EC) No 1099/2009.

EURCAW-Pigs supports:

- inspectors of Competent Authorities (CA's);
- pig welfare policy workers;
- bodies supporting CA's with science, training, and communication.

Website and contact

EURCAW-Pigs' website www.eurcaw-pigs.eu offers relevant and actual information to support enforcement of pig welfare legislation.
Are you an inspector or pig welfare policy worker, or otherwise dealing with advice or support for official controls of pig welfare? Your question is our challenge! Please, send us an email with your question and details and we'll get you in touch with the right expert.

info.pigs@eurcaw.eu

www.eurcaw-pigs.eu

Services of EURCAW-Pigs

- **Legal aspects**
  European pig welfare legislation that has to be complied with and enforced by EU Member States;
- **Welfare indicators**
  Animal welfare indicators, including animal based, management based and resource based indicators, that can be used to verify compliance with the EU legislation on pigs;
- **Training**
  Training activities and training materials for inspectors, including bringing forward knowledge about ambivalence in relation to change;
- **Good practices**
  Good and best practice documents visualising the required outcomes of EU legislation;
- **Demonstrators**
  Farms, transport companies and abattoirs demonstrating good practices of implementation of EU legislation.

Partners

EURCAW-Pigs receives its funding from DG SANTE of the European Commission, as well as the national governments of the three partners that form the Centre:

- Wageningen Livestock Research, The Netherlands
- Aarhus University, Denmark
- Friedrich-Loeffler-Institut, Germany

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