SCIENTIFIC OPINION

Welfare of cattle at slaughter

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Abstract

The killing of cattle for human consumption (slaughtering) can take place in a slaughterhouse or on farm. The processes of slaughtering that were assessed for welfare, from the arrival of cattle until their death (including slaughtering without stunning), were grouped into three main phases: pre-stunning (including arrival, unloading from the truck, lairage, handling and moving of cattle); stunning (including restraint); and bleeding. Stunning methods were grouped into two categories: mechanical and electrical. Twelve welfare consequences that cattle may be exposed to during slaughter were identified: heat stress, cold stress, fatigue, prolonged thirst, prolonged hunger, impeded movement, restriction of movements, resting problems (inability to rest or discomfort during resting), social stress, pain, fear and distress. Welfare consequences and their relevant animal-based measures are described. In total, 40 welfare hazards that could occur during slaughter were identified and characterised, most of them related to stunning and bleeding. Staff were identified as the origin of 39 hazards, which were attributed to the lack of appropriate skill sets needed to perform tasks or to fatigue. Measures to prevent and correct hazards were identified, and structural and managerial measures were identified as those with a crucial role in prevention. Outcome tables linking hazards, welfare consequences, animal-based measures, origin of hazards, and preventive and corrective measures were developed for each process. Mitigation measures to minimise welfare consequences are proposed.

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Summary

In 2009, the European Union (EU) adopted Council Regulation (EC) No 1099/2009 'on the protection of animals at the time of killing', based on two scientific Opinions adopted by the European Food Safety Authority (EFSA, 2004, 2006). In 2013, EFSA published another scientific Opinion related to this subject (EFSA AHAW Panel, 2013).

In parallel, since 2005, the World Organisation for Animal Health (OIE) has developed two chapters in its Terrestrial Animal Health Code: i) Slaughter of animals (Chapter 7.5), and ii) Killing of animals for disease control purposes (Chapter 7.6). OIE has created an ad hoc working group (WG) to revise these two chapters.

Against this background, the European Commission requested EFSA to write a scientific Opinion providing an independent view on the slaughter of cattle.

With specific reference to arrival of the animals, unloading, lairage, handling and moving to the stunning area, restraint, stunning and bleeding, EFSA was asked to: identify the animal welfare hazards and their possible origins in terms of facilities/equipment and staff (Term of Reference (ToR)-1); define qualitative or measurable criteria to assess performance on animal welfare (animal-based measures (ABMs)) (ToR-2); provide preventive and corrective measures (structural or managerial) to address the hazards identified (ToR-3); and point out specific hazards related to species or type of animal (e.g. breeding bulls, young calves) (ToR-4). In addition, the European Commission asked EFSA to provide measures to mitigate the welfare consequences that can be caused by the identified hazards.

This scientific Opinion aims at updating the above reported EFSA outputs by reviewing the most recent scientific publications and providing the European Commission with a sound scientific basis for future discussions at international level on the welfare of cattle in the context of slaughtering.

The mandate also requested a list of unacceptable methods, procedures or practices that need to be analysed in terms of the above welfare aspects. It has to be noted that methods, procedures or practices cannot be subjected to a risk assessment procedure if there is no published scientific evidence related to them. Chapter 7.5.10 of the OIE Terrestrial Animal Health Code includes a list of several unacceptable practices and the Panel agrees with this list. In addition, the Panel listed some practices that lead to serious welfare concerns. These practices should be avoided, re-designed or replaced by other practices, leading to better welfare outcomes.

Council Regulation (EC) No 1099/2009 defines slaughtering as 'the killing of animals intended for human consumption' and the related operations are 'operations that take place in the context and at the location where the animals are slaughtered'. This scientific opinion concerns the killing of cattle for human consumption that could take place in a slaughterhouse or during on-farm slaughter. In the context of this Opinion, each related operation is a process, and several related operations (processes) are grouped in phases. The phases that have been assessed in this Opinion, from arrival until the animal is dead (including slaughtering without stunning), are: Phase 1 – pre-stunning, Phase 2 – stunning, and Phase 3 – bleeding. Phase 1 includes the following processes (in chronological order): a) arrival, b) unloading of the animals from the truck, c) lairage, and d) handling and moving to the stunning area. Because restraint prior to stunning varies depending on the stunning method, restraint is assessed as a part of the relevant stunning method (Phase 2). The bleeding phase (Phase 3) includes exsanguination following stunning and slaughter without stunning.

To address the mandate, three main approaches were used in developing this Opinion: i) literature search and ii) consultation of Member State (MS) representatives, followed by iii) expert opinion through WG discussion. The literature search was carried out to identify peer reviewed scientific evidence providing information on the elements requested by the ToRs (i.e. description of the processes, identification of welfare hazards and their origin, preventive and corrective measures, welfare consequences and related ABMs) on the topic of slaughter of cattle (killing of cattle for human consumption). During the 2019 meeting of the representatives of the EU Member States' organisations designated as National Contact Points (NCPs) for Council Regulation (EC) No 1099/2009 (NCPs Network meeting[1]), hazards pertaining to each process of slaughtering were identified and discussed to gather information on the most common issues in the EU and which issues are considered by national authorities as the most urgent to be addressed in order to safeguard the welfare of cattle during slaughtering.

From the available literature, their own knowledge and the results of the discussion with the NCPs Network, the WG experts identified the processes that should be included in the assessment and

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[1] http://www.efsa.europa.eu/sites/default/files/event/181022-min.pdf

produced a list containing the possible welfare hazards of each process related to the slaughter of cattle. To address the ToRs, experts identified the origin of each hazard (ToR-1) and related preventive and corrective measures (ToR-3), along with the possible welfare consequences of the hazards and relevant ABMs (ToR-2). Measures to mitigate the welfare consequences were also considered. Specific hazards were identified in the case of certain categories of cattle (e.g. breeding bulls, unweaned calves, buffaloes, bison) (ToR-4). In addition, uncertainty analysis on the hazard identification was carried out, but limited to quantification of the probability of occurrence of false-positive (included but non-existent) or false-negative (existing but not-included) hazards.

As this Opinion will be used by the European Commission to address the OIE standards, more methods for slaughter than those reported in Council Regulation (EC) No 1099/2009 were considered. For inclusion of these methods in the Opinion, the following criteria were applied: a) all methods with described technical specifications known to the experts, not only those described in Council Regulation (EC) No 1099/2009, and b) methods currently used for slaughter of cattle as well as those still in development but likely to become commercially applicable, and c) methods for which the welfare aspects (in terms of welfare hazards, welfare consequences, ABMs, preventive and corrective measures) are described sufficiently in the scientific literature. Applying these criteria, some methods that may be applied worldwide have not been included in the current assessment.

For each process related to slaughter, a description on how it is technically and practically carried out is provided. In addition, the relevant welfare consequences and ABMs are identified (ToR-2). A list of the main hazards associated with the relevant welfare consequences is provided (ToR-1).

The stunning methods that have been identified as relevant for cattle can be grouped in two categories: mechanical and electrical. The mechanical methods include penetrative and non-penetrative captive bolt stunning as well as stunning using firearms with free projectiles. Electrical methods include head-only and head-to-body stunning. Because of the diversity of available stunning methods, this Opinion considered the assessment of welfare consequences, hazards, related ABMs and mitigation measures, origin of hazards and preventive/corrective actions for each method.

In total, 12 welfare consequences were identified: heat stress, cold stress, fatigue, prolonged thirst, prolonged hunger, impeded movement, restriction of movements, resting problems, social stress, pain, fear and distress. Cattle experience welfare consequences due to the presence of hazards only when they are conscious, which applies to all cattle during the pre-stunning phase. In the stunning phase, cattle may experience welfare consequences if hazards occur during restraint (before stunning), if induction of unconsciousness is not immediate, or if stunning is ineffective. During bleeding following stunning, cattle will experience welfare consequences in case of persistence of consciousness or if they recover consciousness after stunning and before death. During slaughter without stunning the animals will experience welfare consequences until they become unconscious due to loss of blood or until post-cut stunning is applied.

The mandate requested to provide definitions of qualitative or measurable (quantitative) criteria to assess performance (i.e. consequences) on animal welfare (ABMs; ToR-2); this ToR was addressed by identifying the welfare consequences occurring to cattle during slaughter and the relevant ABMs that can be used to assess qualitatively or quantitatively these welfare consequences. Lists and definitions of ABMs to be used for assessing the welfare consequences have been provided in this Opinion. ABMs for the assessment of all the welfare consequences have been identified, except for prolonged hunger and prolonged thirst at the time of arrival. However, under certain circumstances, not all the ABMs can be used because of low feasibility (e.g. at arrival/during lairage due to the lack of accessibility to the animals in the truck/pen). Even if welfare consequences cannot be assessed during the slaughter of cattle, it does not imply they do not exist. It is to be noted that ABMs during stunning are the signs of consciousness, since consciousness is the prerequisite for animals to experience pain and fear during stunning. These ABMs of consciousness are specific to the stunning methods and were proposed in a previous EFSA Opinion (EFSA AHAW Panel, 2013). Flow charts, including ABMs of consciousness to be used for monitoring of stunning efficacy, are reproduced in this Opinion in order to provide the European Commission with the full welfare assessment at slaughter.

In answering ToR-1, 40 hazards related to the previous welfare consequences from arrival of the cattle at the slaughter slaughterhouse until they are dead were identified. The main hazards are associated with lack of staff skills and training, and poorly designed and constructed facilities.

Animal welfare consequences can be the result of one or more hazards. Exposure to multiple hazards has a cumulative effect on the welfare consequences (e.g. pain due to injury caused at arrival will lead to more severe pain during unloading). Some hazards are inherent to the stunning method and cannot be avoided (e.g. restraint), other hazards originate from sub-optimal application of the

method, mainly due to unskilled staff (e.g. inappropriate handling, use of wrong parameters for electrical methods). In fact, the majority of the hazards (39 out of 40) have staff as origin, and hazards can be attributed to the lack of appropriate skills to perform tasks or to fatigue.

The uncertainty analysis on the set of hazards provided for each process in this Opinion revealed that the experts were 95–99% certain that all listed hazards occur during slaughter of cattle. However, the experts were 90–95% certain that at least one hazard was missing in the assessment, considering the three criteria for the inclusion of methods and practices in this Opinion as presented above.

Furthermore, from a global perspective, the experts were 95–99% certain that at least one welfare hazard was missing. This is due to the lack of documented evidence on all possible variations in the processes and methods being practised (see Interpretation of ToRs on the criteria for selection of stunning/killing methods to be included).

In response to ToR-3, preventive and corrective measures have been identified and described. Some are specific for a particular hazard; others can apply to multiple hazards (e.g. staff training and rotation). For most hazards, preventive measures can be put in place with management having a crucial role in prevention. However, for some hazards related to restraint and bleeding when slaughtering without stunning, no preventive measures could be identified. Corrective measures were identified for 28 hazards. When no corrective measures are available or feasible to put in place, actions to mitigate the welfare consequences caused by the identified hazards should be put in place.

Finally, outcome tables linking all the elements (welfare hazards, origin of hazards, preventive and corrective measures, welfare consequences and related ABMs) were produced for each process in the slaughter of cattle to provide an overall and concise outcome. Conclusions and recommendations are provided, subdivided for the specific phases of slaughter addressed in this Opinion.

To spare cattle from severe welfare consequences, a standard operating procedure (SOP) should include identification of hazards and related welfare consequences, using relevant ABMs, as well as preventive and corrective measures. At arrival, cattle should be unloaded as soon as possible and those with severe pain, signs of illness, or those unable to move independently, should be inspected and a procedure for emergency slaughter should be applied immediately. Keeping cattle in lairage should be avoided, unless it benefits their welfare. Permanent access to water, adequate space and protection from adverse weather conditions should always be ensured during lairage. Restraining, stunning and slaughter methods, which cause severe pain and fear, should not be used. To monitor stunning method efficacy, the state of consciousness of the animals should be checked immediately after stunning, just prior to neck cutting and during bleeding. Death must be confirmed before carcass processing begins.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

The Union adopted in 2009 Council Regulation (EC) No 1099/2009[2] on the protection of animals at the time of killing. This piece of legislation was prepared based on two EFSA Opinions respectively adopted in 2004[3] and 2006[4] . The EFSA provided additional Opinions related to this subject in 2012[5], 2013[6,7,8,9,10,11] , 2014[12,13], 2015[14] and 2017[15,16]

In parallel, since 2005, the World Organisation for Animal Health (OIE) has developed in its Terrestrial Animal Health Code two chapters covering a similar scope:

- Slaughter of animals (Chapter 7.5).
- Killing of animals for disease control purposes (Chapter 7.6)

The chapter slaughter of animals covers the following species: cattle, buffalo, bison, sheep, goats, camelids, deer, horses, pigs, ratites, rabbits and poultry (domestic birds as defined by the OIE).

The OIE has created an ad hoc working group with the view to revise the two chapters.

Against this background, the Commission would like to request the EFSA to review the scientific publications provided and possibly other sources to provide a sound scientific basis for the future discussions at international level on the welfare of animals in the context of slaughter (i.e. killing animals for human consumption) or other types of killing (killing for other purposes than slaughter).

1.1.2. Terms of Reference

The Commission therefore considers it opportune to request EFSA to give an independent view on the slaughter of animals (killing for human consumption) concerning two categories of animals:

- free moving animals (cattle, buffalo, bison, sheep, goats, camelids, deer, horses, pigs, ratites),
- animals in crates or containers (i.e. rabbits and domestic birds).

The request covers the following processes and issues:

- arrival of the animals,
- unloading,
- lairage,
- handling and moving of the animals (free moving animals only)
- restraint,
- stunning
- bleeding
- slaughter of pregnant animals (free moving animals only)
- emergency killing (reasons and conditions under which animals have to be killed outside the normal slaughter line),
- unacceptable methods, procedures or practices on welfare grounds.

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[2] OJ L 303, 18.11.2009, p. 1.

[3] The welfare aspects of the main systems of stunning and killing the main commercial species of animals. EFSA Journal 2004;45, pp. 1–29.

[4] The welfare aspects of the main systems of stunning and killing applied to commercially farmed deer, goats, rabbits, ostriches, ducks, geese and quail. EFSA Journal 2006;326, pp. 1–18.

[5] Electrical requirements for waterbath equipment applicable for poultry. EFSA Journal 2012;10(6):2757.

[6] Electrical parameters for the stunning of lambs and kid goats. EFSA Journal 2013;11(6):3249.

[7] Monitoring procedures at slaughterhouses for bovines. EFSA Journal 2013;11(12):3460.

[8] Monitoring procedures at slaughterhouses for pigs. EFSA Journal 2013;11(12):3523.

[9] Monitoring procedures at slaughterhouses for poultry. EFSA Journal 2013;11(12):3521.

[10] Monitoring procedures at slaughterhouses for sheep and goats. EFSA Journal 2013;11(12):3522.

[11] The use of carbon dioxide for stunning rabbits. EFSA Journal 2013;11(6):3250.

[12] The use of low atmosphere pressure system (LAPS) for stunning poultry. EFSA Journal 2014;12(1):3488.

[13] Electrical requirements for poultry waterbath stunning equipment. EFSA Journal 2014;12(7):3745.

[14] The scientific assessment of studies on electrical parameters for stunning of small ruminants (ovine and caprine species). EFSA Journal 2015;13(2):4023.

[15] The low atmospheric pressure system for stunning broiler chickens. EFSA Journal 2017;15(12):5056.

[16] The animal welfare aspects in respect of the slaughter or killing of pregnant livestock animals (cattle, pigs, sheep, goats, horses). EFSA Journal 2017;15(5):4782.

For each process or issue in each category (i.e. free moving/in crates or containers), EFSA will:

- ToR-1: Identify the animal welfare hazards and their possible origins (facilities/equipment, staff),
- ToR-2: Define qualitative or measurable criteria to assess performance on animal welfare (animal- based measures (ABM)),
- ToR-3: Provide preventive and corrective measures to address the hazards identified (through structural or managerial measures),
- ToR-4: Point out specific hazards related to species or types of animals (young, with horns, etc.).

1.2.   Interpretation of the Terms of Reference

This scientific opinion concerns the slaughter of cattle.

This Opinion will use definitions concerning the killing of cattle, including the related operations, provided by Council Regulation (EC) No 1099/2009 of 24 September 2009[17] on the protection of animals at the time of killing, which entered into force in January 2013. The Regulation defines slaughtering as the killing of animals intended for human consumption; the related operations include handling before and during lairage, restraining, stunning and bleeding of animals. Emergency killing is intended in this Opinion as emergency slaughter (see Section 3.4).

This Opinion therefore concerns the killing of cattle for human consumption that could take place in a slaughterhouse, from arrival until the animal is dead (including slaughter without stunning). In the context of this Opinion, each related operation is a process, and several related operations (processes) are grouped into phases. The phases assessed in this Opinion are: Phase 1 – pre-stunning, Phase 2 – stunning, and Phase 3 – bleeding. Phase 1 includes (in chronological order): b) arrival, c) unloading of animals from the truck, d) lairage and e) handling and moving to the stunning (or sticking) area. Because restraint of cattle prior to stunning varies depending on the stunning method, restraint will be assessed as a part of the relevant stunning method (Phase 2). For the bleeding phase (Phase 3) a distinction has been made between a) the bleeding of cattle following stunning and b) the bleeding during slaughter without stunning, including restraint.

Slaughter can also be performed on-farm with the same phases and processes described above, except arrival, unloading and lairage. Therefore, the assessment carried out in this Opinion applies to both slaughtering in slaughterhouses or on farm.

As this Opinion will be used by the European Commission to address the OIE standards, it considers more methods for slaughter than those reported in Council Regulation (EC) No 1099/2009.

Among the methods that are used for slaughter worldwide, EFSA has applied the following criteria for the selection of methods to include in this assessment: a) all methods known to the experts that have technical specifications, i.e. not limited to the methods described in Council Regulation (EC) No 1099/2009, and b) methods currently used for slaughter of cattle and, c) methods for which the welfare aspects (in terms of welfare hazards, welfare consequences, ABMs, preventive and corrective measures) are sufficiently described in the scientific literature.

Applying these criteria in this Opinion has resulted in the exclusion of some practices; for instance CO_2 stunning for cattle has not been further considered, although it has been used in one study (Gap-Don Kim et al., 2013), but its implementation for commercial purposes appears to be not feasible and no information on welfare outcomes are available.

The mandate requests EFSA to identify hazards at different stages (processes) of slaughtering and their relevant origins in terms of equipment/facilities or staff (ToR-1). When discussing the origin of the hazards, it was considered necessary to provide further details on the actions of the staff or features of the equipment and facilities causing the hazards. Therefore, for each origin category (staff, facilities/ equipment), relevant specifications have been identified by expert Opinion. Hazards originating from the farm or during transport for which welfare consequence persist on arrival are also considered in this scientific opinion.

This scientific opinion will report the hazards that can occur during slaughtering of cattle in all 'types' of slaughterhouses (from industrial slaughterhouses with automated processes to on-farm manual slaughter), but not all of the hazards apply to all slaughter situations, e.g. in small abattoirs or during on-farm slaughter. Indeed, hazards applicable to a specific stunning method may occur in all situations where this method is applied, whereas some other hazards may not apply in certain circumstances, e.g. the ones specific to the arrival or unloading of the animals in on-farm slaughter.

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[17] Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing. OJ L 303, 18.11.2009, pp. 1–30.

Hazards may be specified at different levels of detail and could therefore be subdivided into multiple ones depending on the chosen level of detail. For example, the hazard 'incorrect captive bolt parameters' for captive-bolt stunning, could be further subdivided into 'inappropriate bolt diameter', 'inappropriate exit length' or 'inappropriate cartridge used'. For this Opinion, it was agreed to define hazards by an agreed broad level of detail (e.g. 'incorrect captive bolt parameters' in the example above).

The mandate also asks to define quantitative or qualitative criteria to assess performance (i.e. consequences) on animal welfare (ABMs; ToR-2). This ToR has been addressed by identifying the (negative) welfare consequences occurring to the cattle due to the identified hazards and the relevant ABMs that can be used to assess the welfare consequences qualitatively and/or quantitatively. In this scientific opinion, each welfare consequence is addressed in a separate section that includes information on its assessment (i.e. definition of the welfare consequence and ABMs to measure it). In some circumstances, ABMs may not exist or are not feasible in the context of slaughtering of cattle; in these cases, emphasis will be given to the relevant measures to prevent the hazards or to mitigate the welfare consequences.

Cattle can experience welfare consequences due to the presence of hazards only when they are conscious. This applies to all cattle during the pre-stunning phase. In the stunning phase, cattle may experience welfare consequences (pain and fear), if hazards occur during restraint (before stunning), if induction of unconsciousness is not immediate, or if stunning is ineffective. During bleeding following stunning, cattle will experience welfare consequences in case of persistence of consciousness or if they recover consciousness after stunning and before death. Therefore, consciousness is not a welfare consequence per se but a prerequisite for experiencing pain and fear.

During the stunning phase, the state of consciousness is assessed to identify if animals are successfully rendered unconscious or if they are conscious (e.g. stunning was ineffective or they recovered consciousness) and therefore at risk of experiencing pain and fear. For each ABM of state of consciousness, outcomes either suggesting unconsciousness (e.g. presence of tonic seizures) or suggesting consciousness (e.g. absence of tonic seizures) have been identified.

In this scientific opinion, distress, which can be defined as an aversive, negative state in which coping and adaptation processes fail to return an organism to physiological and/or psychological homeostasis (Carstens and Moberg, 2000; Moberg, 1987; NRC, 1992), has not been included as a specific welfare consequence for Phases 1 and 2 (pre-stunning and stunning). This is due to the consideration that distress may result from, e.g. pain and fear, depending on the duration and magnitude of the latter, which are among the welfare consequences addressed in this Opinion. Therefore, it was not necessary to list distress separately for these phases. However, animals will experience distress when ineffectively stunned or if they recover consciousness during bleeding following stunning as well as during slaughter without stunning; therefore, it has been considered as a stand-alone welfare consequence during Phase 3 (bleeding).

In this opinion, in the description of the processes of each phase, and the relevant welfare consequences that the cattle can experience when exposed to hazards will be reported. In this respect, the ranking of the identified hazards in terms of severity, magnitude or frequency of the welfare consequences that they can cause is not considered in this mandate.

The mandate also requests to indicate preventive and corrective measures to the hazards and the welfare consequences. The preventive and corrective measures to be provided were interpreted as those measures that can be put in practice by the person responsible for the slaughtering in order to prevent or correct the identified hazards. These measures will fall into two main categories: 1) structural and 2) managerial (ToR-3). Some corrective measures of the hazards will mitigate the welfare consequence (e.g. showering at lairage will mitigate the welfare consequence of 'heat stress'). However, other measures, although correcting the hazard, will not mitigate the welfare consequence (e.g. stop shouting will correct the hazard of 'unexpected loud noise' but will not mitigate the fear of the animals already exposed to the noise). Furthermore, training the staff not to shout will prevent the hazard. When corrective measures for the hazards are not available or feasible to put in place, actions to mitigate the welfare consequences caused by the identified hazards will be discussed. In this scientific opinion, preventive, corrective and mitigation measures are presented differently for i) the processes that precede stunning (arrival, unloading from the truck, lairage, handling and moving of the animals to the stunning point) and for ii) the stunning methods: in the first case, all measures are presented in the section on the welfare consequence under assessment and go under the name 'management of the welfare consequence'; in the second case, all measures are presented in a separate subsection 'prevention and correction of welfare consequence and their related hazards'

within the stunning method. In addition, it will be assessed whether specific categories of domestic cattle or related species such as buffaloes and bison might be subjected to specific hazards (ToR-4).

The mandate also requests a list of methods, procedures or practices deemed unacceptable on welfare grounds. In order to answer to this request, the Panel is aware of two issues with this request. First, it has to be noted that some methods, procedures or practices under question cannot be subjected to a risk assessment procedure because there is no published scientific evidence relating to them. Second, although scientific risk assessment can support discussions on what practices are acceptable or unacceptable on welfare grounds, the ultimate decisions on acceptability involve, e.g. ethical and socio-economic considerations that need to be weighed by the risk managers.

In response to this request, the Panel agrees with Chapter 7.5.10 of the terrestrial code of the World Organisation for Animal Health (OIE, 2019) as well as the methods of restraint that are prohibited and listed in EC Regulation 1099/2009. Additionally, the Panel listed practices for which welfare consequences were identified and classified as 'severe'. To do so, expert knowledge was elicited and the available scientific evidence was assessed in order to subdivide practices into two groups, namely the group of those leading to 'severe' welfare consequences and the group of those not leading to 'severe' welfare consequences. For the practices leading to severe welfare consequences, the Panel has serious welfare concerns and therefore recommends that these practices should be avoided, re-designed or replaced by other practices, leading to better welfare outcomes. These practices are discussed in this Opinion.

2. Data and methodologies

2.1. Data

2.1.1. Data from literature

Information from the papers selected as relevant from the literature search described in Section 2.2.1 and from additional literature identified by the working group (WG) experts was used for a narrative description and assessment to address ToRs 1, 2, 3 and 4 (see relevant sections in the Section on Assessment).

2.1.2. Data from Member States and expert opinion

Information on the identification of hazards for cattle at slaughter existing in the EU Member States (MSs) was requested by EFSA to the National Contact Points (NCPs) for Council Regulation (EC) No 1099/2009 Network representatives[18] (see Section 2.2.2).

The data obtained from the literature and network (mainly on the hazards) were complemented by the WG experts' opinion in order to identify the origins of hazards, welfare consequences, ABMs, and hazard preventive and corrective measures relevant to the current assessment.

2.2. Methodologies

To address the questions formulated by the European Commission in ToRs 1–4, three main approaches were used to develop this opinion: i) literature search and ii) consultation with MSs' representatives followed by iii) expert opinion through WG discussion. These methodologies were used to address the mandate extensively (see relevant sections in the Assessment section) and also in a concise way with the development of outcome tables (see Section 2.2.3).

The general principle adopted in the preparation of this Opinion was that relevant reference(s) would be cited in the text when published scientific literature is available, and expert opinion would be used when no published scientific literature was available or to complete the results retrieved.

2.2.1. Literature search

A broad literature search under the framework of 'welfare of cattle at slaughter and killing' was carried out to identify peer-reviewed scientific evidence providing information on the elements requested by the ToRs, i.e. description of the processes, identification of welfare hazards, origin, preventive and corrective measures, welfare consequences and related ABMs.

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[18] https://www.efsa.europa.eu/en/animal-health-and-welfare/networks

Restrictions were applied in relation to the date of publication, considering only those records published after a previous EFSA Scientific Opinion on the topic (EFSA, 2004).

A total of 397 references were retrieved and reviewed by the WG members to select potentially relevant references. This screening produced 45 relevant records. Discrepancies were discussed between the WG members until a final subset of 20 relevant references was selected and considered in this assessment by reviewing the full papers.

Full details of the literature search protocol, strategies and results, including the number of the records that underpin each process, are provided in Appendix A to this Opinion.

In addition, the experts in the WG selected relevant references starting from scientific papers, including review papers, books chapters, non-peer-reviewed papers known by the experts themselves or retrieved through non-systematic searches, until the information of the subject was considered sufficient to undertake the assessment by the WG. If needed, relevant publications before 2004 were considered.

2.2.2. Risk assessment methodology and structure of the Opinion

The WG experts followed the risk assessment methodology from the EFSA's guidance on risk assessment in animal welfare (EFSA AHAW Panel, 2012b).

Based on expert opinion through WG discussion, the WG experts first described the phases and related processes of slaughter and specifically which stunning/killing methods should be considered in the current assessment.

Using the available literature and their own knowledge, the experts then produced a list of the possible welfare consequences characterising each process related to the slaughter of cattle. To address the ToRs, the experts then identified the hazards leading to those welfare consequences and their origin (ToR-1) and the applicable preventive and corrective measures (ToR-3). ABMs for measuring the welfare consequences were identified (ToR-2). Measures to mitigate the welfare consequences were also considered.

Related to the structure of the Opinion, sections are organised by phases: Phase 1 – pre-stunning, Phase 2 – stunning and Phase 3 – bleeding. Phase 1 is divided in processes (e.g. arrival, lairage). In Phase 2, there is only one process, stunning, under which several methods are described (e.g. captive-bolt stunning, head-only electrical stunning). In Phase 3, there is only one process, i.e. bleeding. For each process, there is a description of its welfare consequences, ABMs, hazards, preventive and corrective measures.

2.2.3. Development of outcome tables to answer the ToRs

The main results of the current assessment are summarised in outcome tables, which can be retrieved at the end of each specific section.

The outcome tables link all the mentioned elements requested by ToRs 1, 2 and 3 of the mandate and provide an overall outcome for each process of slaughter in which all retrieved information is presented concisely (see description of the structure below, in Table 1). Conclusions and recommendations of this scientific Opinion are mainly based on the outcome tables.

The outcome tables have the following structure and terminology:

- OUTCOME TABLE: Each table represents the summarised information for each cattle slaughter process (see Section from 3.1 to 3.3).
- HAZARD: The first column in each table reports all hazards pertaining to the specific process; the number of the section where each hazard is described in detail is reported in brackets. For each hazard, the individual row represents the summarised information relevant to the elements analysed for that hazard. Therefore, it links between an identified hazard, the relevant welfare consequences, origin/s of hazards and preventive and corrective measures (see example in Table 1).
- WELFARE CONSEQUENCES OCCURRING TO THE CATTLE DUE TO THE HAZARD: This column lists the welfare consequences to the cattle of the mentioned hazards.
- HAZARD ORIGIN: This column contains the information related to the category of hazard origin, which can be staff-, equipment- or facility-related. Most hazards can have more than one origin.
- HAZARD ORIGIN SPECIFICATION: This column further specifies the origin of the hazard, namely, what actions of the staff or features of the equipment and facilities can cause the

hazard. This information is needed to understand and choose among the proposed preventive and corrective measures.

- PREVENTIVE MEASURE/S FOR THE HAZARD: Depending on the hazard origin/s, several measures to prevent the hazard are proposed in this column. They are also elements for implementing standard operating procedures (SOPs).
- CORRECTIVE MEASURE/S FOR THE HAZARDS: In this column, practical actions/measures for correction of the mentioned hazards are proposed. These actions relate to the identified origin of the hazards.
- ANIMAL-BASED MEASURES: The bottom row lists the feasible measures to be performed on the cattle to assess the welfare identified consequences of a hazard.

Table 1: Example of the structure of an outcome table

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s for the hazard (implementation of SOP)	Corrective measure/s for the hazard
(Number of Section)					
ABMs: (to assess the identified welfare consequences)					

2.2.4. Uncertainty analysis

The outcome tables include qualitative information on the hazards and related elements identified through the methodologies explained in Section 2.2.

When considering the outcome tables, uncertainty exists at two levels: i) related to the completeness of the information presented in the table, namely to the number of rows within a table (i.e. hazard identification) and ii) related to the information presented within a row of the table (i.e. completeness of hazard origins, preventive and corrective measures on the one side, and welfare consequences and ABMs on the other side). Normally, an uncertainty analysis would include a full evaluation according to EFSA guidance (EFSA AHAW Panel, 2019). However, owing to the limited time available to develop this scientific opinion, an uncertainty analysis was only performed for the first point listed above, i.e. for the hazard identification.

Therefore, the uncertainties during hazard identification could result in two types of error:

- Misclassification (false-positive hazards): Some welfare-related hazards may be wrongly included in the list of hazards of an outcome table without being relevant.
- Incompleteness (false = negative hazards): Some welfare-related hazards may be missed in the identification process and so would be considered non-existent or not relevant.

Incompleteness (false negatives) can lead to underestimation of the hazards with the potential to cause (negative) welfare consequences.

The uncertainty analysis was limited to the quantification of the probability of occurrence of false-positive or false-negative hazards.

For evaluation of the risk of occurrence of false-positive hazards in the assessment, the experts elicited for each hazard the probability that it may exist during the slaughter process and should therefore be included in the outcome table (i.e. the probability of being a true positive). For evaluation of the risk of occurrence of false-negative hazards in the assessment, the experts elicited the probability that at least one welfare-related hazard was missed in the outcome table. False-negative hazards can relate to i) the situation under assessment, i.e. limited to the slaughter practices considered in this assessment according to the three criteria described in the Interpretation of ToRs (see Section 1.2), or ii) the global situation, i.e. including all possible variations to the slaughter practices that are employed in the world and that might be unknown to the experts of the WG. The Panel agreed that it was relevant to distinguish the probability of occurrence of false-negative hazards under these two scenarios.

For the elicitation, the experts used the approximate probability scale (see Table 2) proposed in the EFSA uncertainty guidance (EFSA, 2019). Experts first provided individual judgements that were then discussed, and a consensus judgement was obtained.

Table 2:   Approximate probability scale (see EFSA, 2019, Table 4)

Probability term	Subjective probability range	Additional options	
Almost certain	99–100%	More likely than not: > 50%	Unable to give any probability: range is 0–100% Report as 'inconclusive', 'cannot conclude', or 'unknown'
Extremely likely	95–99%		
Very likely	90–95%		
Likely	66–90%		
About as likely as not	33–66%		
Unlikely	10–33%		
Very unlikely	5–10%		
Extremely unlikely	1–5%		
Almost impossible	0–1%		

3.   Assessment

3.1.   Phase 1: pre-stunning

3.1.1.   Introduction to pre-stunning

The pre-stunning phase includes four processes: arrival, unloading from the truck, lairage, and handling and moving of animals from lairage to the stunning/sticking area. These processes are described in Sections 3.1.2–3.1.5. The outcome tables related to each process are reported at the end of each Section. The four processes also take place in the first phase of slaughter without stunning.

Before and during arrival of the animals at slaughterhouse, hazards may be of physical origin. Long and rough transports, food deprivation, inappropriate temperatures or air or water quality, aggression from other animals, stockpersons or equipment may cause fatigue, hunger, thirst, thermal and respiratory discomfort, fear and pain (Terlouw et al., 2008; Hultgren et al., 2014). Impaired welfare may also have a psychological origin, such as social disturbance (separation from the rearing group, mixing of unfamiliar animals, high density) or fear (unfamiliar environments, handling, loud noise, odours) (Terlouw et al., 2008; Hultgren et al., 2014). How an animal reacts to such stressors depends on a number of different internal and external determinants, such as breed, age and previous experiences of human handling (Probst et al., 2012, 2013 cited by Hultgren et al., 2014). Stockperson attitudes and actions will influence the animals' pre-slaughter stress levels and welfare (Coleman et al., 2003; Hemsworth, 2003; Hemsworth and Coleman, 1998; Hemsworth et al., 2011, cited by Hultgren et al., 2014).

For veal calves and adult cattle, Terlouw et al. (2008) identified disruption of the social group, handling, loading and sometimes unloading conditions, novelty of the situation and for calves mixing with unfamiliar animals in the truck pens as stress factors. The same authors report increases in plasma cortisol level, creatine kinase and heart rate immediately after loading and at the beginning of transport indicating stress and decrease in welfare.

The condition of animals when they reach the slaughterhouse and enter in the pre-stunning phase results from the cumulative and synergistic effects of the conditions in which cattle have been prepared for transport, handled at loading in the truck at the farm and transported (Faucitano and Perdenera, 2016).

3.1.2.   Arrival

Arrival of cattle at a slaughterhouse is the first process of the pre-stunning phase and it takes place from the moment the truck arrives at the slaughterhouse until the animals are unloaded from the truck.

During transport, cattle usually try to maintain their balance standing up while the vehicle is moving. When the vehicle is stationary, for example at arrival, the animals may start moving (Knowles, 1999), and it is very likely that aggressive interactions would be detrimental to welfare if the cattle are mixed groups of bulls, or cows and heifers in oestrus (Kenny and Tarrant, 1987a,b).

Cattle can arrive at an abattoir in poor condition for the following reasons (Cockram, 2020):

- They were not fit for their journey to slaughter;

- They are compromised animals, in an impaired condition, at the end of their productive life and were sent for slaughter because of their condition;
- They were injured during handling or during their journey or their health deteriorated during the journey;
- Their journey conditions or their management before and during transport were not satisfactory.

To reduce the risk of adverse animal welfare consequence at arrival, cattle should be unloaded without delay. Scheduling cattle delivery at the slaughterhouse is necessary to ensure that animals are unloaded quickly upon arrival (Miranda-de la Lama et al., 2014). In an observational survey in a French slaughterhouse during two periods of 5 days (Bourguet et al., 2010), the average time between arrival and unloading was 5.6 ± 0.9 min. Other cattle transport surveys reported by Faucitano and Perdenera (2016) revealed average waiting times between arrival and unloading of 20–30 min, with maximum waiting time ranging from 3 h to overnight. Indeed, in a study of González et al. (2012) in cattle transported for long hauls (> 400 km) from Alberta (Canada) to the US, out of 6,152 journeys studied 82.5% of trucks were not unloaded immediately with a mean unloading delay of 39 min and a maximum of 12 h.

Vehicles waiting before unloading may also create a stressful work environment for drivers and slaughterhouse reception staff, often resulting in poor cattle welfare (Gebresenbet et al., 2014; Faucitano and Perdenera, 2016).

According to a review by Vogel et al. (2019), mortality rates among cattle transported by road are generally much lower than those of other livestock species. González et al. (2012) reported in a study involving 6,152 journeys of long hauls in North America that an overall 0.012% of assessed animals (n = 290,866 cattle) became lame, 0.022% non-ambulatory and 0.011% died onboard. The likelihood of cattle to become non-ambulatory, lame, or dead increased significantly after animals spent over 30 h on truck. Therefore, the time of transport is an important risk factor for the different welfare consequences.

Death on arrival can be considered as a non-specific ABM for highly compromised welfare leading to death, but without allowing to identify a specific hazard as the origin of the death.

3.1.2.1. Welfare consequence 'Thermal stress': assessment, hazard identification and management

Cattle are homoeothermic animals which regulate body temperature by controlling the balance between the heat they produce through their basic metabolism and the loss of heat from their body to the environment. Thermal stress can manifest as two extremes: heat stress or cold stress.

Thermal stress will start to appear when the climatic conditions are such that the temperature regulation of the animals cannot be achieved by non-evaporative physical processes alone or without thermogenesis (Aggarwal and Upadhyay, 2013). Thermal stress intensity may vary from very light (e.g. start of sweating) to very severe (e.g. multiorgan failure and death; Silanikove, 2000).

During transport, before arriving at slaughter, animals may face very adverse climatic conditions. A Canadian study on 6,152 long journeys from Alberta to the US showed that ambient temperatures across all journeys ranged from –42 to 45°C with a mean value of 18 ± 11.8°C, while temperature variation within a journey was from 0 to 46°C with a mean value of 15 ± 6.6°C (González et al., 2012).

When arriving at slaughter, long waiting times in a stationary vehicle may expose animals to thermal stress (heat or cold stress) depending on the external climatic conditions as well as on the variation in the internal truck environment and on the welfare state of the animals. The main determinants of the internal thermal microenvironment in the vehicle are ventilation type, internal air flow as well as the total heat and moisture produced by the animals (Norton et al., 2013; Faucitano and Perdenera, 2016). The more the animals wait before unloading, the more they can be submitted to thermal stress.

According to Figure 1, the range of ambient temperature can be split in different areas regarding thermal comfort of the animals. To prevent thermal stress, the ambient temperature should remain in the thermoneutral zone (TNZ), which is defined as 'the range of ambient temperature within which metabolic rate is at a minimum, and within which temperature regulation is achieved by non-evaporative physical processes alone' (Yousef, 1985; Aggarwal and Upadhyay, 2013). Animals in the thermal comfort zone will have no specific cold and warm feeling and their health and welfare regarding temperature are optimal. As temperature rises, they will start feeling warm (point C in Figure 1) and then reach the upper critical temperature (UCT, point D in Figure 1). UCT is the ambient temperature above which thermoregulatory evaporative heat loss processes of an animal are activated.

Below the lower critical temperature (LCT, point A in Figure 1), the animals rely on thermogenesis to maintain the core body temperature. UCT and LCT are then considered to indicate the limits for the occurrence of heat (above UCT) and cold (below LCT) stress.
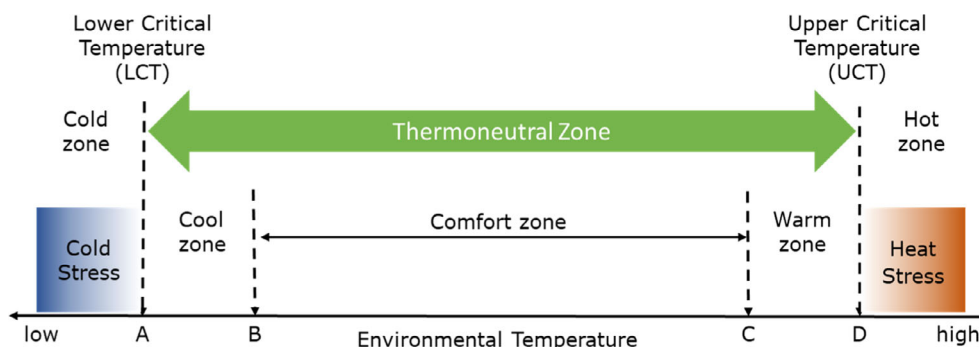
Figure 1: Schematic representation of thermal zones as a function of the environmental temperature

When the environmental temperature exceeds the limit to the warm zone (point C in Figure 1), the animal will start activating strain responses (vasodilatation, sweating in cattle) but homeothermy is still maintained and fitness is not hampered. The UCT for cattle (point D in Figure 1) has been defined around 24–26°C (Silanikove, 2000; Aggarwal and Upadhyay, 2013). At these temperatures, heat stress begins, and the temperature of the animal may start rising, evaporative cooling mechanisms are intensified exponentially, the need for water consumption increases and in addition to sweating panting may occur. When the temperature continues to rise in the hot zone, coping mechanisms to maintain homeothermy are unsuccessful, body temperature continues to rise, and fitness can be impaired (hot zone in Figure 1). At slaughter, all efforts should be in place to prevent animals from entering or staying in the hot zone, in which welfare is compromised. When the environmental strain is very high, increase of body temperature brings acute heat stress with heavy panting and sweating and in extreme cases heat stroke and death (when animal temperature increases by 3–6°C compared to the normal body temperature).

When temperature starts decreasing, animals will start activating strain responses and start to feel cold (from B to A in Figure 1). When they reach the LCT, they get outside the TNZ and the cold adaptation process is intensified. First, shivering will start in order to increase heat production and is intensified as the animal goes deeper into the cold zone, with an increase of energy consumption. When the capacity for heat production is overloaded, homeothermy is not maintained anymore, body temperature decreases and hypothermia starts, leading to death from cold in extreme cases. Compared with heat stress, cold stress has been rarely studied in cattle.

In the slaughterhouse situation, exceeding UCT and falling below LCT is considered as thermal stress.

LCT and UCT depend on a variety of factors including breed, age, physiological stage, among others, and are influenced by other environmental conditions such as relative humidity and wind velocity (Sanz, 2018).

Definition of 'Heat stress':

As explained above, heat stress will set in once an animal is exposed to ambient temperatures above UCT and cannot maintain its body temperature.

Heat loss by the animals is achieved by two mechanisms: the loss of 'sensible heat' (by radiation, convection or conduction) and by 'latent heat' (water evaporation) (Sanz, 2018; Collier and Gebremedhin, 2015). As temperature increases, the ability of animals to dissipate 'sensible heat' is reduced (Caufield et al., 2014) and the loss of 'latent heat' (e.g. by sweating, panting) becomes more important (Mortola and Frappell, 2000). For this reason, heat stress effects are extremely influenced by environmental variables other than temperature at arrival such as relative humidity, wind speed and solar radiation.

Acclimatisation to thermal stress has now been identified as a process under endocrine control (Collier et al., 2006). The process of acclimatisation to heat stress in dairy cows occurs in two phases (acute and chronic) and involves changes in secretion rate of hormones as well as receptor populations in target tissues. The time required to complete both phases is weeks rather than days.

Therefore, the capacity of adaptation of dairy cows to heat stress at slaughter remains low and measures should be taken to prevent or mitigate heat stress.

Dairy breeds are typically more sensitive to heat stress than meat breeds, and higher-producing animals are more susceptible because they generate more metabolic heat (Bernabucci et al., 2010; Kadzere et al., 2002). Therefore, it is not easy to give general figures for UCT at arrival since it might depend on the breed. As an example, Pereira et al., 2014 compared the reaction of two local (Portuguese) breeds versus two exotic (Friesian and Limousin) breeds in different heat stress conditions. They found that the different breeds did not adapt the same way to heat stress (differences in body temperature elevation) and that the strategy for heat evaporation was not the same depending on the breed. Cows of the local breed showed a superior body temperature stability including at highest heat stress conditions, achieving mainly maintenance of homeothermy by tachypnoea (excessive rate and depth of breathing) rather than by sweating, suggesting a specific adaptation to semi-arid climate in relation with water metabolism.

Aggarwal and Upadhyay (2013) compiled UCT in dairy cattle ranging from 20°C to 24°C in Holstein, more than 24°C in Jersey crossbreeds and more than 32°C in indigenous cattle.

Collier and Gebremedhin (2015) reported that properties of the hair coat, such as hair density, hair length, and hair-coat thickness and colour play a role in heat stress regulation. High hair coat density, which is necessary in cold weather to provide insulation by trapping air, becomes an obstruction to free evaporation of water from the skin surface in hot weather.

In a survey by Schwartzkopf-Genswein et al. (2012), a stationary passively ventilated vehicle, such as the North American pot-belly trailer or the European truck, was monitored for journeys exceeding 8 h. The relative humidity and temperature rose quickly resulting in heat stress for the animals, especially when they waited in the truck under warm conditions and at high stocking density.

Heat stress increases dramatically water and electrolyte losses in ruminants and therefore increases their water needs (Silanikove, 2000). Factors such as water deprivation, nutritional imbalance and nutritional deficiency may exacerbate the impact of heat stress.

ABMs for 'Heat stress':

Severely heat stressed cattle are recognisable from the open mouth breathing progressing to protruding tongue as the body temperature steadily rises (Gaughan and Meder, 2013). Both panting and sweating are important mechanisms of evaporative heat loss, with sweating generally accounting for up to 80% of total evaporative heat loss (Robertshaw, 1985; Aggarwal and Upadhyay, 2013), and both creating a microclimate that favours dehydration (Faucitano and Perdenera, 2016). Evaporative heat loss is diminished with increasing ambient humidity levels, although respiratory cooling might still be effective if the temperature of inhaled air is lower than core body temperature (Sparke et al., 2001).

Visible ABMs are panting and sweating, but because sweating is 1) difficult to assess in truck pens at arrival and 2) can occur much earlier than panting, even when the ambient temperatures are still well in the TNZ for dairy cows (e.g. 12–14°C, Silanikove et al., 1997), it is recommended to only use the number of panting animals as ABM at arrival. Mader (2014) showed a positive correlation between cattle body temperature during heat stress and the increase of a panting score. Depending on the physiological stage or the breed (Pereira et al., 2014), cattle may express a variable rate of panting in the same environmental conditions. Assessment of heat stress at arrival can be done by counting the number of animals showing the ABM defined in Table 3.

Alternatively, a temperature–humidity index (THI) can be used as a proxy to detect heat stress conditions (see below under 'Too high effective temperature').

Table 3: ABM for the assessment of 'Heat stress' at arrival

ABM	Description	Welfare consequence
Panting	Breathing with increased respiratory rate, sometimes accompanied by open mouth, drooling and tongue hanging out of the mouth (Tresoldi et al., 2016)	Heat stress

Hazards leading to 'Heat stress':

The hazards leading to heat stress are:

1) Too high effective temperature
2) Insufficient space allowance in the lorry.

Too high effective temperature

The effective temperature perceived by an animal is a combination of the ambient temperature, radiation, humidity and air velocity. In hot and humid environmental conditions, poor ventilation will exacerbate the perceived temperature.

Complementary to the ABM described above, a THI can be used as an environmental measure to detect heat stress conditions. For the calculation of THI, several different formulas have been proposed which are accompanied by different thresholds for heat stress (Bohmanova, 2006). For example, the THI can be derived from a combination of wet and dry bulb air temperatures (WBT+DBT) (Silanikove, 2000) and be expressed as follows:

$$THI = 0.72(WBT+DBT) + 40.6$$

Using this formula, THI values of 70 or less are considered comfortable, 75–78 stressful, and values greater than 78 cause distress and animals are unable to maintain thermoregulatory mechanisms or normal body temperature (Silanikove, 2000; Aggarwal and Upadhyay, 2013).

Temperature and humidity are easier to retrieve with simple devices that can be installed in the arrival area than through measuring dry bulb and wet bulb temperature. Aggarwal and Upadhyay (2013) used a formula integrating relative humidity (RH) and temperature (T) for estimating THI:

$$THI = (1.8 \times T + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T - 26).$$

With a THI of 72 (e.g. 25°C, 50% humidity), they reported similar yet slightly different thresholds as the starting point for heat stress.

Bohmanova (2006) has shown that indices with higher weights on humidity were better estimating heat stress in the humid climate, whereas indices with larger weights on (dry bulb) temperature were the best indicators of heat stress in the semi-arid climate. Therefore, the THI formula used should be adapted to the climate animals have to cope with.

Insufficient space allowance in the lorry

The space allowance is the space provided per animal; it is expressed in m^2 per animal of a certain weight. Apart from the size/weight of the animal, the minimum requirement also depends on various other factors that include according to Visser et al. (2014):

- Ambient conditions (environmental temperature, adequate ventilation, relative humidity),
- Ability of the animals to thermoregulate effectively,
- Need for animals to lie down, to be watered or to be fed.

Since the space available per animal will not change until unloading, the risk of heat stress will increase when the lorry is stationary and without any mechanical ventilation.

Physical space requirements increase with increasing body weight, and can be calculated using the formula (Petherick, 1983):

$$A = k \times (BW)^{2/3}$$

where A is the floor area covered by the cattle; k is a constant value that depends on the cattle posture; and BW is individual body weight. Visser et al. (2014) reviewed the requirements for space for cattle during transport, which are also valid during arrival at the slaughterhouse. They refer to different papers (Petherick, 1983, 2007; Petherick and Phillips, 2009), which report k = 0.019 for standing cattle and k = 0.027 for lying cattle. This review also stipulates that cattle needs extra space, when they need to rest and when they are transported for long journeys. As an example, Randall (1993) recommended that equations used for standing cattle are only suitable for short journeys, which was defined as less than 5 h.

Petherick (2007) studied the extra need of space for cattle to change position from standing to lying or vice versa; in this case k is 0.047.

As an example to illustrate these different k values, for a medium-sized calf with a body weight of 110 kg, k = 0.019 for standing animals equates to 0.44 m^2, k = 0.027 for lying equates to 0.63 m^2 and k = 0.047 for changing position equates to 1.096 m^2. For medium-sized cattle with a slaughter weight of 325 kg, k = 0.019 for standing animals equates to 0.91 m^2, k = 0.027 for lying equates to 1.3 m^2 and k = 0.047 for changing position equates to 2.26 m^2.

The space allowances requested at arrival should be based on the formula provided above (Petherick, 1983). Therefore, at arrival space, allowance for each animal has to be between $0.019 \times (BW)^{2/3}$ if transportation lasted less than 12 h and $0.027 \times (BW)^{2/3}$ if transportation lasted more than 12 h (EFSA AHAW Panel, 2011). Additionally, a k of 0.0315 should be used if cattle are to be offered feed and drink as well as space to rest on a vehicle (SCAHAW, 2002). These values should be regarded as a guiding framework since physical condition of animals, animal categories, meteorological conditions and likely journey times may require adaptations.

The height of compartments in the truck is also important in relation to the welfare of the animals, when adopting a comfortable posture. The height is also relevant for adequate temperature regulation and removal of noxious gases (SCAHAW, 2002 cited by Visser et al., 2014). For cattle, which should be able to stand during the journey, the deck height must be well above the heads of the tallest animals when standing with their heads up in a natural position. Some papers and recommendations (Lambooij et al., 2012; EFSA, 2011; SCAHAW, 2002) indicated 20 cm above the withers of the tallest animals as the minimum height during transport, and hence, at arrival.

Prevention and correction of 'Heat stress' and its related hazards:

A crucial preventive measure is to avoid transportation of cattle during the hottest hours of the day. This is particularly relevant if the truck is not equipped with a forced ventilation system. Under hot climatic conditions, lowering stocking density at loading will help preventing heat stress, especially when no mechanical ventilation is provided. Furthermore, when animals show signs of heat stress or THI exceeds the respective thresholds, animals should be unloaded immediately to prevent or mitigate heat stress.

If unloading cannot be done immediately, immediate assessment of the cattle at arrival will enable the responsible person to decide upon appropriate corrective actions for alleviating further negative welfare consequences such as providing shelter and adequate ventilation at arrival in order to get below the UCT. Showering animals can also be an option that can act as a corrective measure. Sprinkler and fan cooling systems have proved to be effective for dairy cows under shaded housing (Collier et al., 2006). Such systems might be adapted to the arrival area in case animals cannot be unloaded immediately, but such cooling systems may not be effective if the ambient relative humidity is high, in which case additional ventilation is necessary.

Definition of 'Cold stress':

When the temperature is below the LCT (Figure 1), cattle are considered 'cold stressed' in the context of this Opinion, since they show difficulty achieving a balance between body heat production and body heat loss (Dalmau and Velarde, 2016). They will show shivering and in the extreme case their capacity of maintaining their body temperature will be compromised.

High hair coat density can help in cold weather to provide insulation to cattle by trapping air (Collier and Gebremedhin, 2015). In addition, under winter conditions, if an animal's coat cover is wet and muddy, then energy requirements for maintenance can easily double, particularly if the animal is not protected from the wind (Mader, 2014) during transport and at arrival. Aggarwal and Upadhyay (2013) compiled LCT for dairy cattle being from 8 to 10°C for buffaloes and indigenous cattle to 2°C for Jersey and
−10/−20°C for Holstein.

ABM for 'Cold stress':

When cattle are subjected to cold stress at arrival, they may show shivering behaviour on the lorry. Observing all animals properly can be challenging. In case it is possible, the number of animals, which are shivering, according to the definition showed in Table 4, can be taken as a specific ABM.

Table 4: ABM for the assessment of 'Cold stress' at arrival

ABM	Description	Welfare consequence
Shivering	Rapid twitching of muscle groups anywhere on the body (Tucker et al., 2007)	Cold stress

Hazards leading to 'Cold stress':

<u>Too low effective temperature (see Details in Section 3.1.2.1)</u>

In cold and humid environmental conditions with high wind speed, the perceived temperature will decrease rapidly. Cold stress may occur when the THI (using the formula THI = (1.8 × T + 32) − (0.55 − 0.0055 × RH) × (1.8 × T − 26), where T is temperature (i.e. dry bulb temperature) and RH relative humidity) falls below 64 (Aggarwal and Upadhyay, 2013).

The origins of this hazard are described in the outcome table in Section 3.1.2.6; they are mainly linked to cold climatic conditions, lack of skilled operator able to deliver suitable protection to animals, absence of protection from wind and environmental temperatures on the truck and/or prolonged waiting time before unloading on cold days.

Prevention and correction of 'Cold stress' and its related hazards:

Some preventive measures can be taken at the time of transportation, e.g. when the temperature is below the LCT the coldest hours of the day should be avoided for transportation. Cold stress in the truck can be controlled by partially closing the ventilation openings (boarding) in order to reduce air flow and by adding a minimum of 5 cm layer of Styrofoam to the vehicle top ceiling (Gonyou and Brown, 2012) and bedding on the truck floor such as woodchips, sawdust, cellulose or straw (Schwartzkopf-Genswein et al., 2012).

If temperature is still below the LCT or THI under 64 at arrival (in certain cases this will correspond as well to shivering animals), cattle should be unloaded immediately. In case this is not possible, adequate shelter should be provided to allow cattle protection from the wind. Heating systems can be provided in the waiting area if needed. These measures (unloading as soon as possible, protection from wind and heating) can be used separately or in combination, depending on how critical the situation is. They can act as preventive or corrective measures for the hazard and as well to mitigate the welfare consequence cold stress.

3.1.2.2. Welfare consequence 'Prolonged thirst': assessment, hazard identification and management

Definition of 'Prolonged thirst':

The animal has been unable to get enough water to satisfy its needs, resulting in dehydration.

Adult and growing cattle require a large volume of water to maintain homeostasis, for example, growing beef cattle drink ∼ 27 to 66 L per day (von Keyserlingk et al., 2016). Dairy cows producing over 30 kg of milk per day require a significant supply of fresh water as they can consume from 80 to 100 L of water or more per day (von Keyserlingk et al., 2016). Therefore, water requirements of cattle are high (around 0.09 L/kg live weight) and water deprivation can lead to thirst and metabolic and physiological consequences like dehydration.

ABMs for 'Prolonged thirst':

There is no specific ABM feasible for use at arrival. For instance, reduced skin turgidity and sunken eyes can provide a useful measure of prolonged thirst but are not considered feasible measures because the animals cannot be approached (skin tent test) or the eyes are barely visible.

Hazards leading to 'Prolonged thirst':

<u>The hazards leading to prolonged thirst are:</u>

    1) <u>Too long water deprivation</u>
    2) <u>Too high effective temperature (see details in Section 3.1.2.1).</u>

<u>Too long water deprivation</u>

If no water is available in the lorry pens, animals that are transported to slaughter experience water deprivation from the time they are deprived of water on farm until they have access to water in the lairage pens. Phillips et al. (2003) in a review book explain that in cases of prolonged thirst, the concentration of water in body tissues is decreased, leading to haemoconcentration and less efficient circulation and transportation of oxygen. Brain lesions (Padovan, 1980) and hypernatraemia, the clinical manifestation of high serum sodium concentrations, have been also noted in cases of severe dehydration. Other effects of too long water consumption include depression of thermoregulation (Silanikove, 2000), which can be problematic when animals are exposed to high temperatures.

This hazard's origin is mainly due to staff lacking skill or diligence, leading to cattle left too long without access to water on farm, during transport and/or until lairage. In other cases, especially during long distance transport, technical failures can render the water system inaccessible or inefficient or failing completely in the truck. Indeed, in Europe, water deprivation before transport is not practiced, but in other countries (e.g., Australia) a pre-transport period of enforced food and/or water deprivation is applied primarily to reduce the gastrointestinal volume prior to transport, thus reducing the total amount of excreta in trucks and the level of faecal soiling on animals (Sparke et al., 2001; Gregory, 2008).

A review about Australian conditions for cattle transportation indicated that transported cattle are generally not fed or watered in the lorry during the journey (Fisher et al., 2009). The authors claimed that it is not in itself a problem, provided that the overall time off water does not cause dehydration of the animals. The risk of dehydration for transported animals depends on age, physiological state, condition and thermal conditions during the journey. According to these authors, cattle are less sensitive to water deprivation than monogastric animals since their rumen contains water providing a buffer effect. However, even if they are not dehydrated, cattle will experience thirst after a certain time of water deprivation.

In very large countries such as Australia (Fisher et al., 2009) or Canada (Gonzales et al., 2012), transport duration and water deprivation for 30 h or 48 h have been reported. Hogan et al., 2007 estimated that in Australia cattle are frequently subjected to feed and water deprivation for about 12 h before, and then during transport in order to reduce digesta load in the gastrointestinal tract. In the latter study, food and water deprivation was associated with some stress indicated by increased levels of plasma cortisol that may be partly responsible for an observed increase in the output of water and nitrogen in urine and faeces. Loss of body water induces dehydration that may induce feelings of thirst by effects on the hypothalamus structures through the renin–angiotensin–aldosterone system. Dehydration coupled with the discharge of sodium in urine challenges the maintenance of homeostasis. Based on the potential for enteropathogen growth and the potential for an increase in stress to the animal, the authors recommended ensuring that total time off food and/or water does not exceed 24 h.

Data about maximum water deprivation are very scarce. An early study of Padovan (1980) reported in 500 steers deprived from water for 48 h that within the following 10 days, 40 animal showed neurological signs due to polioencephalomalacia (cerebrocortical necrosis) and 14 animals died. Parker et al. (2003) studied the effect of transportation and/or feed and water deprivation on acid-base balance using 19 two-year-old Bos indicus steers. The steers were allocated to one of three groups: 1) control, offered ad libitum access to feed and water (n = 8); 2) water and feed deprived, offered no feed or water for 60 h (n = 6); and 3) transported, offered no feed or water for 12 h, and then transported for 48 h (n = 5). Blood gases, electrolytes, lactate, total protein, albumin, anion gap, strong ion difference and total weak acids were determined at the conclusion of transportation. The study demonstrated that although blood pH remained within normal values in transported and fasted steers, the primary challenge to a transported or feed- and water-deprived animal is a mild metabolic acidosis induced by elevated plasma proteins, which may be the result of a loss of body water. The loss of electrolytes had little effect on the acid-base balance of the animals.

Additionally, too high effective temperature may have a cumulative effect on time for water deprivation since water needs can increase from 1.2- to 2-folds in case of heat stress (Beatty, 2005).

Prevention and correction of 'Prolonged thirst' and its related hazards:

Access to water can reduce both loss of bodyweight and loss of carcass weight (Warriss et al., 1990; Vogel et al., 2010 cited by Vogel et al., 2019; Gregory, 2008). To prevent 'Too long water deprivation' and its direct welfare consequence, 'Prolonged thirst', cattle need to have access to water on farm until being loaded on the truck and ideally while in the truck as well. Indeed (see above) there is no demonstration of advantage in water deprivation prior to transportation (Sparke et al., 2001).

Animals should not be deprived of water before loading and water should be supplied on the truck so that cattle should not suffer from water deprivation. Given the influence of journey conditions on resistance to dehydration in transported livestock, it is difficult to place absolute limits of water deprivation times (Fisher et al., 2009), but regarding the results exposed above, it appears that 48 h water deprivation, have detrimental effect on cattle welfare and health. Water deprivation is not recommended but based on the considerations of Hogan et al. (2007) in any case should not exceed 24 h for cattle.

3.1.2.3. Welfare consequence 'Prolonged hunger': assessment, hazard identification and management

Definition of 'Prolonged hunger':

Deprivation of food leading to a craving or urgent need for food or a specific nutrient, accompanied by an uneasy sensation, and eventually leading to a weakened condition (Merriam-Webster dictionary[19]), as metabolic requirements are not met.

ABMs for 'Prolonged hunger':

There is no specific ABM to assess prolonged hunger of cattle at arrival.

Hazards leading to 'Prolonged hunger':

Too long food deprivation

Food deprivation time is the period that starts when the feed is removed or no longer accessible on-farm in order to load the animals for transport to the slaughterhouse.

In certain parts of the world, fasting in cattle can start a few days before transport (Warriss et al., 1990), since it takes time to empty the digestive tract in ruminants, but this is not a common practice worldwide. Smith et al. (1982) in Australia made an experiment on 144 steers fasting them 53 h pre-slaughter and submitting them to 0, 3 or 12 h of road transportation. The mean rate of live weight loss declined progressively with fasting time, from 2.57 kg/h during the first 5.3 h to 0.71 kg/h during the final 23.6 h, meaning that live weight is mainly decreasing at the beginning of fasting, when the digestive tract is emptying. Over the first 18–24 h of transport, loss of bodyweight can reach up to 11%. Animals that lost more than 10% of their bodyweight during transport had a greater likelihood of dying or becoming non-ambulatory or lame (González et al., 2012) thus indicating a compromised welfare.

Recently, Rabaza et al. (2020) tested different times of feed withdrawal on 20 steers fitted with rumen catheters. Feed was withdrawn for either 12 h, 24 h, 36 h or no feed withdrawal (control group) followed by feed reintroduction. Animal behaviour was affected by the feed withdrawal challenge. Steers from the T12, T24 and T36 treatments showed a higher ingestion rate and a lower frequency of rumination after feed re-introduction. A long feed withdrawal period (36 h) produced rumen pH reductions well below the accepted thresholds for acute acidosis, but without any perceptible clinical signs.

Cattle will lose live weight due to fasting prior to transport and during transportation by loss of gut fill. At a second stage, bodyweight loss can be due to dehydration and energy consumption to maintain balance and homeostasis (Cernicchiaro et al., 2012) leading in case of long-time food deprivation cumulated with other transport stressors to fatigue and even death.

Bourguet et al. (2011) ran an experiment on heifers food-deprived for 30 h, in which food deprivation influenced some of the classical indicators of energy metabolism and exacerbated reactivity to sudden events. In addition, when additional stressors were applied, food deprived cattle were more reluctant to accept handling. Results indicate that a multifactorial origin of stressors during the slaughter period may synergistically increase psychological stress of cattle.

In their review, Fisher et al. (2009) highlighted two situations where metabolic challenge to the welfare of cattle due to feed restriction needs to be given careful consideration: 1) in very cold conditions, which can be exacerbated by wind chill in a moving vehicle, animals rapidly mobilise body energy reserves to try to maintain body temperature (cumulative effect of food deprivation and too low effective temperature); and 2) very young animals (e.g. unweaned) also are at risk, with a higher metabolic demand, and lower fat and energy reserves.

The time of pre-slaughter feed removal should be kept to the minimum. However, there is a risk of feed being removed too early at the farm, transport being delayed or prolonged, and/or too long waiting time before unloading and/or too long lairage period resulting in too long food deprivation.

Prevention and correction of 'Prolonged hunger' and its related hazard

To prevent 'Prolonged hunger' the food should not be withdrawn prior to transportation. It is recommended that the maximum time elapsed between food withdrawal and end of lairage does not exceed 36 h (see Section 3.1.2.2). This can be achieved by careful planning of these processes

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[19] https://www.merriam-webster.com/dictionary/hunger

(including the transport time), and by scheduling and prioritising the slaughter of the animals. The only identified corrective measure is to unload and slaughter animals immediately. If they have to stay in lairage, they have to be fed there.

3.1.2.4. Welfare consequence 'Fatigue': assessment, hazard identification and management

Definition of 'Fatigue':

Physiological state representing extreme tiredness and exhaustion of an animal.

In a review, Terlouw et al. (2008) indicated that balance maintenance in large animals such as cattle involves great physical effort and may cause fatigue. Such effort explains the increased levels of plasma creatine kinase after 15 h of transport described by Knowles (1999). Fisher et al. (2009) noted that although it is a reasonable presumption that animals become tired if they are standing for a long journey, there is no data regarding how tired they become, and what is the risk of associated welfare decrease. For example, in a New Zealand study, 6-month pregnant dairy cows transported for 9 h did not spend any time lying in the 2 h after arrival, but grazed instead (Fisher et al., 1999), suggesting that eating was more of a priority for the animals at arrival than lying down and resting. Fatigue is likely to increase over longer journeys, although it may vary individually. Cattle transported for 31 h in bedded vehicles tended to start to lie down after 24 h of transport, although not all animals did so (Knowles et al., 1999a,b).

More recently, a 'fatigued cattle syndrome' has been described in non-ambulatory or slow and difficult to move meat cattle soon after arrival at slaughterhouses in the USA (Thomson et al., 2015). Affected cattle showed various clinical signs including tachypnoea, lameness and reluctance to move. The clinical signs and serum biochemical abnormalities observed in affected cattle were similar to those observed in pigs with fatigued pig syndrome, and the authors proposed that 'fatigued cattle syndrome' be used to describe the state experienced by such beef cattle. The authors' view is that although there is a concern that cattle fed with the β-adrenergic receptor agonist zilpaterol hydrochloride (used to increase feed efficiency) are at greater risk of developing mobility problems compared with cattle fed without zilpaterol, this fatigue syndrome is likely multifactorial and not only due to zilpaterol consumption. Wood (2015) claims that it is more likely that what is called 'fatigued cattle syndrome' by Thomson et al. (2015) is carbohydrate-induced laminitis followed by transport, with the cattle forced to stand for hours on a hard surface. According to the authors, cattle with laminitis typically spend much of their time lying down, and it is suspected that the transport of cattle with laminitis leads to the sloughing of the hoof walls which was also observed in some of the animals. The use of β-agonists is likely to predispose cattle to heat stress and therefore can have an accumulative effect with hazards identified at the slaughter level. Therefore, fatigued animals can be encountered at arrival, but the existence of a 'fatigued cattle syndrome' which goes beyond the fatigue caused by the mere physical strain of transport is not clearly demonstrated.

ABMs for 'Fatigue':

Animals presenting fatigue at arrival are often laying or sitting and are unable to walk since they are too exhausted. The ABMs that can be used for this welfare consequence are exhaustion and tachypnoea.

Assessment of 'Fatigue' at arrival can be done by counting the number of animals showing the two ABMs in Table 5. The number of animals showing fatigue can be reported.

Table 5: ABMs for the assessment of 'Fatigue' at arrival

ABMs	Description	Welfare consequence
Exhaustion	Conscious animals lying on the floor and not able to stand up (recumbency) (Benjamin, 2005); reluctance to move if the animal is standing, but no signs of lameness such as repeated weight shifting or reluctance to bear weight	Fatigue
Tachypnoea	Excessive rate and depth of breathing, e.g. > 30 per minute in adult, resting cattle (Breeze, 1985)	Fatigue

Hazards leading to 'Fatigue':

The withdrawal of feed and water and the need to stand and maintain balance for transport periods can cause a physiological challenge to the animals. A review of Fisher et al. (2009) about the conditions during cattle transportation in Australia indicated that during the journey the initial psychological stress challenges induced by handling, loading and the novelty of the transport experience tend to lead to challenges associated with transport duration, specifically the risks of dehydration, and metabolic and physical fatigue. Knowles et al. (1999a, cited in Vogel et al., 2019) hypothesised that the animals could possibly lie down during transportation because they are in need of sleep (increase of cortisol in the context of long-time transportation (> 24 h).

Willingness and possibility to lie and rest is discussed as depending as well on animal characteristics because cattle might prefer to stand during transport as they are relatively heavy animals (Vogel et al., 2019). Lying can then produce considerable pressure on the parts of the body in contact with the floor of the vehicle, especially during a rough journey or at arrival.

When not considering the internal factors such as body condition, age, physiological status and breed and factors related to what happened on farm and during transport, which are excluded from the mandate, the hazards which can be responsible for fatigue are:

1) Too high effective temperature (for details see Section 3.1.2.1).
2) Too long water deprivation (for details see Section 3.1.2.2).
3) Too long food deprivation (for details see Section 3.1.2.3).
4) Insufficient space allowance in the lorry.

The physiologic challenges induced by 'Too high effective temperature', independently or cumulated with 'Food and/or water deprivation too long' will lead to exhaustion of body reserve and fatigue.

Insufficient space allowance in the lorry

In relation to fatigue, space allowance is the amount of space an animal has available to lay down, stand up and turn around without hindrance. If space allowance is reduced too much, cattle cannot rest properly, resulting in fatigue.

Whether animals will lie down is dependent on the transport conditions and journey length and if it is comfortable to lie down (stocking density, bedding, driving quality, road conditions, and suspension characteristics of the transport vehicle) (Visser et al., 2014). At some point, it may be necessary for the animals to rest and to avoid states of fatigue or exhaustion.

The changes seen in blood variables indicate that there is some physical effort involved in remaining standing and having to maintain balance against the motion of the vehicle (Vogel et al., 2019).

The space allowances requested during transport and at arrival should be based on the formula $k \times (BW)^{2/3}$ where k varies from 0.019 for standing animals (transport < 12 h) to 0.027 (transport > 12 h) or k of 0.0315 if cattle are to be offered feed and drink on a vehicle as well as space to rest.

Prevention and correction of 'Fatigue' and its related hazards:

The prevention and correction measures regarding the hazards 'Too high effective temperature' and 'Too long water and food deprivation' are described in Sections 3.1.2.2 and 3.1.2.3. Fatigue is often originating from conditions prior to arrival at slaughter. Good conditions at loading on farm, and reduction of transport time can be a way to prevent cattle fatigue at arrival (Vogel et al., 2019).

Stocking densities should be adjusted according to:

- the temperature/humidity combination in the truck
- waiting time in the lorry at arrival
- duration and quality of the journey.

Regarding these elements, the only preventive measure for insufficient space allowance is to adjust the number of cattle to the size of the pen in the truck according to the recommendations. More space should be allowed if a journey is longer than 12 h and if the climatic conditions are warm (EFSA, 2011). No corrective measures for the hazard insufficient space allowance exist, except to unload cattle as soon as possible.

3.1.2.5. Welfare consequence 'Restriction of movement': assessment, hazard identification and management

Definition of 'Restriction of movement':

The animals are unable to move (e.g. to avoid aggression or seek resources such as lying space, feed or water) as a result of insufficient space available.

ABMs for 'Restriction of movement'

At arrival, it is very difficult to see animals in the lorry pens to assess restriction of movement unequivocally. Therefore, assessment of space allowance can be considered as a proxy. Space allowance is calculated as the area of the compartment available for physical occupation and for behavioural activity divided by the number of animals inside. It is usually expressed in area (in m^2) per animal.

Hazards leading to 'Restriction of movement':

1) Insufficient space allowance in the lorry (see Section 3.1.2.4).

Prevention and correction of 'Restriction of movement' and its related hazards:

The space allowance should be adjusted according to body weight, environmental conditions and travel time. As a preventive measure, it is recommended to adjust the number of cattle to the size of the compartment when loading at the farm.

As it is not feasible to provide more space for the animals in the truck pens at arrival, the mitigation measures should be to unload the cattle as soon as possible and then to offer sufficient space allowance for all animals to be able to lie at the same time in lairage, or to slaughter them as soon as possible.

3.1.2.6. Outcome table on 'Arrival'

Table 6: Outcome table on 'Arrival'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Too high effective temperature (see Section 3.1.2.1)	Heat stress, fatigue	Equipment, facilities, staff	Lack of skilled operators Environment Not enough ventilation in the truck Prolonged waiting time	• Staff training • Increase space allowance • Scheduling to avoid hottest hours of the day for transport • Unload immediately following the arrival, especially on hot days • Provide adequate ventilation to the truck at arrival place • Protect from adverse weather conditions	• Provide adequate ventilation or/and cooling systems
Too low effective temperature (see Section 3.1.2.1)	Cold stress	Equipment, facilities, staff	Lack of skilled operators No protection from the environment Prolonged waiting time	• Staff training • Prepare the vehicle according to weather conditions (e.g. closing the openings in the truck, providing bedding material) • Avoid coldest hours of the day for transport • Unload immediately following the arrival • Provide adequate shelter to the truck at arrival place	• Unload the truck immediately and bring the animals to a thermal neutral zone (with heaters)
Insufficient space allowance (see Section 3.1.2.4)	Restriction of movements, heat stress, fatigue	Staff	Lack of skilled operators Too many animals are put in the truck compartments	• Staff training • Adjust the number of animals to size of the compartment	• Unload the animals ASAP
Food deprivation too long (see Section 3.1.2.3)	Prolonged hunger, fatigue	Staff	Lack of skilled operators Feed withdrawn too early prior to transport Prolonged transport and/or prolonged waiting time in slaughterhouse	• Staff training • Planning of feed withdrawal according to transport schedule and duration of transportation and waiting time prior to slaughter • Scheduling slaughter of animals • Prioritising slaughter	• Unload and provide food to the animals, or • Unload and slaughter ASAP

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Water deprivation too long (see Section 3.1.2.2)	Prolonged thirst, fatigue, heat stress	Staff	Lack of skilled operators Water removed too early prior to transport Prolonged transport and/or prolonged waiting time	• Staff training • Animals should have access to water till loading in the truck	• Unload and provide water to the animals, or • Unload and slaughter ASAP

ABMs: Panting (heat stress), shivering (cold stress), exhaustion, tachypnoea (fatigue)

3.1.3. Unloading from the truck

Following arrival at the slaughterhouse, cattle should be unloaded from the truck immediately and moved to the lairage or slaughter areas. While the cattle are unloaded it is important to avoid that animals get scared and hurt themselves during this stressful process.

Unloading implies as well handling and moving cattle to lairage pens. The principles and practice of good cattle handling have been described in detail by Grandin (1993, 1998b). People who handle cattle need to understand the basic behavioural principles of moving cattle, in particular, flight distance and point of balance. For an animal to move forward, the handler should be within the flight zone but behind the point of balance at the shoulder of cattle (see Figure 2).
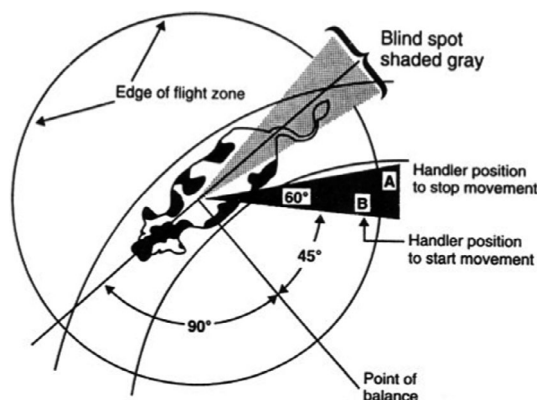
Figure 2: Flight zone and point of balance when handling cattle (Source: Temple Grandin[20])

The individual characteristics of animals do have an influence on their ease of handling, and this should be taken into account by the staff. Terlouw et al. (2008) presented several studies related to the impact of the early experience of cattle with humans. They showed that the rearing system and the type and frequency of contacts with the stockperson influence the animals' fear reactions to novel situations during loading and then in the pre-stunning phase, such as unloading, handling or moving of animals. For example, calves having received positive and more frequent contacts from their stockbreeder were easier to handle and had lower heart rates during loading compared to calves that had not (Lensink et al., 2000a,b, 2001). Familiarity among animals could be also used to ease the unloading and moving process. Cattle tend to follow their conspecifics, thus reducing stress due to separation or emotional reactions to the slaughter context. For example, bulls which had been kept in stable social groups from 4 months of age had lower cortisol levels in blood collected at bleeding than animals which had been mixed at the beginning of the fattening period (at the age of 9 months) (Mounier et al., 2006).

Finally, breed and temperament effects should as well be taken into account when unloading. Animals with a more excitable temperament will often become more agitated when suddenly exposed to a novel situation compared to animals with a calmer temperament (Grandin, 2013[21]).

Inappropriate unloading will lead to welfare problems such as impeded movement (see Section 3.1.3.1) and pain and fear (see Section 3.1.3.2).

3.1.3.1. Welfare consequence 'Impeded movement': assessment, hazard identification and management

Definitions of 'Impeded movement':

Difficulty of movement resulting in slipping and falling when unloading.

Animals not handled correctly or in poorly designed and maintained premises will experience impeded movement that can lead to pain when animals are slipping and falling.

ABMs for 'Impeded movement':

Animal welfare, as affected by impeded movement, can be assessed during unloading by recording animals slipping and falling (Welfare Quality®, 2009). The assessment can be done by counting the number of slips and falls per animal (see description in Table 7).

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[20] https://www.grandin.com/ritual/euthanasia.slaughter.livestock.html
[21] https://www.grandin.com/references/cattle.during.handling.html

Table 7: ABMs for the assessment of 'Impeded movement' at unloading

ABMs	Description	Welfare consequence
Falling	Loss of balance in which parts of the body other than feet and legs are in contact with floor surface (Welfare Quality®, 2009)	Impeded movement
Slipping	Loss of balance in which the animal loses its foothold or the hooves slide on the floor surface. No other body parts except hooves and/or legs are in contact with the floor surface (Welfare Quality®, 2009)	Impeded movement

Hazards leading to 'Impeded movement'

The impairment of animal welfare at this stage can be mainly due to two hazards:

1) Improper design, construction and maintenance of premises
2) Inappropriate handling

Improper design, construction and maintenance of the premises

This hazard occurs when the unloading area is not well designed (angle, depth of slope, flooring, lack of foot battens or lateral protection, etc.) so that it causes impeded movement to animals. It is considered inappropriate design and construction if the ramp angle is greater than 20° for calves or 26° for adult cattle (Faucitano and Perdenera, 2016).

Slips and falls occur mostly when concrete floors are wet with rain, urine or manure and it occurs especially when cattle are running or turning. When cattle use a steep ramp there is a risk of injury from both jumping, slipping and falling (Sandstrom, 2009).

Cattle that slip and fall have increased reluctance to move, what may increase inappropriate handling, leading to additional fear and/or injuries of cattle during unloading.

Inappropriate handling

It is considered inappropriate handling causing fear and/or pain when staff move single animals since cattle are gregarious; force the cattle to get off from the truck too quickly or through non-adapted bridges and raceways; or use the wrong material (e.g. goads instead of flags). The use of electric goads causes pain and leads to aversion (Pajor et al., 2000) and is considered a serious welfare concern. Inappropriate handling might cause animals rushing and getting scared and then slipping and falling during unloading. If animals are running, they are more likely to slip and fall (Sandstrom, 2009). It may also lead to animals being reluctant to move, freezing or turning back which in turn may provoke using force and harsh methods (e.g. with electric goads).[22]

Trying to unload downer animals, which are animals unable to move without assistance, from the truck is also considered inappropriate handling.

Prevention and correction of 'Impeded movement' and its related hazard

Methods to minimise impeded movement are the following:

- The dock should be as close as possible to the truck deck level to avoid unloading ramps. When not possible, the best option is that trucks have an integrated loading/unloading device, where the ramp angle is less than 20° for calves or 26° for adult cattle (Faucitano and Perdenera, 2016). When the slope is steeper than 10°, ramps should be equipped with foot battens or cleats which prevent animals from slipping while walking on the ramp, reducing the risk of falls (EFSA, 2011). A 20-cm spacing between the cleats is recommended to ease cattle walking smoothly through the ramp (Grandin, 2014a,b). Simple modifications can often improve the situation (Faucitano and Perdenera, 2016) like having a clean and dry unloading area. When the design of the unloading area is not adequate, using appropriate handling methods for unloading cattle with a low speed of moving can help reducing impeded movement.
- The presence of an external unloading ramps built at the truck deck level will avoid the use inclined ramps.
- When the unloading area is dark, installing a lamp to illuminate the unloading ramp and the corridor entrance often facilitates cattle movement, but the light must not shine into the animal's eyes (Grandin, 2008).

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[22] Grandin T. Available online: https://www.grandin.com/design/non.slip.flooring.html

- Animals should be handled calmly by trained personnel who knows how to behave and place themselves when moving the animals, to allow smooth unloading. Cattle are gregarious animals that feel secure in groups and are stressed by isolation. Therefore, it is recommended to move cattle in small groups (ideally of familiar animals) using flags, a plastic bag on a stick or a paddle in order to ease handling and reduce occurrence of slipping and falling (Grandin, 2008).

As corrective measures, the first step in improving animal movement is to correct mistakes that staff make while handling and/or moving animals. The best practice would be to (Faucitano and Perdenera, 2016): i) use the flight zone and the point of balance principle, iii) stop the use of electric prods and use flags, plastic bags on a stick or paddles, and iv) use following behaviour and move the cattle in small groups. Stopping obvious handling mistakes will make it possible to determine if the problems with animal unloading in a particular slaughterhouse are due to staff making mistakes or to flaws in the design and/or maintenance of the unloading ramp.

3.1.3.2. Welfare consequence 'Pain and fear'': assessment, hazard identification and management

Definitions of 'Pain', 'Fear':

Pain is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (IASP, 1979).

Fear is defined as an emotional state induced by the perception of a danger or a potential danger that threatens the integrity of the animal (Boissy, 1995).

When getting scared, animals might try to escape and can then hurt themselves, which exposes them to pain. That is why the welfare consequence pain and fear are grouped together here. There is only one hazard, 'unexpected loud noise', which leads to fear alone.

Animals might also have been injured before or during transport and then unloading will cause pain without fear. Lesions happening to cattle during handling at loading and unloading and transport are mainly bruising, lameness and dislocation (Faucitano and Perdenera, 2016).

ABMS for 'Pain' and 'Fear':

Cattle vocalise only when they experience something aversive or threatening, and therefore it can be used as an ABM for fear (Grandin, 1998a, 2001). Reluctance to move, freezing, turning back and moving backward during unloading are also signs of fear (Sandstrom, 2009; Welfare Quality®, 2009).

Slipping and falling (see Section 3.1.3.1) can lead to injuries, leading to pain. Animals can also suffer from injuries originating from the rearing period or from loading and/or from transport. In this case, when an animal is injured in a foot or a limb, the injury leads to pain that may be expressed as lameness.

Pain and/or fear can be assessed during unloading by counting the animals with injuries or lameness and the occurrence (per animal) of vocalisations, reluctance to move, animal turning back and escape attempts described in Table 8.

Table 8: ABMs for the assessment of 'Pain' and 'Fear' at unloading

ABMs	Description	Welfare consequence
Escape attempts	Attempts to go through, under or over gates and other barriers. Head and neck stretched forward and either slightly raised above back, slightly lowered, or level with back (modified after Lanier et al., 2001)	Fear
Vocalisation	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin, 2012)	Pain, fear
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012a)	Pain
Lameness	Abnormality of movement caused by reduced ability to use one or more limbs. Lameness can vary in severity from reduced mobility to inability to bear weight (modified after Welfare Quality®, 2009)	Pain
Reluctance to move	An animal that refuses to move when coerced by the operator or that stops for at least 4 seconds not moving the body and the head (freezing) (adapted from Welfare Quality®, 2009)	Fear, pain

ABMs	Description	Welfare consequence
Turning around or moving backwards	The animal turns around or moves backwards (by itself or as a reaction to the handling), e.g. when arriving to the end of the unloading area or at the entrance to passageways (modified after Welfare Quality®, 2009)	Fear

Hazards leading to 'Pain', 'Fear'

The impairment of animal welfare at this stage can be mainly due to three hazards appearing alone but most of the time combined:

1) Improper design, construction and maintenance of premises
2) Inappropriate handling
3) Unexpected loud noise

Improper design, construction and maintenance of premises

It has been reported by Faucitano and Perdenera (2016) that during handling at unloading, distractions, such as seeing moving people up ahead, sparkling reflections, shiny metal that jiggles or air blowing into the faces of approaching cattle, can result in cattle balking and backing up (Grandin, 1980, Grandin, 1996, 1998a,b cited by Faucitano and Perdenera, 2016) and therefore are improper if present in the unloading area.

It is improper as well to have dark zones, since cattle prefer moving from dark to light (Grandin, 1980) and often balk when they enter a dark race.

Inappropriate handling

See Section 3.1.3.1.

Unexpected loud noise

A slaughterhouse is an environment in which loud noises may occur. The noises originate mainly from machines, gates clanging, and personnel shouting. Noise can be continuous or sudden. The latter is defined here as 'unexpected loud noise'. This may provoke fear to cattle.

Cattle hearing ranges from 25 Hz to 35 kHz while human frequency hearing ranges from 20 Hz to 20 kHz (Heffner, 1998; Weeks et al., 2009, cited by Iulietto et al., 2018). An unexpected loud noise is a non-specific stressor that excites the endocrine and autonomic nervous systems (Brouček, 2014; Münzel et al., 2017 cited by Iulietto et al., 2018).

An increase in noise intensity can lead to stress for both animals and operators subjected to it. The sound intensity is measured in decibels, which is a logarithmic scale, meaning that 80 dB is 10 times the intensity of 70 dB. According to Weeks et al. (2009), 80 dB is considered an arbitrary limit for animal exposure, since this value is defined as the threshold level for human ear protection for continual exposure. A noisy environment can make all the operations more complex and increase the animals' reluctance to move (Berg, 2012; Grandin, 2006; Grandin, 2012; Velarde and Dalmau, 2012). Iulietto et al. (2018) studied a way to monitor the level of noise in cattle slaughterhouses (n = 3) with a smartphone app. For the bovine abattoirs, at unloading, the average values were 75–76 dB with a minimum of 60 dB and a maximum of 100 dB. This means that in a certain number of cases, even in the unloading area, which is not the noisiest place in cattle abattoirs (Iulietto et al., 2018), noise over 80 dB occurred, probably impairing cattle welfare by generating fear.

Prevention and correction of 'Pain' and 'Fear' and their related hazards.

The preventing methods to avoid pain and fear at unloading are the following:

- Distractions, such as seeing moving people up ahead, sparkling reflections, shiny metal that jiggles or air blowing into the faces of approaching cattle should be avoided.
- Animals should be handled calmly by trained personnel who knows how to behave and place themselves when moving the animals, to allow smooth unloading. It is recommended to move cattle in small groups (ideally of familiar animals) using adapted tools (see Section 3.1.3.1) and without rushing them.

- Sudden loud noise should be avoided as well as noise in general (from machine, metallic gates and fences, etc.) since cattle can hear sounds inaudible for man.
- Downer animals should be killed immediately. This emergency killing will spare them pain and fear from being unloaded from the truck.

Corrective measures described for handling in Section 3.1.3.1 apply here as well. All scaring objects and distractions should be removed from the cattle route and floors should be dry and well lighted to avoid shadows and reflections. All mechanicals noise should be stopped, and staff should stop shouting and whistling.

3.1.3.3. Outcome table on 'unloading of cattle from the truck'

Table 9: Outcome table on 'Unloading of cattle from the truck'

Hazard	Welfare consequences occurring to the cattle due to the hazard	Hazard origin	Hazard origin specification	Preventive measures	Corrective measures
Inappropriate handling (see Section 3.1.3.1)	Pain, fear, impeded movement	Staff	Lack of skilled operators Improper handling of animals Use of electric prods	• Training of staff for proper handling • Staff rotation • Appropriate equipment to move animals	• Instruct the operator to stop inappropriate handling • Implement staff rotation, or • Slaughter the animal as soon as possible
Improper design, construction and maintenance of premises (see Section 3.1.3.1)	Pain, fear, impeded movement	Facilities	Too steep slope Lighting Slippery and/or dirty floor or ramp Absence of solid lateral protection Presence of a gap between the lorry and the ramp	• Ensure maintenance of the area • Rebuild the unloading area to accommodate cattle behaviour	• Clean the slippery floor or ramp • Provide sawdust or straw to make it non slippery
Unexpected loud noise (see Section 3.1.3.2)	Fear	Staff	Staff shouting and making noise	• Identify and eliminate the source of noise • Staff training • Avoid personal shouting	• None

ABMs: Injuries, lameness (pain), vocalisations (pain, fear), escape attempts, reluctance to move, turning back (fear)

3.1.4. Lairage

Lairage conditions per se can have their own impact on the welfare of cattle and can also exacerbate the welfare consequences originating from the hazards the cattle have been previously exposed to before reaching the lairage pens.

Lairage is essential to carry out ante mortem inspection by the official veterinarians. Lairage is also used by the business operator to keep a reservoir of animals in order to maintain a constant slaughter rate. It also provides an opportunity for animals to rest and recover from the stresses of handling and transport from farm or market. This recovery can occur only when animals have enough space, ventilation in the lairage is of an adequate standard and the environment is quiet (FAWC, 2003) and they are provided with water.

The number of cattle kept in each lairage pen may vary according to the source or origin. For example, individual animals intended for private slaughter or village butchers may be kept separately, whereas a large group of familiar animals from a single farm or a mixed group of animals from auction markets will be kept together in a pen. Jarvis et al. (1996) recorded group sizes in lairage from 1 to 27 with a median of 8, and Weeks (2008) cited a range of 1–34, also with a median of 8. Inevitably, larger group sizes may be kept together when cattle from feedlots are involved.

Space allowance given to each cattle should be sufficient for them to lie down, get up, turn around and access resources such as water without hindrance. In addition, cattle also need space to move away/escape from an aggressor in a mixed/unfamiliar group situation.

Proper design, construction and management of the lairage area can help to overcome most of the hazards. Pen shape is of particular importance for bulls with aggressions being reduced in long, narrow pens in which each bull can 'defend' a line of fence, compared to squarer pens of the same area (Weeks, 2008). In some countries, bulls are kept in individual pens separated by gates every 3 m, which when opened form a race to e.g. the stunner.

3.1.4.1. Welfare consequences 'Social stress': assessment, hazards identification and management

Definitions of 'Social stress':

Social stress, for the purpose of this Opinion, is defined as stress resulting from group hierarchy formation, associated with aggression.

Conflict with pen mates as well the inability for subordinate animals to escape the dominant ones can lead to fear. In case of social stress, animals can be bruised, injured and suffer from pain. Continuous fights can lead to resting problems within the group and fatigue.

Steers, heifers and anoestrous cows are not aggressive in lairage. Bulls on the other hand need to be managed carefully. Young bulls in a familiar group exhibit play mounting, whereas in mixed groups the interaction between them is of agonistic nature, including butting, mounting, pushing and chasing others. These behaviours can continue for up to 12 h and even in the darkness at night (Kenny and Tarrant, 1987a,b). Owing to this, young bulls in a mixed group are prone to pain, fear and fatigue

ABMs for "Social stress":

Social stress can be assessed by observing the occurrence of aggressive behaviours and mounting in cattle (Table 10).

Table 10: ABMs for the assessment of 'Social stress' at lairage

ABMs	Description	Welfare consequence
Aggressive behaviour	Butting, hitting, striking or pushing with forehead, horns, horn base or any other part of the body with a forceful movement; following an animal or running after an animal (chasing); pushing the heads vigorously against each other (fighting) (Welfare Quality®, 2009)	Social stress
Mounting	Raising the brisket onto the rear or front end of the other animal and clasping with the front legs (or attempting to clasp) (modified after Phillips, 2002)	Social stress

Hazards leading to 'Social stress'

Mixing unfamiliar animals

Cattle are social animals which naturally live in groups. They have a social hierarchy which becomes established over time; consequently, any changes to the group can lead to aggressive behaviour and fighting as the social order is re-established.

Mixing unfamiliar animals, i.e. animals that were not pen-mates during the rearing or fattening period, is the main hazard for the appearance of social stress. Such mixing can occur in the lairage pens.

Prevention and correction of 'Social stress' and its related hazards

Preventive measure is to avoid mixing unfamiliar groups of bulls/keep familiar groups together from farm to slaughter. Corrective measures include removal of aggressive cattle or slaughter of the mixed groups immediately after unloading.

3.1.4.2. Welfare consequences 'Pain and fear': assessment, hazard identification and management

Definitions of 'Pain and fear'

For definitions of 'Pain' and 'fear', see Section 3.1.3.2.

ABMs for 'Pain and fear'

Assessment of pain and fear at lairage can be done by counting the animals showing the following ABMs (Table 11).

Table 11: ABMs for the assessment of 'Pain' and 'Fear' at lairage

ABM	Description	Welfare consequence
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012a)	Pain
Vocalisation	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin 2012)	Pain and/or fear

Hazards leading to 'Pain and fear'

The impairment of animal welfare at this stage can be mainly due to the hazards listed below, appearing alone but most of the time combined:

1) Improper design, construction and maintenance of premises
2) Unexpected loud noise
3) Mixing of unfamiliar animals (see Section 3.1.4.1)

Improper design, construction and maintenance of premises

During lairage, features related to the pen design or poor maintenance of the pen may result in injuries and pain (e.g. broken gates and metal parts). Exposure to hard, abrasive or slippery surfaces during resting will also provoke injury or lameness.

Unexpected loud noise

Noise levels in a slaughterhouse, especially in lairages where metallic gates and ventilation fans are used and pressure washing equipment may be operated, can have a significant effect on the welfare of cattle (Grandin, 1998b). In an exhausted individual, the compensatory mechanisms are more vulnerable than in a rested individual (Brouček, 2014). Thresholds for discomfort for cattle was noted at 90–100 dB, with physical damage to the ear occurring at 110 dB (Phillips, 2009). Cattle, with an auditory range between 25 Hz and 35 kHz (Heffner, 1998), can detect lower pitched sounds than other farm animal species (Heffner and Heffner, 1993). Dairy breeds are more sensitive to noise than beef breeds (Lanier et al., 2000). Weeks et al. (2009) measured the average noise value during the 24 hr in 34 abattoirs in England and Wales and recorded values from 52 to 79 dB for cattle lairages. Iulietto et al. (2018) used a mobile phone app to record noise levels in cattle lairages in three Italian slaughterhouses and reported a range of average values of 56–101 dB.

Prevention and correction of 'Pain', 'Fear' and their related hazards

Preventive measures include training of staff to avoid shouting, avoiding using noisy equipment close to the animals, identifying and eliminating the source of noise, keeping animals in familiar groups and avoiding mixing, avoiding mixing of horned animals with animals without horns, as well as clearly displaying notices regarding maximum number and category of animal holding capacity in lairage pens. Mounting in bulls can be avoided by provision of a tubular overhead.

Corrective measures are warning of staff shouting, removing aggressive animals, prioritising slaughter of mixed groups, adjusting the number of animals to the size of the pen, cleaning and drying the lairage to prevent animals from slipping and falling. In case no specific corrective actions can be taken, animals should be slaughtered as soon as possible.

3.1.4.3. Welfare consequence 'Thermal stress': assessment, hazard identification and management

Definition of 'Thermal stress':

In the lairage area, temperature variation can be significant and depends on the time of the day, the season and the ventilation equipment of the lairage zone.

For definition of heat and cold stress, see Section 3.1.2.1.

ABMs for 'Thermal stress':

At lairage, counting the animals panting can be used to monitor heat stress (Weeks, 2008). In extreme uncontrolled conditions, morbid animals can be seen in case of heat stress. Shivering can be used to monitor cold stress in cattle (Table 12).

Table 12: ABMs for the assessment of 'Thermal stress' at lairage

ABMs	Description	Welfare consequence
Panting	Breathing with increased respiratory rate, sometimes accompanied by open mouth, drooling and tongue hanging out of the mouth (Tresoldi et al., 2016)	Heat stress
Shivering	Rapid twitching of muscle groups anywhere on the body (Tucker et al., 2007)	Cold stress

Hazards leading to 'Thermal stress'

1) Too high effective temperature (see Section 3.1.2.1).
2) Too low effective temperature (see Section 3.1.2.1).
3) Insufficient space allowance (see Section 3.1.2.1).

Prevention and correction of 'Thermal stress' and its related hazards

During lairage, adequate ventilation should be provided to prevent build-up of noxious gases and to remove excess heat and moisture. An easily measured indication of sufficient ventilation in hot weather is the temperature difference between the inside of the building and the outside which, in general, should be less than 3°C (Seedorf et al., 1998). Maximal ventilation rates in excess of 4 m^3/h kg may be needed, especially in hot weather and when lairages are stocked to capacity, in which case fan-assisted ventilation is likely to be needed. Air movement should be easily detected at animal height. Additionally, THI can be used as an indicator of potential heat stress and THI of 75 or more (see Section 3.1.2.1) should be avoided (Silanikove, 2000).

Showering animals can also be an option that can act as a preventive measure, but if not applied first, can act as a corrective measure for the hazard and to mitigate the welfare consequence. Sprinkler and fan cooling systems have proved to be effective for dairy cows under shaded housing (Collier et al., 2006). Such systems, including misting, might be adapted to lairage areas, but it should be kept in mind that evaporative cooling systems may have a limited efficiency if the ambient relative humidity is high. Therefore, forced ventilation in enclosed lairage areas or high headspace in outdoor lairages may be required to avoid build-up of humidity at animal level. It is also worth noting that misting provided under the roof may be more effective in removing hot air raising from the animal level and accumulating under the high roof. Whereas, sprinklers are usually provided at the animal level in order to wet the fleece (hair) to achieve effective evaporative cooling.

The space allowance should be adjusted according to the increasing physical space requirements associated with increasing body weight (BW), following the formula $A = k \times (BW)^{2/3}$ (Petherick, 1983) where A is the floor area covered by the cattle and k is a constant value that depends on the cattle posture. For lairage, a minimum k value of 0.0315 is recommended, which should be increased according to the climatic conditions (Visser et al., 2014).

In case of too low ambient temperature, adequate shelter should be provided in lairage to allow cattle protection from the wind. Heating systems can also be provided. Protection from wind and heating can be used separately or in combination, depending on how critical the situation is. They can act as preventive or corrective measures for the hazard and as well to mitigate the welfare consequence cold stress.

3.1.4.4. Welfare consequences 'Prolonged thirst and hunger'': assessment, hazard identification and management

Definitions of 'Prolonged thirst and hunger':

For definitions, see Sections 3.1.2.2 and 3.1.2.3.

It has to be noticed that prolonged hunger and/or thirst can bring the animal to its physiologic limits and induce fatigue due to exhaustion of animal's reserves and adaptation capacities.

ABMs for 'Prolonged thirst and hunger':

As at arrival, there is no feasible ABM to detect prolonged hunger, since the duration of hunger is often not long enough to impair body condition. Prolonged thirst should normally not be observed in lairage, since it is recommended to supply animals in lairage with water. If, for any reason, animals are thirsty and not provided with enough water, then an increase of aggression at the water trough due to competition and/or an increase of water intake will be considered as good indicators to detect prolonged thirst.

Assessment of 'Prolonged thirst' at lairage can be done by counting the animals showing the ABMs reported in Table 13.

Table 13: ABM for the assessment of 'Prolonged thirst' at lairage

ABM	Description	Welfare consequence
Increased aggression at water trough	Aggressive encounters (butting, pushing, chasing away) at the water trough	Prolonged thirst

Hazards leading to 'Prolonged thirst and hunger'

1) Too long food deprivation: (see Section 3.1.2.3).
2) Too long water deprivation.

Food deprivation described under the 'Arrival' section will be prolonged by the period of lairage since usually no food is provided in lairage.

Too long water deprivation

During transport, animals are usually deprived of water, which might provoke dehydration and prolonged thirst. In lairage, thirst is usually corrected by allowing the animals to drink. Lack of water provision as well as an inappropriate design or construction of the drinking point that prevent cattle to have easy access to clean water at all times will result in severe dehydration which is considered a serious welfare concern.

Prevention and correction of 'Prolonged thirst and hunger' and their related hazards

To prevent or correct prolonged thirst from transport, clean water should always be available in the lairage pen. The supply system should be designed and constructed to allow all animals easy access to clean water at all times, without being injured or limited in their movements, and so that the risk of contamination of the water with faeces is minimised (Velarde, 2008).

The only identified corrective measure is providing water to the animals.

3.1.4.5. Welfare consequences 'Fatigue': assessment, hazard identification and management

Definitions of 'Fatigue':

For definition, see Section: 3.1.2.4

Other welfare consequences such as restriction of movement and resting problem can lead to fatigue.

ABMs for 'Fatigue':

Tired animals may recover during lairage if they are housed under adequate conditions. If this is not the case, animals experiencing fatigue will show immobility, recumbency and exhaustion (for description see Section 3.1.2.4)

Assessment of fatigue at lairage can be done by counting the number of animals showing the ABMs reported in the following Table 14:

Table 14: ABMs for the assessment of 'Fatigue' at lairage

ABM	Description	Welfare consequence
Exhaustion	Conscious animals lying on the floor and not able to stand up (recumbency) or unable to move when the animal is standing	Fatigue
Tachypnoea	Excessive rate and depth of breathing, e.g. > 30 per minute in adult, resting cattle (Breeze, 1985)	Fatigue

Hazards leading to 'Fatigue'

Fatigue can also be due to the following hazards:

1) Too high effective temperature (see Section 3.1.4.3).
2) Too long water deprivation (see Section 3.1.4.4).
3) Too long food deprivation (see Section 3.1.4.4).
4) Insufficient space allowance (see Section 3.1.4.6).
5) Mixing of unfamiliar animals (see Section 3.1.4.1).

A combination of deprivation from water and high effective temperature can increase the risk of fatigue. Delayed slaughter will increase the effect of these five hazards and then can seriously impair welfare.

Prevention and correction of 'Fatigue' and its related hazards

To prevent fatigue, depending on the main reason for fatigue to appear, the following measures can be taken:

- allow animals to rest in good condition in lairage (space, comfort)
- avoid mixing unfamiliar animals
- allow animals to recover from heat stress or not be submitted to heat stress
- provide water in lairage to avoid suffering from prolonged thirst or to rehydrate animals
- provide food if cattle reserve is too low for its energy requirement.

As a corrective measure, when cattle are suffering from fatigue in lairage, they should be given good conditions to recover and be slaughtered as soon as possible. If they cannot move, emergency slaughter should be performed.

3.1.4.6. Welfare consequences 'Restriction of movement' and 'Resting problems': assessment, hazard identification and management

Definitions of 'Restriction of movement' and 'Resting problems'

For definition of restriction of movement, see Section 3.1.2.5.

Resting problems: the animal is unable to rest comfortably because of insufficient space or space of inadequate quality in terms of surface texture, dryness and hygiene.

ABMs for 'Restriction of movement' and 'Resting problems'

As described before (for details see Section 3.1.2.5), in lairage, like in transport, cattle should have space to lie without being in contact with other animals. There is no specific feasible ABM at lairage,

but space allowance can be considered as a proxy to assess if animals have enough space to rest, access water and run away from aggressors.

There is no ABM for resting problems.

Hazards leading to 'Restriction of movement' and 'Resting problems'

Hazards responsible for these two welfare consequences are:

1) Insufficient space allowance
2) Improper design, construction and maintenance of premises

<u>Insufficient space allowance</u>

The space allowances requested in lairage should be considered regarding the formula: $k \times (BW)^{2/3}$ (see Section 3.1.2.1). At lairage, a k of 0.0315 should be used if cattle are to be offered water in the pen as well as space to rest. Therefore, for a calf of 110 kg, space of less than 0.73 m²/animal will be considered insufficient space allowance and for medium-sized cattle of 325 kg it will be less than 1.5 m². This should be regarded as guidelines since physical condition of animals, animal categories, meteorological conditions, journey times and state of fatigue of the animals may require adjustments.

<u>Improper design, construction and maintenance of premises</u>

This means that the design and/or maintenance of the lairage area is not fulfilling cattle needs to comfortably rest and recover before slaughter. The design and the maintenance of the lairage area cannot be considered as adequate unless it fulfils the following requirements:

- Provide enough space to allow thermal comfort, comfort around resting, access to drinkers and possibility for the subordinate to avoid aggression
- Protect animals from adverse weather conditions and provide ventilation to remove noxious gases
- Have pens of different sizes in order to adapt to different group sizes without mixing unfamiliar animals
- Provide solid floor, smooth, non-slippery and easy to clean with adequate slope for water and urine evacuation
- Provide lighting so that animals can move easily

Prevention and correction 'Restriction of movement', 'Resting problems' and their related hazards

Preventive measures include design, construction and maintenance of lairage facilities to suit the behavioural needs of cattle and provide tubular overhead restriction to prevent mounting and training of staff to avoid overstocking pens (at least 0.0315 $BW^{2/3}$ m²/animal available to allow all animals to lie down at the same time), keep familiar animals together and avoid mixing unfamiliar cattle.

Corrective measures include surveillance for overcrowding and adjustment of the number of animals to the size of pens, removal of aggressive animals or prioritising slaughter of mixed groups of cattle, maintaining lairage area clean and dry.

Regarding inappropriate design of lairage area, no corrective measure is available, except to provide to animal adequate surface (remove animals from an overstocked pen) and the furnishing they need or to proceed to slaughter as soon as possible in case their welfare is severely impaired.

3.1.4.7. Outcome table on 'Lairage'

Table 15: Outcome table on 'Lairage'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Too high effective temperature (see Section 3.1.2.1)	Heat stress, fatigue	Equipment, facilities, staff	Environmental conditions Not enough ventilation in lairage	• Training of staff • Increase space allowance • Scheduling to avoid hottest hours of the day for transport • Provide adequate ventilation and cooling system (showering, nebulisation, etc.) in lairage	• Prioritise slaughter of animals • Provide cooling system (shower) to bring the animal to the thermoneutral zone
Too low effective temperature (see Section 3.1.2.1)	Cold stress	Equipment, facilities, staff	No protection of the lairage area against wind and rain Direct exposure to low temperatures	• Training of staff • Before departure provide curtains and other protection and close the ventilation • Avoid coldest hours of the day for transport • Protect lairage area from adverse climatic conditions • Provide adequate bedding	• Slaughter the animals as soon as possible
Food deprivation too long (see Section 3.1.2.3)	Prolonged hunger, fatigue	Staff	Prolonged food deprivation prior to transport Prolonged transport and/or prolonged waiting time at slaughterhouse Prolonged lairage time	• Training of staff • Avoid feed withdrawal before transport and waiting time prior to slaughter • Scheduling slaughter of animals • Prioritising slaughter • Providing food when a delay is expected in the slaughter process	• Slaughter ASAP • Provide food
Water deprivation too long (see Section 3.1.2.2)	Prolonged thirst, fatigue	Staff, facilities	Water not accessible prior to transport Prolonged transport Absence of effective watering in lairage	• Training of staff • Water availability until loading of farm • Water availability during transport • Provide access to water in the lairage and check the functioning of the watering system	• Slaughter ASAP • Provide water

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Unexpected loud noise (see Section 3.1.3.2)	Fear	Equipment, facilities, staff	Staff shouting Machine noise Poor design and layout of the premises	• Identify and eliminate the source of noise • Training of staff • Avoid personnel shouting • Proper machine construction • Avoid noisy equipment close to the animals	• Warn the staff
Insufficient space allowance (see Section 3.1.4.6)	Restriction of movements, heat stress, resting problem, fatigue	Staff	Too many animals are put in the pen	• Training of staff • Display notice regarding number of maximum animals in each pen regarding the category	• Adjust the number of animals to the size of the pen
Mixing unfamiliar animals (see Section 3.1.4.1)	Fear, pain, social stress, fatigue	Staff, facilities	Mixing animals from different origins	• Keep familiar animals together from farm to slaughter • Do not mix horned animals	• Remove aggressive animals, • Slaughter mixed groups ASAP
Improper design, construction and maintenance of premises (see Sections 3.1.4.2 and 3.1.4.6)	Fear, pain, restriction of movement, resting problem	Staff, facilities	Inappropriate conception at the building of the premises No or insufficient cleaning of the area/lack of appropriate drainage	• Design the facilities regarding species specific behavioural requirements • Provide tubular overhead restriction to prevent mounting in bulls	• Clean and dry the lairage area • Provide bedding

ABMs: Panting (heat stress), shivering (cold stress), injuries (pain), aggression at water trough (prolonged thirst), vocalisations (fear), slipping and falling (restriction of movement), exhaustion, tachypnoea (fatigue), aggressive behaviour and mounting (social stress)

3.1.5. Handling and moving of the animals to the stunning point

Handling and moving refers to the process of driving cattle to the stunning point.

The movement from the lairage pen to the stunning area constitutes one of the key points regarding animal welfare in abattoirs. Handling and moving of cattle from lairage pens to the restraint should be done calmly and without the use of force by a person. The principles and practice of cattle handling have been described in detail by Grandin (1993, 1998b).

In abattoirs with high slaughter throughput, most of the time animals are forced to move quickly during the last meters prior to stunning to maintain the throughput rate. Factors which determine the welfare outcomes are mainly associated with:

- Design, layout and construction of facilities

Cattle are gregarious animals and they feel secure in groups and are stressed by isolation. Therefore, they should be moved in small groups. However, matured bulls and horned or fractious cattle may be kept separately and moved individually, for security reasons. In addition, cattle also instinctively like to follow each other provided there is no distraction, loss of sight of leading animal or impediment. Therefore, a good practice would be to maintain a continuous movement of animals such that subsequent groups have sight of cattle moving ahead. However, overcrowding in corridors leading from the lairage, 'crowding' pen and raceways has been recognised as a major problem during movement of cattle. Crowding pens and raceways should not be used as an additional lairage facility to hold cattle. In this sense, cattle moved into these, especially raceways, should be able to go forward, without any delay, to the stunning area.

Cattle are highly responsive to visual stimuli and move forward spontaneously if they can see way ahead. Hence, curved raceways with solid sides, rather than raceways with right angles appearing as dead end, are important to facilitate easy movement (Grandin, 1996). Cattle will baulk or refuse to move forward if they see any distraction, which can be a drain, open ditch or potholes in the floor, shadows, shiny or moving objects, band of sun light across the floor, dark race, blinding light shining into the face, etc. One easy way to keep cattle moving forwards is to illuminate the end of the race or stunning pen such that cattle perceive it to be like point of escape from the handler.

Grandin (1998b) categorised main problems leading to distractions in cattle: i) lighting problem; ii) seeing moving equipment or people up ahead; iii) seeing contrasts; iv) excessive noise; and v) air draft blowing in the face of approaching animals.

It is also important to ensure raceways are designed and constructed so as to avoid cattle slipping and falling and they should be routine cleaned and maintained (Grandin, 2013).

Many stunning boxes have design faults that contribute to levels of distress in cattle (FAWC, 2003). Stepped or sloped floor surfaces are built to assist with roll-out of unconscious cattle from the stun box, which may cause animals to panic. Even small steps can lead to animals constantly stepping up and down. Floors within the stunning box should therefore be level with no obstructions or steps. Poor design results in resorting to the use of goads, addressing the symptom rather than the cause (FAWC, 2003). It is also important to ensure that the floor within the stun box is non-slippery and there are no distractions that may lead to poor welfare.

- Operators' knowledge and skill levels

People who handle cattle need to understand the basic behavioural principles of moving cattle, in particular, flight distance and point of balance. For an animal to move forward, the handler should be within the flight zone but behind the point of balance at the shoulder of cattle (see Figure 2 in Section 3.1.3). In general, extensively reared cattle are less tame and they have a bigger flight zone. On the other hand, tame animals that are accustomed to human approach and handling may be difficult to move. These animals require additional care during handling.

3.1.5.1. Welfare consequences 'Impeded movement': assessment, hazard identification and management

Definition of Impeded movement:

For definition see Section 3.1.3.1.

Impeded movement is a difficulty of movement of the cattle resulting in slipping and falling when moving from lairage to the restraining area. It will provoke fear and pain. This will happen if the handling is not appropriate or the raceway and the dock for unloading are not well designed and

maintained; then animals might experience impeded movement, not going smoothly into the raceway, slipping, falling and eventually hurting themselves. If cattle have been injured previously, for example during transport or during a fight in lairage, or are suffering from lameness, impeded movement can be worsened.

ABMs of 'Impeded movement'

During moving and handling of animals, some studies report the use of a 'handling scoring' for welfare assessment. These scorings contain the measurement of percentages of animals slipping or falling, freezing, backing up, turning, occurrence of vocalisation and use of electric goads (Grandin, 2012; Welfare Quality®, 2009).

ABMs that are suggested in this Opinion for the assessment of 'Impeded movement' are the same as those used in the unloading (see Section 3.1.3.1) process i.e. slipping and falling (Table 16). The assessment can be done by counting the number of slips and falls per animal.

Table 16: ABMs for the assessment of 'Impeded movement' during handling and moving of the animals

ABM	Description	Welfare consequence
Slipping	Loss of balance in which the animal loses its foothold, or the hooves slide on the floor surface. No other body parts except hooves and/or legs are in contact with the floor surface. (Welfare Quality®, 2009)	Impeded movement
Falling	Loss of balance in which parts of the body other than feet and legs are in contact with floor surface (Welfare Quality®, 2009)	Impeded movement

Hazards leading to 'Impeded movement':

Difficulties in handling and moving the animals are mainly linked to handling mistakes by the personnel (inappropriate handling) and/or flaws in the design, construction and maintenance or construction of the raceways to restraining point. As an example, yelling has been demonstrated as highly stressful for animals (Grandin, 2016).

The hazards are:

1) Improper design, construction and maintenance of premises.
2) Inappropriate handling (see Section 3.1.3.1).

Improper design, construction and maintenance of premises

When the animals are moving from the lairage area to the stunning /slaughter area, they generally are expected to go through a raceway in a single line. If the raceway is not well designed (angle of the slope, type of floor, etc.) or maintained (e.g. slippery) this could lead to impeded movement due to slipping or falling (Grandin, 1996; Disanto et al., 2014) (see more details in Section 3.1.3.1).

Prevention and correction of 'Impeded movement' and their related hazards

The preventing methods to avoid impeded movement are the following:

- The dock for unloading should be as close as possible to the truck deck level to avoid unloading ramps. When not possible the best option is that trucks have an integrated loading/unloading device, where the ramp angle is less than 20° for calves or 26° for adult cattle (Faucitano and Perdenera, 2016). When the slope is steeper than 10°, ramps should be equipped with foot battens or cleats which prevent animals from slipping while walking on the ramp, reducing the risk of falls (EFSA, 2011). A 20-cm spacing between the cleats is recommended to ease cattle walking smoothly through the ramp (Grandin, 2014a,b). Simple modifications can often improve the situation (Faucitano and Perdenera, 2016) like having a clean and dry unloading area. When the design of the unloading area is not adequate, using appropriate handling methods for unloading cattle with a low speed of moving can help reducing impeded movement.
- Animals should be handled calmly by trained personnel who knows how to behave and place themselves when moving the animals, to allow smooth unloading. Cattle are gregarious animals that feel secure in groups and are stressed by isolation. Therefore, it is recommended to move cattle in small groups (ideally of familiar animals) using flags, a plastic bag on a stick or a paddle in order to ease handling and reduce occurrence of slipping and falling (Grandin, 2008).

As corrective measures, the first step in improving animal movement is to correct mistakes that people make while handling and/or moving animals. When design of the raceway is not adequate, using adapted handling methods for unloading cattle with a low speed of moving can help reducing impeded movement. The practices would be to (Faucitano and Perdenera, 2016): i) use the flight zone and the point of balance principle, iii) stop the use of electric prods and use flags, plastic bags on a stick or paddles, iv) use following behaviour and move the cattle in small groups. Stopping obvious handling mistakes will make it possible to determine if the problems with animal unloading in a particular slaughterhouse are due to people making mistakes or to flaws in the design and/or maintenance of the unloading ramp.

3.1.5.2. Welfare consequences 'Pain, 'Fear': assessment, hazard identification and management

Definition of 'Pain', 'Fear':

For definition- see Section 3.1.3.2.

ABMs of 'Pain', 'Fear':

Animal based measures that can be used during this process are the same in nature and protocol of observation as the ones used in the unloading process (see Section 3.1.3).

If the raceway is not well designed (angle, slope, type of floor, lighting, etc.) or maintained (slippery, etc.), this could lead to reluctance for animals to move and eventually pain and fear.

Pain can be assessed indirectly by the number of cattle showing injuries and number of vocalisations (referred to as distress vocalisation) that can be heard during handling and moving. Cattle vocalise only when they experience something aversive or threatening, and therefore, scoring number of cattle vocalising during handling and movement is an objective way of assessing animal welfare (Grandin, 1998a) (see Table 17).

Table 17: ABMs for the assessment of 'Pain' and 'Fear' during handling and moving of the animals

ABM	Description	Welfare consequence
Escape attempts	Attempts to go through, under, or over gates and other barriers. Head and neck stretched forward and either slightly raised above back, slightly lowered, or level with back (modified after Lanier et al., 2001)	Fear
Vocalisation	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin 2012). Frequently referred to as distress vocalisation in the literature	Pain, Fear
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012a)	Pain
Lameness	Abnormality of movement caused by reduced ability to use one or more limbs. Lameness can vary in severity from reduced mobility to inability to bear weight (modified after Welfare Quality®, 2009)	Pain
Reluctance to move	An animal that refuses to move when coerced by the operator or that stops for at least 4 seconds not moving the body and the head (freezing) (adapted from Welfare Quality®, 2009)	Pain, Fear
Turning around or moving backwards	When an animal facing towards the restraint area turns around or moves backwards (adapted from Welfare Quality®, 2009)	Fear

Hazards leading to consequences 'Pain', 'Fear':

The hazards are:

1) Improper design, construction and maintenance of premises.
2) Inappropriate handling (see Section 3.1.3.1).
3) Unexpected loud noise (see Section 3.1.4.2).
4) Moving animals from a group into a single line into the restraint.

Improper design, construction and maintenance of premises:

When the animals have to move from the lairage area to the restraining point, they generally have to go through a race in one line. If the raceway is not well designed or maintained, it could lead to reluctance of animals to move and eventually pain, fear and restriction of movement due to slipping or falling, for example. Traditionally, slaughterhouses are designed based on conventional architectural criteria, such as the optimisation of space or the facilitation of human activities, and not on the behavioural needs of the animals (Miranda-de la Lama et al., 2010, 2011).

Moving cattle from a group into a single line into the restraint:

Cattle are moved from lairage pen to the stunning area in small groups and then they are coerced into entering a raceway leading to the stun box in a single line.

Prevention and correction of 'Pain', 'Fear' and their related hazards

To design the raceway and to behave correctly, it is crucial to understand how cattle explore, interpret and behave in their environment. As preventive measures, Grandin (2016) recommends to avoid distractions in the raceway such as: reflection or shiny metal, air blowing into the face of approaching animals, seeing people walking by or moving equipment, chain hanging, hose on floor, coat on fence, high contrast walls or changes in flooring type, entrance of stun box, restrainer or race too dark, flapping paper towels.

Flags and paddles can be considered good alternatives to prevent the use of electric goads, although their effectiveness depends on the personnel using it (training and attitudes) and the design of the facilities, as mentioned above (Grandin, 2008). In addition, it is recommended to move cattle in small groups. Since cattle like to follow each other, curved raceways with solid sides, rather than raceways with right angles appearing as dead end, are important to facilitate easy movement (Grandin, 1996). For an animal to move forward, the handler should be within the flight zone but behind the point of balance at the shoulder of cattle (see Figure 2 in unloading).

As a corrective measure, for example when cattle are reluctant to move, it is recommended to remove the distractions listed above.

Floors within the stunning box should be level with no obstructions or steps. It is also important to ensure that the floor within the stun box is non-slippery and there are no distractions that may lead to poor welfare.

Hazards identified during 'Handling and moving of animals', relevant welfare consequences and related ABMs, origin of hazards, and preventive and corrective measures are reported in the following outcome table (see Section 3.1.5.3).

3.1.5.3. Outcome table on 'Handling and moving cattle to the stunning area'

Table 18: Outcome table on 'Handling and moving cattle to the stunning area'.

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Inappropriate handling (see Section 3.1.3.1)	Pain, fear, impeded movement	Staff, equipment, facilities	Lack of skilled operators Improper handling of animals Use of electric prods Rushing	• Training of staff for proper handling • Appropriate equipment (alternatives to electric prod) and facilities to move animals	• None • Correct staff to discontinue inappropriate handling
Moving animals from a group into a single line into the stunning box (see Section 3.1.5.2)	Pain, fear	Staff, facilities	Presentation of animals to the method is required Use of force or of electrical prods Too high throughput rate	• Staff training • Design, construct and maintain facilities such that step-wise reduction to form single line of animals for loading into the stunning box • Do not force an animal if it doesn't have space ahead to move • Reduce throughput rate	• None • Correct staff to discontinue forced movement of animals • Allow time for animals to move spontaneously
Improper design, construction and maintenance of premises (see Section 3.1.5.2)	Pain, fear, impeded movement	Staff, facilities, equipment	Improper conception (slope, right angles raceways) Improper lighting (high contrast with bright and shades areas) Lack of solid walls Distraction Poor daily management of the premises (slippery and dirty floor)	• Ensure proper design, construction and maintenance of the area • Rebuild the handling area regarding recommendation and animal behaviour	• None
Unexpected loud noise (see Section 3.1.4.2)	Fear	Staff, facilities, equipment	Staff shouting Machine noise Equipment noise	• Identify and eliminate the source of noise • Staff training • Avoid personal shouting	• Identify and eliminate the source of noise

ABMs: Injuries (pain), vocalisations (pain, fear), escape attempts, reluctance to move and turning back (fear), slipping and falling (impeded movement)

3.2. Phase 2: stunning

3.2.1. Introduction to stunning methods

Stunning is any intentionally induced process that causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death. The stunning phase includes the stunning method itself as well as the relevant restraint practices. In this perspective, 'restraint' means the application to an animal of any procedure designed to restrict its movements in order to facilitate effective stunning and killing.

Animals must be rendered immediately unconscious and insensible by the stunning method and they must remain so until death occurs through bleeding.

The main stunning methods employed in the slaughter of cattle are grouped into mechanical and electrical methods. For each of the methods, the welfare consequences, animal-based measures, related hazards and preventive and corrective measures are described in Sections 3.2.2–3.2.5; an outcome table relevant to each method is provided in each section.

Mechanical stunning methods: Mechanical stunning methods induce brain concussion resulting in unconsciousness through the impact of a penetrative captive bolt, a non-penetrative captive bolt, or free projectiles on the skull of the animal.

Electrical stunning methods: The principle of electrical stunning is the application of sufficient current through the brain to induce generalised epileptiform activity in the brain, so that the animal becomes immediately unconscious (head-only electrical stunning, Section 3.2.5.1). Head-only electrical stunning can be performed in combination with or immediately followed by passing an electrical current through the body to generate fibrillation of the heart or cardiac arrest (head-to-body electrical stunning, Section 3.2.5.2).

Independently of the specific stunning method, the identified welfare consequences for Phase 2 (stunning) are pain and fear. Therefore, differently from previous sections, these two welfare consequences are presented below in Section 3.2.1.1 (presented together as they have same ABMs), while in the specific stunning methods sections only hazards and their management are presented.

3.2.1.1. Welfare consequences 'Pain and fear': assessment, hazards identification and management

Definition of 'Pain and fear':

'Pain' and 'Fear' are defined in Section 3.1.3.2.

During Phase 2, cattle might experience pain and fear during restraint. Pain and fear can also be caused by ineffective stunning, which will lead to persistence of consciousness during hoisting, sticking and bleeding. Furthermore, recovery of consciousness might occur in effectively stunned animals if sticking was delayed or was not properly done. Both these situations are considered an important animal welfare concern in the stunning process.

Consciousness is defined as the capacity to receive, process and respond to information from internal and external environments and therefore the ability to experience emotions, leading to pain and fear (Le Neindre et al., 2017). Therefore, in this phase these welfare consequences are assessed through the presence of consciousness. For this reason, ABMs related to the presence of consciousness are described within the specific stunning method sections, and instead ABMs for pain and fear during restraint are described here.

ABMs for 'Pain and Fear':

In particular, ABMs related to pain and fear during restraint are vocalisations, escape attempts, and injuries. Assessment of pain and fear during restraint can be done by counting the animals showing the ABMs described in Table 19.

Table 19: ABMs for the assessment of 'Pain' and 'Fear' related to restraint during stunning

ABM	Description	Welfare consequence
Vocalisations	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin 2012). Frequently referred to as distress vocalisation in the literature	Pain, fear
Escape attempts	Attempts to go through, under, or over gates and other barriers. Head and neck stretched forward and either slightly raised above back, slightly lowered, or level with back (modified after Lanier et al., 2001)	Pain, fear
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012a,b)	Pain

3.2.2. Penetrative captive bolt stunning

Captive bolt stunning requires restraining of the animal to limit forward, backward and sideways movement and some form of head restraint to permit the operator to shoot the bolt in the correct position and direction. Head restraint used for cattle can be 'passive' or 'active' (HSA, 2016a,b). Passive restraint can be a fixture such as the fixed shelf that is fitted at the front of the stunning box. These prevent the animal from lowering its head. On the other hand, there are two types of active head restraints. The first is the neck yoke system consisting of one or two vertical bars which grip the animal's neck within the stunning box. The second is a head yoke and chin lift device, which holds the head right outside the stunning box (for details see HSA, 2016a,b).

Penetrative captive bolt powered by cartridge or compressed air is the most commonly used method to stun cattle. The gun powder content (strength) of the cartridge or air line pressure should be selected according to the manufacturers' instructions to suit the animal type. The guns are designed to fire a retractable steel bolt that penetrates the cranium and enters the brain. The impact of the bolt on the skull results in brain concussion and immediate loss of consciousness (EFSA, 2004). Penetration of the bolt into the skull and subsequent withdrawal causes structural damage to the brain due to cavitation, which results in marked subarachnoid and intraventricular haemorrhages, especially adjacent to the entry wound and at the base of the brain. The bolt diameter, velocity and penetration depth are important parameters to ensure efficacy of the stun. It causes subsequent disruption of the brain tissue and helps to prolong the duration of unconsciousness and insensibility (EFSA, 2004). Some guns have a captive bolt that protrudes from the muzzle when it is in the primed position and some others have a bolt that is recessed within the muzzle. Normally, when a bolt is fired it requires a short distance to reach its maximum velocity before impacting on the skull. Therefore, guns with protruding bolts should be held slightly (up to 5 mm) away from the animal's head, whereas guns with recessed bolts must always be pressed firmly against the head. Various factors such as anatomical differences due to breed, sex or age of the animal, choice of the captive bolt gun and its maintenance, cartridge strength and its condition, shooting position and type of restraint used determine the effectiveness of stun. The ideal stunning position is in the middle of the forehead at the crossing point of two imaginary lines drawn between the eyes and the centre of the base of the opposite horns (HSA, 2016b). Death may occur depending on the degree of injury to the brain but is not a guaranteed outcome (Lambooij and Algers, 2016). Therefore, captive bolt stunning shall be followed as quickly as possible by bleeding or destruction of the brain and upper spinal cord by pithing.

3.2.2.1. Hazard identification for 'Penetrative captive bolt stunning'

The hazards identified during this process are:

1) Restraint and/or inappropriate restraint
2) Incorrect position and direction of the shot
3) Incorrect captive bolt parameters.

These hazards can lead to the welfare consequence of pain and fear and can lead to failure in onset of unconsciousness or to early recovery before or during bleeding.

Restraint and/or inappropriate restraint

Von Wenzlawowicz et al. (2012) reported that 35% of cattle were inaccurately shot, when abattoirs were not equipped with restraint devices to steady the head prior to the application of the captive bolt

gun. Fries et al. (2012) reported that restraint devices for the head of the animal during stunning are imperative. However, excessive pressure may be applied during restraint. Conveyor systems are also used to restrain cattle and they either hold the animal between two belts, set in a 'V' formation, or on a belly support system where the animal straddles on a moving mono- or double-rail. The conveyors must be properly adjusted for the size of the animal being stunned and animals should not be left in a restraint during breaks or stoppages. Procedures must be in place to enable the evacuation of animal from the restraint in case of an emergency (HSA, 2016a,b).

Incorrect position and direction of the shot

Shooting of captive bolt at the right angle into the skull and in the recommended position is vital to induce brain concussion. It is stated that shooting position should be no further away than a 2 cm radius from the recommended shooting position (EFSA, 2004). The direction of the bolt should also target the brain stem to be effective and failing to do so may have animal welfare consequences.

Fries et al. (2012) investigated the efficacy of captive bolt stunning in two cattle head deboning slaughterhouses, where a total of 8,879 cattle skulls were investigated for number and precision of shots. Overall, 64.7% of the skulls in slaughterhouse 1 and 65.3% in slaughterhouse 2 were shot in the ideal position and direction. A medium precision (i.e. shots within a range of a maximum distance of 3.0 to 4.5 cm from the crossing point and/or a maximum deviation of $10°$ to $20°$ from the vertical direction) was observed in 31.3% and 31.5% of cases, while 4.0% and 3.1% of the skulls indicated a poor precision. In both plants, skulls with more than one shot hole were observed.

Incorrect captive bolt parameters

The bolt parameters, i.e. velocity, exit length (depth of penetration into the skull) and diameter, are determinants of the effectiveness of stun, i.e. depth of brain concussion. Ineffective stunning occurs due to low cartridge power, low bolt velocity, shallow penetration, too narrow bolt diameter and faulty equipment (EFSA, 2004). The cartridges used should be those recommended for the equipment and type of animal (calf vs. bull) by the manufacturer (HSA, 2016a,b). Minimum recommended bolt velocities are 55 m/s for steers, heifers and cows and 72 m/s for young bulls. Normally, recommended bolt diameter is a minimum of 7 mm and recommended penetration depth is at least 9 cm. Cartridges vary in strength and are classified according to the amount of propellant (gun powder) they contain, with 3.0 grain and 4.0 grain for large cattle and mature bulls (1 grain = 0.0648 grams). It is important to refer to the manufacturers' instructions so that the correct cartridges are used for each model of stunner; they are identified by calibre (0.22 or 0.25), colour and headstamp (HSA, 2016a,b). Captive bolt equipment powered by compressed air works exactly the same as the cartridge fired equipment, but the energy is supplied via a high-pressure compressor. The air line pressure may vary between 160 and 190 PSI (1,103.16 kpa and 1,310 kpa, respectively); higher pressures (1,448 kpa) have been reported in the literature (Martin et al., 2018; Kline et al., 2019). Most commercial slaughterhouses use a standard captive bolt length of 15.2 cm for pneumatic stunners in which only 9.02 cm of the bolt actually penetrates into the animal's skull (Kline et al., 2019). Longer bolts (16.5 and 17.8 cm) are used in order to induce more brain damage and increase the effectiveness of the stun, but also increase the prevalence and intensity of post stun convulsions (Martin et al., 2018; Kline et al., 2019). Wagner et al. (2019) reported that the longer bolt length inflicted more visible damage to the brain. Bolt length had no significant impact on specified risk material (SRM) dispersion.

3.2.2.2. Assessment of animal welfare for 'Penetrative captive bolt stunning'

During restraint, the welfare consequences are pain and fear. After captive bolt application, if the stunning is ineffective or if the animals recover consciousness, the welfare consequences are pain and fear due to persistence or recovery of consciousness.

ABMs related to pain and fear after stunning are the signs of state of consciousness, which have to be checked through the three key stages of monitoring during the slaughter process: after stunning (between the end of stunning and hoisting), during sticking (cutting of the brachiocephalic trunk) and during bleeding. The assessment of the state of consciousness leads to two possible outcomes: consciousness and unconsciousness.

ABMs related to consciousness were selected in a previous Opinion (EFSA AHAW Panel, 2013) and are described in full in the table below (Table 20).

Table 20: ABMs for assessment of 'State of consciousness' after penetrative captive bolt stunning (from: EFSA AHAW Panel, 2013)

ABMs	Description
Posture	Failure to collapse, attempts to regain posture (also when rolling out of the stunning box)
Breathing	Effective stunning will result in the immediate onset of apnoea (absence of breathing). Ineffectively stunned animals and those recovering consciousness will start to breathe in a pattern commonly referred to as rhythmic breathing, which involves a respiratory cycle of inspiration and expiration. Rhythmic breathing can be recognised from regular movement of the flank and/or mouth and nostrils. Recovery of breathing, if not visible through these movements, can be checked by holding a small mirror in front of the nostrils or mouth and watching for the appearance of condensation on the mirror as a result of the expiration of moist air
Tonic seizures	Lack of occurrence of an arched back and rigidly flexed legs under the body
Corneal reflex	Blinking response elicited by touching or tapping the cornea with a finger or paint brush
Palpebral reflex	Blinking response elicited by touching or tapping a finger on the inner/outer eye canthus or eyelashes
Muscle tone	Stunned animals will show general loss of muscle tone after the termination of tonic–clonic seizures coinciding with the recovery of breathing and the corneal reflex if not previously stuck. Loss of muscle tone can be recognised from the completely relaxed legs, floppy ears and tail and relaxed jaws with protruding tongue. Ineffectively stunned animals and those recovering consciousness will show a righting reflex and attempts to raise the head
Eye movements	Eye movements, including nystagmus (spontaneous rapid side-to-side movements of the eyeballs) or rotation of the eyeball, as effectively stunned animals will exhibit fixed eyes
Vocalizations	Grunting, bellowing or mooing
Body movement	Intentional or purposeful kicking or body or head movements as a response to incision of the skin and/or insertion of the knife
Spontaneous blinking	Animal opens/closes eyelid on its own (fast or slow) without stimulation

For penetrative captive bolt stunning, EFSA AHAW Panel (2013) suggested the following flow chart (Figure 3), where ABMs to monitor the state of consciousness are suggested and included in toolboxes (blue boxes in Figure 3), to be used at three key stages. For each key stage, three or four ABMs that are reliable in monitoring consciousness are suggested (above the dashed line), plus other two or three ABMs, which are less reliable, that can be additionally used (below the dashed line). For each ABM, corresponding outcomes of consciousness and unconsciousness are reported (EFSA AHAW Panel, 2013). In case outcomes of consciousness are observed in key stage 1, then an intervention should be applied (i.e. a backup method). After any reintervention, the monitoring of unconsciousness, according to the flow chart, should be performed again. Only when outcomes of unconsciousness are observed the process can continue to the next steps. Following key stage 3, in case outcomes of life are observed an intervention should be applied; only when outcomes of death are observed, the animal scan be processed further.

CATTLE – SLAUGHTER WITH STUNNING (CAPTIVE BOLT)

Key Stage 1 (between end of stunning and shackling): check for outcomes of consciousness

OUTCOMES OF UNCONSCIOUSNESS

TOOLBOX 1

OUTCOMES OF CONSCIOUSNESS

OUTCOMES OF UNCONSCIOUSNESS	TOOLBOX 1	OUTCOMES OF CONSCIOUSNESS
Immediate and permanent collapse	posture	no collapse / attempts to regain posture
apnoea	breathing	rhythmic breathing
presence of tonic seizures	tonic seizures	no tonic seizure
absence of corneal or palpebral reflex	corneal or palpebral reflex	presence of corneal or palpebral reflex
loss of muscle tone	muscle tone	righting reflex
fixed eyes	eye movements	presence of nystagmus, eye rotation
absence of vocalisation	vocalisation	presence of vocalisation

Risk of consciousness: apply intervention

Key Stage 2 (during neck cutting or sticking): check for outcomes of consciousness

OUTCOMES OF UNCONSCIOUSNESS	TOOLBOX 2	OUTCOMES OF CONSCIOUSNESS
absence of body movements in response to sticking	body movements	body movements in response to sticking
loss of muscle tone	muscle tone	righting reflex
apnoea	breathing	rhythmic breathing
fixed eyes	eye movements	presence of nystagmus, eye rotation
absence of corneal or palpebral reflex	corneal or palpebral reflex	presence of corneal or palpebral reflex
absence of spontaneous blinking	spontaneous blinking	presence of spontaneous blinking

Risk of consciousness: apply intervention

Key Stage 3 (during bleeding): check for outcomes of consciousness

OUTCOMES OF UNCONSCIOUSNESS	TOOLBOX 3	OUTCOMES OF CONSCIOUSNESS
loss of muscle tone	muscle tone	flexion of forelegs
apnoea	breathing	rhythmic breathing
absence of spontaneous blinking	spontaneous blinking	presence of spontaneous blinking

No risk of consciousness

Risk of consciousness: apply intervention

Figure 3: Flow chart including indicators for the monitoring of state of consciousness

3.2.2.3. Prevention and correction of welfare consequences and their related hazards

Pain and fear during restraint and application of the penetrative captive bolt stunning can be prevented through adequate design and maintenance of the restraining and stunning equipment and staff competence and training.

Restriction of movement during restraint will cause fear in most of the cases due to the inability of the animal to escape from a threatening situation. In the case of manual restraint, gentle handling of the cattle while they are restrained can mitigate fear (e.g. use of head halter). To prevent pain, mechanical restraint should suit the size of the animal. Most of the restraints used in cattle slaughterhouses are not adjustable. Owing to this, the duration of restraint should be as short as

possible and, as a guide to good practice, animals should not be restrained until the operator(s) is ready to stun and bleed the animal. Careful selection of people with adequate skills and the right attitude or training them to acquire the skills appropriate to the tasks would help to minimise fear and pain in the animals being handled. Staff training and rotation, use of an appropriate restraint, proper placement and firing of the gun, equipment fit for the purpose, and regular cleaning and maintenance of equipment according to manufacturer's instructions (also see HSA (2016b)) for daily and weekly maintenance routines) are preventive measures.

After an ineffective shot, the mitigation measures are addressed to re-stun as soon as possible in the correct position and direction, and with the correct parameters or with an alternative backup method.

However, when a captive bolt enters the skull, it causes massive damage to the brain and acute swelling around the wound on the skull; the swelling will absorb much of the impact of the second shot and this will mean the shock wave is not as effectively transmitted to the brain. As a corrective measure, a repeat shot must always be placed so as to avoid the immediate area of the first shot. If the first shot is off target, the second should be placed as close to the correct stunning position as possible. If the first shot is on target but fails to produce an effective stun, the second shot should be above and to one side. If a third shot is required, this should be above and to the other side of the first shot.

3.2.2.4. Outcome table on 'Penetrative captive bolt stunning'

Table 21: Outcome table on 'Penetrative captive bolt stunning'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Restraint and/or inappropriate restraint (see Section 3.2.2.1)	Pain, fear	Staff, equipment	Immobilisation of the animal and presentation of the head of the animal to the operator are required	• Use passive head restraint or use optimum pressure to the head and the body according to the size of animal in active restraint	• Keep the duration of restraint to the minimum • Reduce the pressure
Incorrect position and direction of the shot (see Section 3.2.2.1)	Pain, fear	Staff	Lack of skilled operators Operator fatigue Poor restraint Inappropriate placement of the gun due to the shape of the head	• Staff training and rotation • Appropriate restraint of the animal • Proper placement of the gun	• Stun in the correct position and with the correct direction
Incorrect captive bolt parameters (see 3.2.2.1)	Pain, fear	Staff, equipment	Lack of skilled operators Wrong choice of equipment Inappropriate cartridge and power Poor maintenance of the equipment Too narrow bolt diameter Too short bolt low bolt velocity	• Staff training • Appropriate restraint of the animal • Ensuring equipment is fit for the purpose • Regular maintenance of equipment	• Stun with correct parameters, or • Apply backup method

ABMs: Vocalisations, escape attempts (pain, fear), signs of consciousness after stunning (as a prerequisite for experiencing pain and fear)

3.2.3. Non-penetrative captive bolt stunning

Non-penetrative captive bolt stunning requires restraint, which is described in Section 3.2.2.

Non-penetrative captive bolts have a 'mushroom-headed' bolt tip, which impacts with the skull, but does not enter the brain. This type of equipment causes unconsciousness due to concussion of the brain. A non-penetrative captive bolt should be positioned approximately 20 mm above the position used for the penetrative captive bolt and the animal must be bled within 30 s (HSA, 2016b). Greater precision is needed to shoot an animal with a non-penetrating than with a penetrating captive bolt. The skin covering the site of impact of the bolt on the skull may remain intact, but the skull bone underneath may suffer compressed fracture. Owing to this, the impact energy may not be entirely transferred to the brain, leading to shallow depth of concussion or fail to stun the animal. Oliveira et al. (2018) reported that pneumatically powered penetrating and non-penetrating captive bolts resulted in immediate collapse, indicative of effective stunning, in 99% and 91% of cattle, respectively. Gibson et al. (2019) reported that shooting bulls with a pneumatic penetrating captive bolt was 100% effective, whereas cattle shot with a non-penetrating bolt was effective in only 82% on the basis of electroencephalogram (EEG) parameters indicative of unconsciousness. In both the studies, the non-penetrative captive bolts were powered by an air line pressure of 220 psi (1,517 kPa). Oliveira et al. (2018) found that the impact of the non-penetrative captive bolt produced extensive haemorrhaging around the cerebrum but did not cause any macroscopic lesions in the brainstem. However, Gibson et al. (2019) reported that effective stunning cattle with the non-penetrative captive bolt resulted in rapid onset of an isoelectric EEG.

3.2.3.1. Hazards identification for 'Non-penetrative captive bolt stunning'

Hazards leading to 'pain and fear'

The hazards identified during this process are:

1) Restraint and/or inappropriate restraint (see Section 3.2.2.1).
2) Incorrect position and direction of the shot (see Section 3.2.2.1).
3) Incorrect captive bolt parameters (see Section 3.2.2.1).

The hazards identified related to the 'Non-penetrative captive bolt stunning' relevant welfare consequences and related ABMs, origin of hazards, preventive and corrective measures are reported in Table 22.

3.2.3.2. Assessment of animal welfare for 'Non-penetrative captive bolt stunning'

As for penetrative captive bolt stunning, ABM's related to 'Pain and Fear' during restraint are escape attempts, vocalisations, injuries, reluctance to move, turning back.

ABMs related to pain and fear after stunning are the signs of consciousness. The same signs of consciousness that are in the flow chart for penetrative captive bolt stunning were retrieved from the scientific literature and are therefore suggested for non-penetrative captive bolt stunning (see flow chart in Section 3.2.2.2).

3.2.3.3. Prevention and correction of welfare consequences and their related hazards

The same preventive and corrective measures presented in Section 3.2.2.3 can be applied also for non-penetrative captive bolt stunning.

3.2.3.4. Outcome table on 'Non-penetrative captive bolt stunning'

Table 22: Outcome table on 'Non-penetrative captive bolt stunning'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Restraint and/or inappropriate restraint (see Section 3.2.2.1)	Pain, fear	Staff, equipment	Immobilisation of the head and presentation to the operator are required	• None • Use passive head restraint or use optimum pressure according to the size of animal	• Keep the duration of restraint to the minimum
Incorrect position and direction of the shot (see Section 3.2.2.1)	Pain, fear	Staff	Lack of skilled operators Operator fatigue Poor restraint Inappropriate placement of the gun due to the shape of the head	• Staff training and rotation • Appropriate restraint of the animal • Proper placement of the gun	• Stun in the correct position and with the correct direction
Incorrect captive bolt parameters (see Section 3.2.2.1)	Pain, fear	Staff, equipment	Lack of skilled operators Wrong choice of equipment Inappropriate cartridge and power Poor maintenance of the equipment Too narrow bolt diameter Low bolt velocity	• Staff training • Appropriate restraint of the animal • Ensuring equipment is fit for the purpose • Regular maintenance of equipment	• Stun with correct parameters, or • Apply backup method

ABMs: Vocalisations, escape attempts (pain, fear), injuries (pain), signs of consciousness after stunning (as a prerequisite for experiencing pain and fear)

3.2.4. Firearm with free projectile killing method

Firearms with free projectile, such as shotguns, rifles, and humane killers, can be used to kill cattle. With a successful head shot, death is immediate. In perfect placement of the shot, the projectile would penetrate the skull, immediately expand, travel through the brain case, obliterate the midbrain-brainstem and come to rest in the foramen ovale or the foramen of first or second cervical vertebrae (Whiting and Will, 2019). Ideal point of penetration of the free bullet in cattle is in the middle of the forehead – at the crossing point of two imaginary lines drawn between the middle of each eye and the centre of the base of the opposite horn. This should give a position about 7 cm $\pm$ 1 cm above a line drawn across the forehead at the back of the eyes. When shooting bovine animals at range, the operator should be in an elevated position to ensure the correct angle of impact is achieved (HSA, 2017). Free bullets have a lower mass than the bolts used in captive bolt stunners, but they travel with higher velocity (typically > 300 m/s for rifles). The impact of the bullet on the skull will send shock waves through the brain and it will tumble while travelling through the brain creating cavitation and severe structural damage. To improve energy transfer upon impact and prevent exiting the target tissue, bullets are constructed to fragment and / or deform after hitting the target (these are also known as Dum Dum bullets). Deformation projectiles do not lose any material, so that the rest of the projectile in the target tissue weighs almost as much as the original projectile. They are mainly used in handguns and possess muzzle velocities below 450 m/s. In the case of fragmentation projectiles, the loss of mass accounts for up to half of the original mass. At the same time heavy fragmentation takes place that increases the total area of cross section. These types of projectiles are normally used in rifles and are fired with higher initial velocities (above 600 m/s) Non-deforming projectiles with a cylindrical shape (like the Wadcutter projectiles) do not tumble and therefore produce a straight shooting channel.

Primer is the explosive chemical used to ignite the gunpowder contained within the bullet, which occurs when struck by the firing pin. A rimfire cartridge has a base that is filled relatively evenly with the primer. In the centerfire cartridge, the primer is filled in the centre of the cartridge. The firing pin on a centerfire rifle needs to be finely tuned to strike in the exact centre of the chamber. On the other hand, a rimfire gun's firing pin can strike at any point on the perimeter of the cartridge. Centerfire cartridges are more powerful and precise than rimfire ammunition and, since the centerfire ignites from the centre, instead of from one side, it has a balanced discharge. Owing to this, hunting laws in many countries prescribe centre-fire ammunition for long distance shooting.

The most commonly used equipment includes (HSA, 2017):

- Humane killers (specifically manufactured/adapted, single-shot weapons and 'Bell Guns' of various calibres)
- Shotguns (0.12, 0.16, 0.20, 0.28 bore[23] and 0.410)
- Rifles (0.22, 0.243, 0.270, 0.308)
- Handguns (various calibres from 0.32 to 0.45).

Humane killers are a purpose-made, single-shot weapon, which has a chamfered muzzle and vented barrel to facilitate its use with the muzzle end of the barrel in full contact with the target. However, in practice, some animals will move if contact is made. If this should happen, fire from as close as possible, preferably within 5 cm. A shotgun is a long-barrelled, smooth-bore gun, normally used for discharging small shot at modest ranges. For farmed livestock species, 12, 16 or 20 bore shotguns may be used with No. 4, 5 or 6 birdshots; (a 28 bore or 0.410 can be used if nothing larger is available but should not be used on mature bulls). The muzzle should be held from 5 to 25 cm from the animal's forehead, aiming down the line of the neck into the main bulk of the body. On no account must the muzzle of a shotgun be held directly against the animal's head, as this could result in a burst barrel and severe injury to the operator (HSA, 2017). Rifle is a small bore, long-barrelled gun, usually fired from the shoulder, the bore of which has been scored with spiral grooves to impart spin on the bullet. The most common rifles in use on farms are general purpose 0.22-inch rim-fire, telescope sighted 0.22-inch centre-fire, 0.243-inch centre-fire and larger bore centre-fire weapons. The 0.22-inch rim-fire can be used effectively when loaded with the correct ammunition, to kill young cattle, when shooting from a short distance (from 5 to 25 cm away). However, they do have limitations in that there is no margin for error in respect of position and angle of incidence. The larger calibre, centre-fire

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[23] The Calibre is the outer diameter of the projectile/bullet. In a barrel which has rifling the caliber is the diameter outside of the rifling and the bore is the diameter of the inside of the rifling or the deeper part of the barrel.

rifles are more specialised weapons used for long range shooting. They offer greater projectile velocities and subsequent kinetic energies than the common .22-inch rim-fire, and as such they do not fall into the categories of weapon which can be used at close quarters. These weapons can effectively kill all sizes of cattle, but they should only be used from a suitable distance, in an outdoor location with a safe backdrop, and by an expert marksman. Handgun is a small, short-barrelled, rifled firearm, which can be held and fired with one hand. There are two important points to remember when using a general-purpose handgun to humanely kill animals. First, the muzzle must never be placed in direct contact with the target: shoot from a distance of 5–25 cm and aim down the length of the neck into the main bulk of the body. Second, make sure that the ammunition is suitable for the task: most commercially available handgun ammunition is of the 'wadcutter' type (bullet that travels in a straight trajectory, instead of tumbling within the tissue) and is loaded for target shooting. Although this type of ammunition is used by some individuals for shooting animals, it is not suitable and it should be replaced immediately with round-nose, lead bullets. From operator's safety point of view, it is advisable not to use an unnecessarily high velocity bullet that will exit the animal's head. On the other hand, the velocity must be sufficient to stun the animal. For bulls, a low velocity 0.44 bullet has been recommended, as the chance of it exiting the animal is less than a high velocity 0.303 or 0.27 bullets. Alternatively, bullets which fragment inside the skull could be used (Gregory, 2008). Retz et al. (2014) investigated the effectiveness of shooting cattle in the field with four different calibres, two bullet-types (deformation or fragmentation bullets) and two different shot placements (frontal or lateral head shots). All of the calibres exhibited an entry-energy over 400 J and provided sufficient stunning potential. Yet, only calibre 0.22 Magnum caused no exit of the bullet out of the scull, which provides higher safety conditions for man and cattle. In this study, the shooter stood on a 4 m high platform and the distance between the muzzle of the gun and the skull of the animal was 15 m.

3.2.4.1. Hazards identification for 'Firearm with free projectile'

Hazards leading to 'Pain and fear':

The hazards identified during this process, which can cause consciousness, leading to pain and fear are:

1) Incorrect position of the shot
2) Inappropriate power and calibre of the cartridge
3) Inappropriate type of projectile.

The hazards identified related to the 'firearm with free projectile', relevant welfare consequences and related ABMs, origin of hazards, preventive and corrective measures are reported in Table 23.

Incorrect position of the shot

The aim is to inflict severe and irreversible damage to the brain. However, sudden movement of the head by an animal could lead to the projectile failing to enter the skull or miss the vital part of the brain.

Inappropriate power and calibre of the cartridge

It is important to use a calibre that provides, proportionate to the shooting distance, the sufficient energy required to damage the brain according to breed, age, gender and live weight of the cattle. It is also important to follow manufacturer's instructions.

Inappropriate type of projectile

The projectile should be appropriate to the type of animal and the shooting distance. Retz et al. (2014) reported that the type of the projectile, i.e. deformation or fragmenting bullet, did not have any effect on the impact of destruction of the brain. However, the advantage of using soft point bullets compared to full metal jackets is that they expand their surface when they hit the target and release more energy into the tissue. This is vital for a sufficient destruction in the brain if the bullet remains in the skull. The choice between rim- or centre-fired cartridge depends upon the shooting distance.

3.2.4.2. Assessment of animal welfare for 'Firearm with free projectile'

ABMs related to pain and fear after stunning are the signs of state of consciousness. The same signs of consciousness that are suggested for penetrative bolt stunning were retrieved from the

literature and therefore are suggested here for firearm with free projectile (see Table 20 for description of ABMs of state of consciousness and flow chart in Section 3.2.2.2).

3.2.4.3. Prevention and correction of welfare consequences and their related hazards

The use of appropriate firearm and ammunition are essential for preventing poor welfare outcomes. Furthermore, it is important to follow manufacturer's instructions and staff training can help to prevent incorrect position of the shot and inappropriate power, calibre of the cartridge and type of projectile. Training of staff to use adequate procedures to monitor (un)consciousness will benefit to prevent and correct shooting failures. Inadequate shooting should be corrected by application of an adequate back-up procedure.

3.2.4.4. Outcome table on 'Use of firearm with free projectile'

Table 23: Outcome table on 'Use of firearm with free projectile'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Incorrect position of the shot (see Section 3.2.4.1)	Pain, fear	Staff	Lack of skilled operator Operator fatigue	• Staff training and rotation	• Correct shooting position
Inappropriate power and calibre of the cartridge (see Section 3.2.4.1)	Pain, fear	Staff, equipment	Lack of skilled operator Wrong choice of equipment and cartridge Poor maintenance of the equipment	• Appropriate equipment • Staff training	• Correct application of the power and calibre
Inappropriate type of projectile (see Section 3.2.4.1)	Pain, fear	Staff, equipment	Lack of skilled operator Wrong choice of projectile	• Staff training	• Shoot with a correct type of projectile

ABMs: Signs of consciousness after stunning (as a prerequisite for experiencing pain and fear)

3.2.5. Electrical stunning

There are two types of electrical stunning used for cattle: 1) head-only electrical stunning and 2) head-to-body electrical stunning. While the process description is given separately (see Sections 3.2.5.1 and 3.2.5.2, respectively), hazards, animal welfare assessment and management, as well as the outcome table are commonly presented for both types of 'electrical stunning'.

3.2.5.1. Head-only electrical stunning

Restraint used for electrical stunning of cattle differs from restraint for slaughter in other species as a stun box is used to restrain the movement of animal and the stunning electrodes are used as head restraint. Individual cattle are driven into the stunning box and a guillotine-type, non-return gate descends behind the animal restraining it in the stun box. When the animal is in the appropriate position, the automatic electrical stunner is activated and the pneumatic neck yoke (with associated electrodes) applied, which restrains the head of the animal. Then, a chin-lift moves vertically, lifting the head, to allow contact with a nose plate electrode (HSA, 2016a). Alternatively, head-only electrical stunning is also performed in cattle by placing one electrode on the bridge of the nose and two electrodes positioned as neck yoke (see Figure 4).
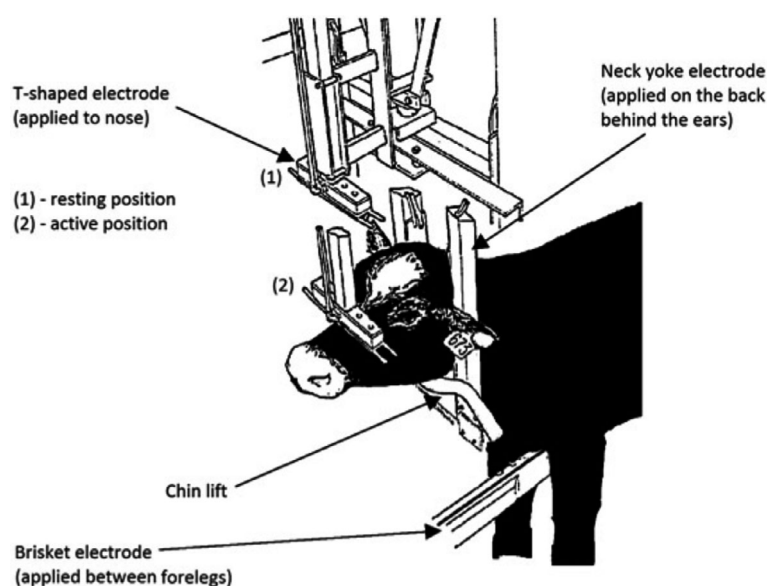

Figure 4: Illustration of equipment used for head-only or head-to-body electrical stunning of cattle (HSA, 2016a)

Head-only electrical stunning involves passage of a current of sufficient magnitude through the brain to induce a generalised epilepsy in the brain, characterised by the immediate collapse of the animals and onset of tonic–clonic seizures, indicative of unconsciousness. The electric current is passed between the nose plate or the electrode placed on the bridge of the nose and the neck yoke, spanning the brain for head-only electrical stunning.

Cook et al. (1991) reported that passing an electric current (50 Hz, 400 V open circuit, current limited to 1.5 A) between the two neck yoke electrodes placed on either side of the dorsal surface of the neck (cervical vertebrae C2–C5 region) resulted in epileptiform activity in the EEG of young bulls weighing 75–100 kg. Lambooij et al. (2012) also reported that application of 300 V (constant voltage of a 50 Hz sine wave alternating current) for three seconds across the head of pink veal calves (average warm carcass weight 185 kg) produced epileptiform EEG and tonic–clonic seizures.

In another study by Wotton et al. (2000), an effective and immediate stun was produced when 1.15 A was delivered with a sine wave alternating current (AC) at 50 Hz between the nose and neck electrodes for less than 1 second. However, when applied for 3 seconds, head-only currents ranging between 0.46 and 3.57 A sine wave AC at 50 Hz delivered using a variable voltage (0–600 V) transformer were sufficient to induce epileptiform activity in the brain, identified as high amplitude low frequency activity in the EEG. The induction of effective head-only electrical stunning resulted in an average duration of unconsciousness lasting for 50 seconds before the return of rhythmic breathing

movements, and positive corneal and palpebral reflexes (Wotton et al., 2000). The minimum recommended currents for head-only stunning are > 1.28 A and 1.25 A for cattle and calves, respectively (HSA, 2016a,b). Effective stunning leads to immediate collapse of the animals and onset of tonic–clonic seizures that are expected to last for seconds (Table 24, HSA, 2016a,b). However, bleeding should commence as soon as possible.

Table 24: Duration of unconsciousness (in seconds) induced by the minimum head-only electrical stunning currents (> 1.28 A and 1.25 A for cattle and calves, respectively)

Animal	Tonic seizure	Clonic seizure	Recovery
Adult cattle	5–20	10–60	45–90
Calves	8–14	8–28	40–70

It is also worth reporting that new experimental research and developments are taking place in the area of electrical stunning of cattle to improve its effectiveness and eliminate post-stun seizures occurring in unconscious animals. For example, it has been reported that application of a single pulse of ultra-high electrical current (SPUC) consisting of a minimum of 5,000 V, 70 A for approximately 50 ms from a nose plate to neck yoke electrodes resulted in a high level of stunning efficacy, with unconsciousness lasting for up to 4 min (Robins et al., 2014). However, this method has not been fully validated and is therefore not used under commercial slaughterhouse conditions.

3.2.5.2. Head-to-body electrical stunning

Head-to-body electrical stunning has the welfare advantage of eliminating the chance of recovery of consciousness and preventing formation of carotid arteries aneurysm due to cardiac arrest (rapid fall in blood pressure) (Gregory, 2009).

Restraint used for head-to-body stunning is the same as described under head-only electrical stunning, but an extended pneumatic brisket electrode is applied between the forelimbs of each animal to make electrical contact with the brisket and to act as the body electrode (Figure 4). Water is applied to the electrodes to improve electrical conductivity. An electric current of sufficient magnitude is passed between the nose plate and the brisket electrode, such that the electrodes span the brain and the heart, leading to generalised epilepsy and cardiac ventricular fibrillation. The number of current cycles used to stun/kill cattle, the electrical parameters and duration of exposure seem to vary in slaughterhouse conditions.

Head-to-body electrical stunning of cattle can be achieved using three sequential current applications (HSA, 2016a,b): a three-second head-only phase applying current between the nose plate and neck yoke electrodes to stun the animal followed by a 15-s cardiac phase (current flow between the nose plate and brisket electrode) to induce ventricular fibrillation (cardiac arrest cycle). Then a four-second spinal depolarisation cycle is applied between the nose plate electrode and the rear of the animal to reduce clonic convulsions. A 50 Hz sine wave AC is applied for all three cycles, with the voltage limited to allow for a maximum current of approximately 3.5 A via a voltage-limiting choke and the average stun to stick interval is about 50 seconds (Wotton et al., 2000; Mpamhanga and Wotton, 2015). The minimum recommended currents for head-to-body stunning are > 1.51 A and 1.0 A for cattle and calves, respectively.

Mpamhanga and Wotton (2015) carried out a study under commercial slaughterhouse conditions involving 144 bulls, 244 heifers and 400 steers of 29 different breeds from 63 producers. The mean carcass weight was 359.1 kg (SD ± 54.1). Cattle were stunned in the so-called Jarvis Beef Stunner using three consecutive cycles as described above and were examined by two researchers, the first assessing animals on a restraining cradle immediately following ejection from the stun box and a second following shackling and hoisting at the point of sticking. Each researcher recorded, as either present or absent, the respiratory activity, limb movement, muscle tone, eye-roll, palpebral and corneal reflexes for all animals and, in addition, the overall physical response of each animal was subjectively assessed. It was reported that cattle entering the stun box with less prior agitation made better contact with the brisket and rear electrodes during the ventricular fibrillation and spinal discharge current cycles, respectively. As a result, a lesser proportion of cattle exhibited responses and reflexes.

The authors suggested that the use of a cardiac arrest stunning system with cattle demonstrated that there was sometimes a resumption of the eye reflexes, first the corneal, then the palpebral reflexes, following a cardiac arrest stun. However, these responses were lost subsequently, and brain death occurred without the resumption of consciousness. It is probable that the mid-brain and cortex,

which succumb to anoxia faster following cardiac arrest than the brain stem region (control of brain stem reflexes), initiate the end of global epileptiform activity in the brain. These higher centres, which are necessary for consciousness, die first, but the more resistant brain stem region survives longer. However, this hypothesis has not been proved with stunning systems that induce a cardiac arrest.

3.2.5.3. Hazards identification for 'Electrical stunning'

Hazard leading to 'Pain and Fear'

The hazards identified during this process are:

1) Restraint and/or inappropriate restraint
2) Wrong placement of the electrodes
3) Poor electrical contact
4) Too short exposure time
5) Inappropriate electrical parameters.

As a consequence, these hazards can lead to the welfare consequence pain and fear during restraint and loading into the restraining device and can lead to failure in onset of unconsciousness after stunning or to early recovery before or during bleeding.

Restraint and/or inappropriate restraint:

Excessive pressure applied during restraint could lead to pain and fear. Lack of adequate pressure leading to poor electrical contact can cause ineffective stunning

Wrong placement of the electrodes:

When during head-only stunning the neck electrodes are positioned on the neck too far away from the head (i.e. in caudal direction), the electrodes do not span the brain to induce immediate unconsciousness in spite of good electrical contact. Factors leading to wrong placement of the electrodes are variation in the size of animal, malfunctioning of the equipment in case of automated restraint or presence and direction of horns in some breeds of cattle hindering the accurate placement of electrodes.

Poor electrical contact:

The electric contact between the animal and stunning electrodes is not sufficient to facilitate current flow necessary to achieve immediate stunning.

Too short exposure time:

For electrical stunning methods, the duration of exposure to the electrical current is too short to result in epileptiform activity in the brain indicative of unconsciousness.

Inappropriate electrical parameters:

The electrical parameters (current, voltage and frequency) are not adequate to induce immediate loss of consciousness and/or death.

Several factors can contribute to this hazard (see Outcome Table 25). In particular, wrong choice of electrical parameters, too low applied voltages or current unable to overcome the electrical impedance/resistance in the pathway, lack of calibration of equipment, lack of monitoring of stun quality and lack of adjustment to the settings to suit different animal types (calves vs bulls; dairy vs beef breeds).

3.2.5.4. Assessment of animal welfare for 'Electrical stunning'

ABM's related to pain and fear during restraint and loading into the restraining device are escape attempts, vocalisations, injuries, reluctance to move and turning back. For definitions, see Table 8 in Section 3.1.3.2.

ABM's related to pain and fear after stunning are the signs of consciousness. The same signs of consciousness that are suggested for penetrative captive bolt stunning (see ABM definitions in Table 20 and flow chart in Figure 3, Section 3.2.2.2) were retrieved from the scientific literature and are therefore suggested for electrical stunning.

3.2.5.5. Prevention and correction of welfare consequences and their related hazards

Pain and fear during restraint and application of head-only electrical stunning should be mitigated through adequate design and maintenance of the restraining and stunning equipment and staff competence and training. Animals must be restrained only when the stunning can be performed without any delay. Animals should not be left in restraint during work breaks, and in the event of a breakdown animals should be removed from the restraint promptly. Moving a group of animals into a single line at the commercial slaughter speed is a challenging procedure. As seen during unloading and handling and moving of the animal, the use of too much pressure, shouting, hitting or the use of (electric) goads to force the animals from a group into a single line raceway will lead to fear and reluctance of the animals to move.

Design of the raceway like a carousel or curved raceways can facilitate the flow of the cattle (Jones, 1999; Grandin 1990) and therefore reduce the level of pain and fear. The raceways and entrance to the restraint 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, 2012). It is also important to note that the restraint should be adjusted to suit cattle of different sizes and weight range to minimise pain and fear. Duration of restraint should be as short as possible and, as a guide to good practice, animals should not be restrained until the operator is ready to stun and bleed them. In addition, the width of the restraint should be appropriate for the size of the animals and loading of animals into the restraint should be done smoothly.

Staff should be trained to acquire adequate knowledge and skills to understand the behaviour of cattle and the need for optimum restraint required for stunning or adjusting restraint according to the size of the animal.

The automatic electrical stunner should be equipped with a built-in timer monitoring exposure time or visual or auditory warning system to alert the operator.

Staff should be trained for correct placement of the stunning electrodes, maintaining adequate pressure, continuous contact between the animal and electrodes and use of current necessary to achieve effective stunning appropriate to the waveform and frequency. The operator should also have adequate knowledge, understanding and skills to recognise any variable (e.g. variation in the size of animal, dirt around the electrode contact area on the animal or build-up of dirt on the electrodes, malfunctioning of equipment) leading to wrong placement of electrodes or insufficient flow of current. Slowing down the process will help to prevent or minimise the incidence of some of the hazards, if high throughput is the cause.

Regular cleaning of electrodes using a wire brush, calibration and maintenance of the equipment is essential to prevent hazards that might lead to ineffective stunning.

Inadequate stunning should be corrected by application of an adequate back-up procedure. For this purpose, staff should be trained to recognise signs of ineffective stunning by continuous monitoring and identify causes of failures such as high electrical resistance/impedance.

Regular auditing of the effectiveness of stunning by assessing the incidence of wrong electrode placement or of the number of animals vocalising as consequence of poor placement will help to implement appropriate prevention/correction measures (Temple Grandin website, 2010[24]).

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[24] http://grandin.com/ritual/aspca.html

3.2.5.6. Outcome table on 'Electrical stunning'

Table 25: Outcome table on 'Electrical stunning'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Restraint and/or inappropriate restraint (See Section 3.2.5.3)	Pain, fear	Staff, equipment, facilities	Presentation of the animal to the method is required	• Use optimal restraint according to the size of the animal	• Keep the duration of restraint to the minimum • Reduce the pressure
Wrong placement of the electrodes (See Section 3.2.5.3)	Pain, fear	Staff, equipment	Failure to adjust the equipment to suit the size of animal Lack of skilled operator Improper restraint	• Adjust/synchronise the equipment • Training of staff	• Use of a back-up method
Poor electrical contact (see Section 3.2.5.3)	Pain, fear	Staff, equipment	Lack of skilled operators Poorly designed, constructed and maintained equipment Intermittent contact	• Training of staff • Ensure correct presentation of the animal • Ensure correct maintenance of the equipment • Ensure the equipment includes appropriately sized electrodes • Ensure continuous contact between the electrodes and the head • Ensure regular calibration of equipment • Regular cleaning of the electrodes	• Use of a back-up method
Too short exposure time (see Section 3.2.5.3)	Pain, fear	Staff	Lack of skilled operators High throughput rate	• Staff training • Reduce throughput rate • Ensure a timer is built in the stunner to monitor the time of exposure or use of a visual or auditory warning system to alert the operator	• Use of a back-up method

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Inappropriate electrical parameters (see Section 3.2.5.3)	Pain, fear	Staff, equipment	Wrong choice of electrical parameters or equipment Poor or lack of calibration Voltage/current applied is too low Frequency applied is too high for the amount of current to be delivered Lack of skilled operators Lack of monitoring of stun quality Lack of adjustments to the settings to meet the requirements Poor maintenance and cleaning of the equipment	• Use parameters appropriate to the frequency and waveforms of current • Ensure the voltage is sufficient to deliver minimum current • Regular calibration and maintenance of the equipment • Training of staff training • Consider the factors contributing to high electrical resistance and minimise/eliminate the source of high resistance • Monitor stun quality routinely and adjust the equipment accordingly • Use constant current source equipment • Clean the electrodes regularly	• Use of a back-up method

ABMs: Vocalisations, escape attempts (pain, fear), injuries (pain), signs of consciousness after stunning (as a prerequisite for experiencing pain and fear)

3.3. Phase 3: bleeding

3.3.1. Bleeding following stunning

Exsanguination of cattle immediately following stunning is an important step in the slaughter process intended to causing death in unconscious animals. Under commercial slaughter situations, cattle are bled out with a chest stick (referred to as sticking) aimed at severing the brachiocephalic trunk which gives rise to the carotid arteries and vertebral artery supplying oxygenated blood to the brain (EFSA, 2004; HSA, 2016a,b). 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 5). The blade of the knife should be long enough to reach the brachiocephalic trunk. The size of the sticking wound should be large enough to allow profuse bleeding leading to rapid onset of death in animals.
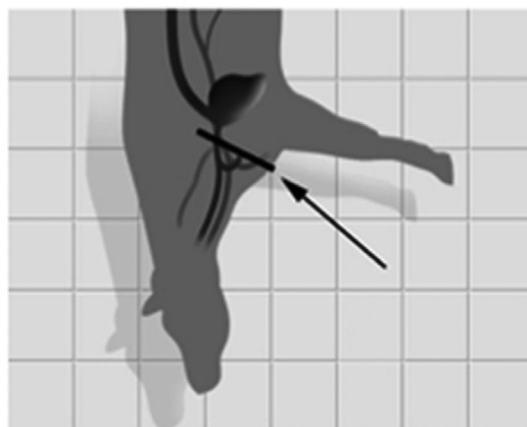

Figure 5: Illustration of chest sticking aimed at cutting the brachiocephalic trunk in cattle (HSA, 2016a)

Alternatively, effectively stunned cattle may also be bled out by severing two carotid arteries and jugular veins in the neck, referred to as neck cutting. In this process, an incision is made usually between second and fourth cervical vertebrae, severing all the soft tissues including the major blood vessels in the upper neck. Sticking or neck cutting should be performed swiftly and accurately following the effective application of a reversible stunning method. In this sense, reversible stunning methods induce momentary loss of consciousness and therefore the onus of preventing recovery of consciousness following stunning relies solely on prompt and accurate sticking. It is expected that unconsciousness induced by stunning should last longer than the time between the end of stunning and sticking and the time to onset of death due to blood loss following sticking together (Figure 6). The bleed out time should be long enough to allow for death to occur in animals which should be confirmed before carcass processing begins.
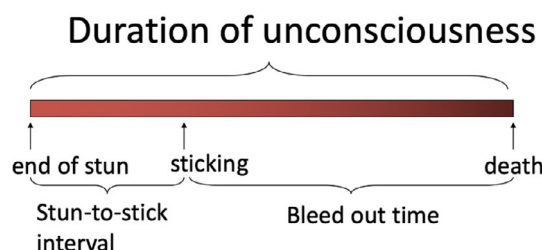
Figure 6: An illustration of the duration of stun-to-stick interval and bleeding (EFSA, 2004)

The brain of ruminants is perfused with blood from a vascular network (Rete mirabile) that receives branches from the carotid and vertebral arteries. In cattle, unlike sheep or pigs, vertebral arteries have anastomosis with the carotid rete via the basioccipital plexus (Baldwin and Bell, 1963a; Figure 7). Therefore, perfusion of the brain would continue following neck cutting, i.e. severing carotid arteries in the upper neck.
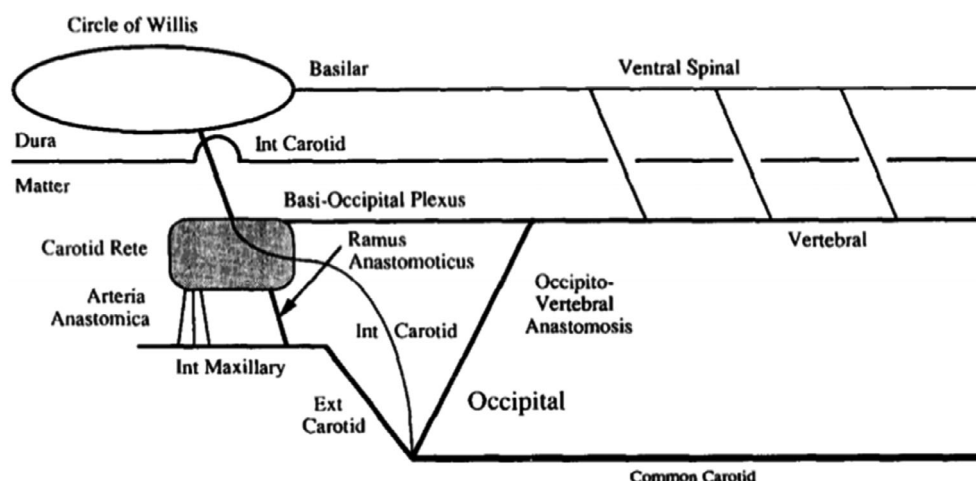
Figure 7: Illustration of cerebral blood circulation in cattle (Baldwin and Bell, 1963)

Anil et al. (1995) reported that, when carotid occlusion occurred, vertebral artery blood flow was maintained at about 30% of its initial level for up to 3 min, and in some calves, it increased substantially following neck cutting. Carotid occlusion delayed the time to onset of an isoelectric electrocorticogram (ECoG) in calves for up to 127 s. In the same study, it was also found that no occlusion of the severed blood vessels occurred following chest sticking, i.e. severing brachiocephalic trunk, the mean arterial blood pressure fell promptly (within 8 s) in all the calves, and the maximum time to onset of an isoelectric ECoG was 60 s following chest sticking. These results clearly demonstrated that chest sticking not only prevents occlusion of blood vessels due to false aneurisms but also significantly reduces the time to onset of brain inactivity/death.

The combination of false aneurysm formation in the carotids plus collateral blood flow through the plexuses presents a risk of recovery of consciousness during slaughter following reversible stunning methods (e.g. penetrative captive bolt stunning, head-only electrical stunning). In cattle, 40–50% of the blood is lost within 60 s, and blood loss can continue for up to 300 s following severance of carotid arteries (Gregory et al., 1986). The rate of bleed-out following the severance of brachiocephalic trunk (chest sticking) is not known.

The presence of consciousness at sticking or cutting, or recovery of consciousness during bleeding, is a serious animal welfare concern for at least two reasons. First, the incision made in the neck and chest sticking involves substantial tissue damage in areas well supplied with nociceptors (Kavaliers, 1988). The activation of the protective nociceptive system induces the animal to experience pain. Second, onset of death due to sticking is not immediate, and there is a period of time during which the animal may regain consciousness and then experience pain, fear and distress (EFSA AHAW Panel, 2013).

3.3.1.1. Welfare consequences 'Pain, fear and distress': assessment, hazard identification and management

Definition of 'Pain, fear and distress' related to bleeding following stunning

For definitions of 'Pain' and 'fear', see Section 3.1.3.2.

Distress can be defined as an aversive, negative state in which coping and adaptation processes fail to return an organism to physiological and/or psychological homeostasis (Carstens and Moberg, 2000; Moberg, 1987; NRC, 1992).

ABMs for 'Pain, fear and distress' related to bleeding following stunning

The presence of consciousness during bleeding, leading to pain and fear can be recognised from the ABMs listed in the third key stage of the flow charts (EFSA AHAW Panel, 2013), which are reported in Table 26, here below.

In addition, death should be confirmed before dressing and can be recognised by relaxed body, cessation of bleeding and dilated pupils.

Table 26: ABMs for the assessment of 'State of consciousness' and 'State of death' after bleeding following stunning (from EFSA AHAW Panel, 2013)

ABMs	Description
State of consciousness	
Breathing	Ineffectively stunned animals and those recovering consciousness will start to breathe in a pattern commonly referred to as rhythmic breathing, which may begin as regular gagging and involves respiratory cycle of inspiration and expiration. Rhythmic breathing can be recognized from the regular flank and/or mouth and nostrils movement. Recovery of breathing, if not visible through these movements, can be checked by holding a small mirror in front of the nostrils or mouth to look for the appearance of condensation due to expiration of moist air
Muscle tone	Conscious animals will not lose muscle tone. Loss of muscle tone can be recognised from the completely relaxed legs, floppy ears and tail, and relaxed jaws with protruding tongue. Ineffectively stunned animals and those recovering consciousness will show a righting reflex and attempts to raise the head (EFSA AHAW Panel, 2013)
Spontaneous blinking	Conscious animals may show spontaneous blinking and therefore this sign can be used to recognise ineffective stunning or recovery of consciousness after electrical stunning. However, not all the conscious animals may show spontaneous blinking
State of death	
Relaxed body	Complete and irreversible loss of muscle tone leads to relaxed body of the animal, which can be recognized from the limp carcass
Bleeding	Slaughter leads to cessation of bleeding, with only minor dripping, from the neck cut wound, and therefore end of bleeding in both carotid arteries and jugular veins can be used as an outcome of death
Pupil size	Dilated pupils (mydriasis) is an indicator of the onset of brain death (outcome of death), the assessment of which requires close examination

Hazards leading to 'Pain, fear and distress' related to bleeding following stunning

Hazards are:

1) Prolonged stun-to-stick interval
2) Incomplete sectioning of brachiocephalic trunk or of the carotid arteries
3) Failure to recognise carotid occlusion
4) Sticking of conscious cattle
5) Dressing of cattle while still alive.

Prolonged stun-to-stick interval

The interval between the end of stunning and sticking is too long to sustain unconsciousness until death occurs due to bleeding.

The appropriate stun-to-stick interval needs to be calculated under the prevailing stunning method and slaughter situations. In effectively stunned cattle, sticking should be performed as soon as possible. In any case a maximum stun-to-stick interval of 60 seconds for the penetrative captive-bolt and 30 seconds for the non-penetrative captive-bolt have been suggested (HSA, 2016a,b). In commercial slaughterhouses, sticking of cattle may be performed after captive bolt stunning, which is most commonly used, following shackling and hoisting the unconscious animals and moving it on an overhead rail to the bleeding area. Owing to this, there would be a delay between the end of stunning and sticking. Lack of a skilled operator, delayed shackling, hoisting and sticking of animals (e.g. when stunned animals convulse excessively, or when it is difficult to eject the animal from the stunning pen because of the position in which it has collapsed and lying in the stun box) and positioning of the stunner too far away from the bleeding rail are therefore the origins of this hazard.

Incomplete sectioning of brachiocephalic trunk or of the carotid arteries

Failure to cut the brachiocephalic trunk, which gives rise to carotid and vertebral arteries, or failure to completely sever the two carotid arteries that supply oxygenated blood to the brain.

This hazard may lead to recovery of consciousness during bleeding in effectively stunned cattle and prolong the time to onset of death. The prevalence of this hazard is not known. Lack of skilled operator and use of blunt or short knives are identified as hazard origins.

Failure to recognise carotid occlusion

Carotid occlusion or false aneurysms develop when the severed end of carotid retracts within its surrounding connective tissue sheath, blood flowing from the severed end impregnates the adventitia, and the artery end becomes sealed as the adventitia swells with blood (Gregory et al., 2006; Gregory, 2009). Cattle subjected to penetrative captive bolt stunning can develop false aneurysms at the severed ends of the carotids after neck cutting (Gregory et al., 2006). A study carried out in slaughterhouses involved stunning of cattle with a penetrative captive bolt and cutting the carotid arteries at first (C1) or third (C3) cervical vertebra (Gregory et al., 2012). The results showed that the frequency of arteries with early arrested blood flow was over four times higher when the soft tissues of the neck were cut at C3 compared to C1. The corresponding frequency of cattle with early arrested blood flow from at least one artery was 44% at the C3 position, compared with 12% at C1. With the cut in the C1 position, 82% of the arteries did not develop a false aneurysm and continued to bleed throughout the 45 s, whereas 42% of the arteries cut at the C3 position developed false aneurysms with early arrested blood flow. The frequencies of false aneurysms, irrespective of whether or not the arteries showed early arrested flow, at the C1 and C3 positions were 17% and 42%, respectively. Clearly, cutting carotid arteries at C1 reduces the incidence of this hazard.

More importantly, none of the cattle subjected to cardiac ventricular fibrillation by head to body electrical stunning using 2.1 A applied to the head followed by 1.4 A applied between the nose and brisket while they were in a rotary pen, developed carotid occlusion (Gregory et al., 2008). This study also demonstrated that strong arterial pressure was essential for false aneurysm formation in cattle.

If bleeding is arrested due to a false aneurism, blood can continue to flow to the brain via the collateral vertebrobasilar plexus, which is particularly well developed in cattle. This hazard may lead to recovery of consciousness during bleeding in effectively stunned cattle and prolong the time to onset of death.

Lack of a skilled operator is the hazard origin.

Sticking of conscious cattle

Sticking comprises the incision of skin, soft tissues, nerves and of the brachiocephalic trunk. This hazard applies only to ineffectively stunned cattle or those recovering consciousness during sticking. Lack of skilled operators and lack of monitoring consciousness at the time of sticking are hazard origins.

Dressing of cattle while still alive

Cattle with signs of life undergoing dressing may recover consciousness and consequently experience pain, fear and distress. Lack of skilled operators, short bleeding time, incomplete sectioning of the brachiocephalic trunk or carotid arteries, occlusion of carotids (false aneurisms) and lack of monitoring of death before dressing begins are hazard origins.

3.3.1.2. Prevention and correction of 'Pain fear and distress' and their related hazards during bleeding following stunning

Preventive measures include training of staff to stun the cattle correctly as soon as it is restrained, to monitor the state of consciousness post-stun, to swiftly shackle and hoist the stunned animals, to use a sharp knife that is long enough to reach the brachiocephalic trunk, to perform promptly and accurately the cutting of the brachiocephalic trunk or carotid arteries, to ensure sticking wound is large enough to facilitate profuse bleeding and to confirm death before dressing begins.

Corrective measures include the use of back-up stunning when animals show signs of consciousness, cutting again properly the brachiocephalic trunk or carotid arteries if bleeding is slow and removing carotid occlusion in unconscious animals. Animals showing signs of life should be examined to ascertain the cause(s) of delayed onset of death and appropriate intervention should be applied. For example, carcass dressing should be delayed if the bleed out time is found to be too short or the neck cutting wound inspected and any obvious blood clot or carotid occlusion removed, including removal of the section of occluded carotid artery.

3.3.1.3. Outcome table on 'Bleeding following stunning'

Table 27: Outcome table on 'Bleeding following stunning'

Hazard*	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Prolonged stun-to-stick interval (see Section 3.3.1.1)	Pain, fear, distress	Staff, equipment	Lack of skilled operator Delayed hoisting and sticking of animals Positioning of the stunner too far away from the bleeding rail	• Training of staff • Speedy hoisting of animals after stunning • Prompt and accurate cutting of brachiocephalic trunk/carotid arteries	• Re-stunning
Incomplete sectioning of brachiocephalic trunk or of the carotid arteries (see Section 3.3.1.1)	Pain, fear, distress	Staff, equipment	Lack of skilled operators Blunt or short knife Narrow sticking wound	• Training of staff • Use of sharp knife long enough to reach brachiocephalic trunk • Ensuring brachiocephalic trunk is cut • Ensuring the sticking wound is large enough to facilitate profuse bleeding	• Correct cutting of brachiocephalic trunk • Correct cutting of brachiocephalic trunk
Sticking of conscious cattle (see Section 3.3.1.1)	Pain, distress	Staff	Lack of skilled operators Ineffective stun or recovery of consciousness before sticking Lack of monitoring of unconsciousness at the time of sticking	• Proper stunning and proper stun-to-stick interval • Training of staff to monitor consciousness	• Re-stunning before sticking
Failure to recognise carotid occlusion (see Section 3.3.1.1)	Pain, fear, distress	Staff, equipment	Lack of skilled operator Lack of monitoring	• Training of staff • Monitoring of bleeding	• Re-stunning if animal has regained consciousness • Removing occlusion

Hazard*	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Dressing of cattle while still alive (see Section 3.3.1.1)	Pain, fear, distress	Staff	Lack of skilled operators Short bleeding time Incomplete sectioning of brachiocephalic trunk or carotid arteries Lack of monitoring of death before carcass dressing	• Training of staff • Ensuring death before dressing	• Delay dressing if it is due to short bleeding time • Cut again the carotid arteries or brachiocephalic trunk if it is due to incomplete sectioning

ABMs: Signs of consciousness after stunning (as a prerequisite for experiencing pain and fear) [although not a direct welfare consequence, additionally monitoring of signs of life should be monitored to avoid dressing of cattle while still alive]

3.3.2. Bleeding during slaughter without stunning

When slaughtered without stunning, cattle are killed through exsanguination by severing all the soft tissues, including blood vessels, in the neck usually at the level of second to fourth cervical vertebrae (EFSA, 2004; von Holleben et al., 2010).

In this process, cattle are restrained from all around and the neck is stretched to facilitate cutting all the soft tissues, including major blood vessels on the ventral aspect of the neck. There are different restraining systems available for cattle and each device can be operated manually or automatically involving pressure sensors.

Cattle are either restrained in an upright, rotated or inverted position. For example, in Europe, from the 2.1 million animals slaughtered without stunning, more than 1.6 million (78%) are slaughtered in a rotating device, while the rest (22%) are slaughtered in an upright device, as reported in the EC funded research project on 'Restraining systems for bovine animals slaughtered without stunning/ Welfare and socio-economic implications (BoRest study report[25]) .

According to Temple Grandin,[26] one particular device known as ASPCA pen consists of a narrow restraining box with an opening in the front for the animal's head. After the animal enters the box, it is nudged forward with a pusher gate and a belly lift comes up under the brisket. The head is restrained by a chin lift for the operator to perform slaughter without stunning. The rear pusher gate, belly lift and chin lift are pneumatically operated. Vertical travel of the belly lift should be restricted so that it does not lift the animal off the floor. The rear pusher gate should be equipped with either a separate pressure regulator or special pilot-operated check valves to allow the operator to control the amount of pressure exerted on the animal. The pen should be operated from the rear toward the front. Restraining the head is the last step. In some restraining devices, one side of the box can be pneumatically moved to gently squeeze and restrain the animal. Rotation of the restrained animal to 45° or 90° prior to neck cutting is also practiced in some devices. Other devices involving rotation of the restrained animal to 180° may involve a dorsal plate to provide support when the animal is restrained on its spine. The operator should perform neck cutting as soon as the animal is restrained.

The welfare consequences of restraining cattle prior to slaughter without stunning vary widely depending on the type and severity of restraint. As cattle are usually restrained from all around, inappropriate pressure exerted from the restraining device on the animals may lead to pain and fear. Rotating or inverting the animals generates a series of animal welfare concerns: the animal is exposed in an unnatural posture, generating abdominal pressure and fear due to the inversion especially if the animal is kept for a long time (See above BoRest study report). On the other hand, restraining in upright position for slaughter without stunning makes the cutting more difficult for the slaughterman due to the upward thrust of the knife and without the use of pressure or force, which is a religious requirement (see above BoRest study report) or will lead to hampered bleeding (Verhoeven et al., 2016).

The presence of consciousness during slaughter without stunning causes severe welfare consequences. First, the incision made in the neck and chest sticking involves substantial tissue damage in areas well supplied with nociceptors (Kavaliers, 1988). The activation of the protective nociceptive system induces the animal to experience pain. Second, onset of death due to sticking is not immediate, and there is a period of time during which the animal remains conscious and experiences pain, fear and distress (EFSA AHAW Panel, 2013).

The question whether the cut is painful, even if it is performed by a perfectly trained operator with a perfectly sharp knife on a calm animal is most important with regard to animal welfare during slaughter without stunning (von Holleben et al., 2010). The perception of pain is based on an interaction of receptors, nerves, the spinal cord and the brain including the thalamus and the cortex (Brooks and Tracey, 2005; Treede et al., 2000).

Pain receptors are located in skin, muscles, joints, periosteum, most internal organs and around blood vessels. Pain can lead to different experiences (e.g. sharp or dull) as different anatomical structures are involved, and different tissues contain different types of sensors, density of sensors and different types of fibres for conduction of information. Sharp pain is signalled by A-fibres (conduction time 5–30 m/s) and the reaction time for perception of sharp pain is short. C-fibres (conduction time 0.5–2 m/s) are associated with a slower burning type of pain. Both types of nociceptive fibres

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[25] Restraining systems for bovine animals slaughtered without stunning/ Welfare and socio-economic implications – BOREST - by Institut de l'Elevage (as coordinator). June 2015. (https://ec.europa.eu/food/sites/food/files/animals/docs/aw_practice_slaughter_com_borest_report.pdf).
[26] http://grandin.com/ritual/aspca.html

innervate the skin and deep somatic or visceral structures (Ringkamp and Meyer, 2008; Hellyer et al., 2007). The results of a series of controlled laboratory studies showed that the act of slaughter by ventral-neck incision is associated with noxious stimulation and it is widely accepted that this is perceived as painful during the time interval between the incision and loss of consciousness (Mellor et al., 2009; Johnson et al., 2015). The use of changes in the EEG power spectral analysis and a minimal anaesthesia model (light general anaesthesia using halothane) was validated for the assessment of noxious sensory input using amputation dehorning as a noxious stimulus (Gibson et al., 2007). The model was then used to investigate the impact of ventral-neck incision without prior stunning (Gibson et al., 2009a). The results indicated that ventral neck incision produced changes in the EEG indicating that it was a noxious stimulus and therefore is perceived as painful in conscious animals. This was then confirmed in the second study addressing the question whether the EEG responses after ventral neck incision were due primarily to the cutting of neck tissues or to interruption of blood flow to and from the brain. The results demonstrated that the predominant noxious stimulus was the transection of neck tissue and not the loss of blood flow to and from the brain (Gibson et al., 2009b).

In cattle, 40–50% of the blood is lost within 60 s, and blood loss can continue for up to 300 s following severance of carotid arteries (Gregory et al., 1986). Another study demonstrated that 90% of bleed out (i.e. % of blood loss at 120s after neck cutting) is very similar regardless of whether cattle have been stunned with a captive bolt or subjected to slaughter without stunning (Table 28; Anil et al., 2006).

Table 28: Average times (standard error in brackets) to different levels of loss of blood (% of the blood loss at 120 s post cut) in cattle after neck cutting (Anil et al., 2006)

Time to loss of:	Slaughter without stunning	Captive-bolt stunning	Statistical significance
25% of blood loss at 120 s post-cut	17.3 s ($\pm$ 2.4 s)	10.6 s ($\pm$ 1.5 s)	$p < 0.05$
50% of blood loss at 120 s post cut	37.5 s ($\pm$ 2.8 s)	35.8 s ($\pm$ 3.7 s)	Not significant
75% of blood loss at 120 s post cut	68.0 s ($\pm$ 4.5 s)	67.6 s ($\pm$ 2.9 s)	Not significant
90% of blood loss at 120 s post cut	94.4 s ($\pm$ 4.9 s)	94.0 s ($\pm$ 2.0 s)	Not significant

During slaughter without stunning, animals will have to endure the welfare consequence of remaining conscious during bleeding until they become irreversibly unconscious. In the DIALREL study project, von Holleben et al. (2010) reviewed laboratory studies assessing the time to loss of brain function on cattle which is presented in Table 29. These studies, evaluating neurophysiological parameters, have shown that most of the cattle seem to lose consciousness between 5 and 90 seconds after the cut, but resurgence of consciousness has been reported for more than 5 min (von Holleben et al., 2010; see Table 29). In a recent study, the reported average time to unconsciousness (assessed by corneal reflex) ranged from a minimum of 69.3 s to a maximum of 115.5 s after cutting (Alam et al., 2019). Studies have shown that the delayed onset of unconsciousness in some cattle is due to the development of false aneurism and blood supply to the brain via the vertebral artery. Rosen (2004) raised doubt whether this prolonged blood and oxygen supply to the brain via this anastomosis is sufficient to maintain consciousness in cattle. However as described in Section 3.3.1, blood supply to the cattle brain via the vertebral artery makes a significant contribution to sustained periods of consciousness in cattle that suffer from carotid aneurysms following slaughter without stunning.

Table 29: Time to loss of brain function in cattle (means and/ or ranges (s) (from von Holleben et al., 2010)

Cattle category (age, weight)	Number of animals	Parameter for loss of consciousness, used in the respective study	Time post cut to appearance of indicators for loss of consciousness (mean, range)	Source
Calves (1 week old)	8	EEG[2] amplitudes not consistent with sensibility	34s (1 animal), 65-85s (7 animals)	Blackmore and Newhook (1982)
		Periodic resurgence of possible sensibility	123–323s	
		Isoelectric EEG	132–326s	
Calves (40–60 kg)	10	Relevant EEG changes[1] Isoelectric EEG	10s (up to 18s, 24s)[1] 23s	Schulze et al. (1978)
Calves (30–40 kg)	8	Loss of VEPs [2] Flat ECoG[2]	17s (12–23s) 23s (14–28s)	Gregory and Wotton (1984)
Calf (6 weeks old)	1	EEG amplitudes not consistent with sensibility	79s	Devine et al. (1986)
Calves (4–8 weeks old)	6	ECoG analysis (power content and frequency)	10s	Bager et al. (1992)
Cattle (170 kg), shechita	4	ECoG isoelectric	10.8s (8.7–12.8s)	Kallweit et al. (1989), Daly et al. (1988)
Cows (436 kg), shechita	8	Start of HALF[2]	7.5s (5–13s)	
		Duration of HALF	28s (9–85s)	
		ECoG < 10μV	72s (19–113s)	
		Loss of SEPs[2]	77s (32–126s)	
		Loss of VEPs[2]	55s (20–102s)	
Calves/Bull	4	Loss of ability to stand/loss of coordinated attempts to rise (only animals with satisfactory cut and no occlusion)	7 days old (2 calves with (severed exteriorised vessels): 16-40s/30-47s	Blackmore (1984)
			7 days old (1 calf): 5s/41s	
			13 months old (1 Bull): 3s (fractured leg)/20s	
Adult cattle	174	Time to collapse	19.5s (maximum 265s)	Gregory et al. (2010)

[1]: The original report and data of the project (Hazem et al., 1977) revealed that, though the authors concluded loss of consciousness being highly probable in calves after 10 s, they recorded unchanged EEG until 18 s after the cut, and in one animal, which had to be recut because of obviously low bleeding, the EEG showed only very small changes until 24 s after the first cut.

[2]: HALF: high amplitude low frequency waves; VEPs: visual evoked potentials; SEPs: somatosensory evoked potentials; EEG: electroencephalogram; ECoG: electrocorticogram.

The combination of false aneurysm formation (also referred to as ballooning) in the carotids plus collateral blood flow through the plexuses presents a risk of prolonged periods of consciousness following slaughter without stunning. Gregory et al. (2010) reported the time to loss of posture, as an indicator of onset of unconsciousness, in adult cattle after slaughter without stunning in upright restrained position as follows: when the cattle were released from the head restraint, most stepped backwards, stood for varying lengths of time, swayed or became unsteady and then either fell to one side and slid down the wall or their hind limbs buckled and they fell backwards followed by loss of support from the forelimbs. When down, some animals sat in sternal recumbency, but most fell into lateral recumbency or were leaning laterally. Loss of posture happened average 19.5 seconds post-cut (median 11 s, maximum 265 s). The study also showed that 14% of the cattle stood up again after the first collapse, indicative of full state of consciousness, before finally collapsing. The average time to final collapse for all the cattle was 20 s. Eight per cent of the animals took 60 s or more to achieve their final collapse, only one of which had incompletely severed carotid arteries. It is more than likely

that the cattle repeatedly resumed consciousness between the first and the final collapse (von Holleben et al., 2010).

Downing (2015) proposed that the principle of protecting welfare during slaughter without stunning should include some clear guidelines to minimise suffering in animals:

a) Cattle must be slaughtered in an upright position in a restraining pen approved for that purpose by the competent authority;
b) Restraint of a bovine animal is prohibited until the slaughterer is ready to make the incision;
c) Shackling and hoisting are prohibited until the animal is unconscious and not before a specific period has elapsed;
d) Back-up stunning equipment has to be available for use in an emergency;
e) The knife must be of a sufficient size and sharpness for slaughter.

Although Downing (2015) did not state what constitutes emergency in this context, it is assumed that it refers to delayed loss of consciousness (e.g. due to carotid occlusion). In some countries (e.g. The Netherlands), mitigation measures to deal with this emergency is to apply post-cut stun if the animal is not rendered unconscious within certain period of time (e.g. 40 s). This stipulation of 40 s is an arbitrarily chosen value based on the observation that most of the cattle are rendered unconscious within 40 s (von Holleben et al., 2010). Some countries (e.g. Austria, Australia, Denmark, Estonia, Finland) stipulate application of post-cut stun immediately after the cut has been made (Ferrari and Bottoni, 2010). Although a second incision distal to the carotid occlusion or manual removal of the clot can be considered as mitigation measures, it should be taken in consideration that any manipulation of the neck wound is additionally painful (FAWC, 2003; von Holleben et al., 2010). Lambooij et al. (2012) reported that when captive bolt stunning was applied immediately after neck cutting in veal calves (that were restrained in a rotary pen at 90°, 120° or 180°), an isoelectric EEG resulted on average at 7 s post-neck cutting. In the control group of calves that were subjected to neck cutting alone, an isoelectric line on the EEG was observed on average at 42 s after the neck cut. In some animals, a temporary acute shock may block the sensation or expression of pain (Lambooij and Kijlstra, 2009). Furthermore, pain can also be modulated by the central nervous system (Tracey and Mantyh, 2007), and stress can inhibit the transmission of pain stimuli in the brain and spinal cord (Gregory, 2004). This phenomenon called stress-induced analgesia is part of the body's self-protection measures during life-threatening situations; it involves endogenous opioids, which modulate signalling and synaptic transmission in the neural loci contributing to the pain experience (Corder et al., 2018). It must be considered in this context that stress induced analgesia does not apply in every life threatening situation and for every individual. The possibility that animals, subjected to bleeding without stunning, might be in such a state of analgesia exists, but with correct pre-slaughter handling this would not be the routine situation. Furthermore, only around 30–40% of humans experience stress-induced analgesia in an emergency situation (Melzack et al., 1982). Hence it is likely that endogenous opioid-induced analgesia may not often occur during slaughter (von Holleben et al., 2010).

Grandin and Regenstein[27] (1994) observed slaughter without stunning in more than 3,000 beef cattle and formula-fed veal calves and described little or no reaction to the throat cut by calves and cattle restrained in low-stress upright restraint system, except for a slight flinch where the blade first touched the throat. The animals made no attempt to pull away and there were almost no visible reactions of the animal's body or legs during the throat cut. Little or no reaction to the cut occurred in 6 calves reported by Bager et al. (1992). Some papers stated that the low behavioural responses to the cut demonstrate that the cut is not painful (Levinger, 1995; Levinger, 1976). However, it should be emphasised that there is no validated indicator that could be used in this situation in which the animal is severely restrained, rotated and blood is flowing over the face of the animal, and therefore, these interpretations are purely subjective and warrant further investigations to identify valid indicators that could be reliably used and correlated with the EEG responses reported in the scientific literature.

Moreover, reports on behavioural reactions of animals during slaughter without stunning are often based on anecdotal observations where the conditions of the cut are not clearly depicted (e.g. sharpness of the knife, skills of the operator), or where it is not mentioned whether the reactions to the first cut or to a multiple cut or back-up cut are described (von Holleben et al., 2010). An additional difficulty in interpreting reactions to the cut is that animals may not be able to react or reactions are masked due to the animals' position (e.g. within a head restrainer), due to natural freezing behaviour or due to limitations in the reactions because the necessary tissues have been severed (e.g.

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[27] https://www.grandin.com/ritual/kosher.slaugh.html

vocalisation not being possible through a cut trachea). Fainting during haemorrhagic shock may also make movement difficult. Hence low levels of behavioural response following throat-cutting do not necessarily indicate that the individual was not experiencing pain (EFSA, 2004; Schatzmann, 2001).

Especially for Shechita, it is stated that the exquisite sharpness of the knife, coupled with the smoothness of the incision means that there is minimal stimulation of the incised edges, typically below a level adequate to activation of pain pathways. This can be compared to the experience of surgeons, who have cut themselves in the course of an operation and only noticed it well after the event (Rosen, 2004). It must be taken into account, however, that the throat cut involves a major tissue damage over a large area and that pain is not exclusively related to the quality of the cut (von Holleben et al., 2010). With regard to humans when injuries were deep (e.g. fractures, crushes, amputations and deep stabs), 72% of subjects experienced prompt pain and 28% perceived pain only later. When injuries were limited to skin (e.g. lacerations, cuts, abrasions, burns), 53% of subjects had a pain-free period immediately following the injury. In the case of deep injuries (fractures) where there was no immediate pain, there was instead an initial feeling of numbness at the wound and persistent pain developed later when the pressures associated with haemorrhage, oedema and inflammation developed, and when pain receptor agonists released from the injured tissue accumulated at the wound (Gregory, 2004; Melzack et al., 1982).

Nevertheless, even if there is the possibility that some animals may not experience pain or only to a limited extent due to stress-induced analgesia, the throat cut involves major tissue damage which is likely to activate pain pathways in all animals. Since appropriate handling and restraint is aimed at avoiding highly stressful situations and stress-induced analgesia will not occur in all animals, slaughter without stunning seriously impairs welfare in a significant proportion of animals due to the experience of severe pain, fear and distress.

3.3.2.1. Welfare consequences 'Pain, fear and distress': assessment, hazard identification and management

Definition of 'Pain, fear and distress' related to bleeding during slaughter without stunning

For definitions of 'Pain' and 'fear', see Section 3.1.3.2.

Distress can be defined as an aversive, negative state in which coping and adaptation processes fail to return an organism to physiological and/or psychological homeostasis (Carstens and Moberg, 2000; Moberg, 1987; NRC, 1992). In the case of slaughter without stunning, it is caused by pain and fear experienced by the animals as well as the rotated or inverted position of the animal.

ABMs for 'Pain, fear and distress' related to bleeding during slaughter without stunning

Pain, fear and distress during restraint for bleeding during slaughter without stunning can be recognised from the presence of escape attempts, vocalisation and facial expression (Table 30).

Table 30: ABMs for the assessment of 'Pain, fear and distress' during restraint for slaughter without stunning

ABMs	Description	Welfare consequence
Escape attempts	Attempts to move any part of the body as far as restraint allows for it modified after BoRest report)	Pain, fear and distress
Vocalisations	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin, 2012)	Pain, fear and distress
Facial expression	'Pain face': 1) Ears are tense and backwards or low/lambs ears. 2) Eyes have a tense stare or a withdrawn appearance. Tension of the muscles above the eyes may be seen as 'furrow lines'. 3) Tension of the facial muscles on the side of the head. 4) Strained nostrils, the nostrils may be dilated and there may be 'lines' above the nostrils. There is increased tonus of the lips (Gleerup et al., 2015)	Pain

Pain fear and distress during bleeding following slaughter without stunning can be recognised from the presence of signs of consciousness, using ABMs listed in the flow chart (EFSA AHAW Panel, 2013) which is reported in Figure 8 here below.

In addition, death should be confirmed before dressing and can be recognised by relaxed body, cessation of bleeding and dilated pupils. Occurrence of false aneurisms (ballooning) can be recognised

from the impeded bleeding to complete cessation of bleeding in extreme cases. Impeded bleeding can be visibly seen from blood squirting out through the blood clot.

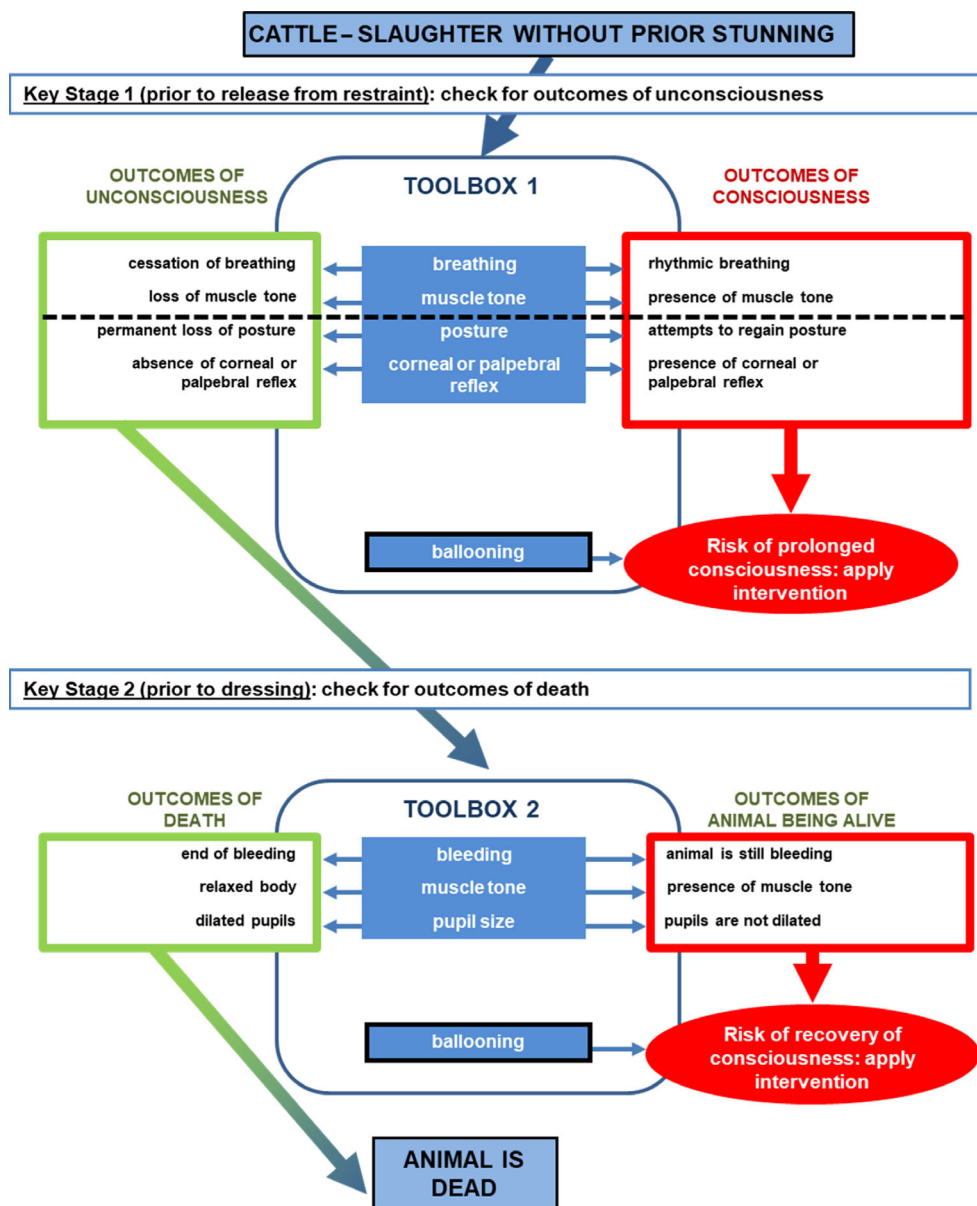For definition of the ABMs of consciousness and death, see details in Section 3.3.1.1.

CATTLE – SLAUGHTER WITHOUT PRIOR STUNNING

Key Stage 1 (prior to release from restraint): check for outcomes of unconsciousness

OUTCOMES OF UNCONSCIOUSNESS

TOOLBOX 1

OUTCOMES OF CONSCIOUSNESS

cessation of breathing	breathing	rhythmic breathing
loss of muscle tone	muscle tone	presence of muscle tone
permanent loss of posture	posture	attempts to regain posture
absence of corneal or palpebral reflex	corneal or palpebral reflex	presence of corneal or palpebral reflex

ballooning

Risk of prolonged consciousness: apply intervention

Key Stage 2 (prior to dressing): check for outcomes of death

OUTCOMES OF DEATH

TOOLBOX 2

OUTCOMES OF ANIMAL BEING ALIVE

end of bleeding	bleeding	animal is still bleeding
relaxed body	muscle tone	presence of muscle tone
dilated pupils	pupil size	pupils are not dilated

ballooning

Risk of recovery of consciousness: apply intervention

ANIMAL IS DEAD

Figure 8: Flow chart including indicators for the monitoring of state of consciousness and death in cattle slaughtered without stunning

Hazards leading to 'Pain, fear and distress' related to bleeding during slaughter without stunning

Hazards are:

1) Inappropriate body support
2) Excessive pressure
3) Immobilisation of the head
4) Rotation of the animal
5) Inversion
6) Hoisting
7) Casting
8) Incomplete sectioning of carotid arteries

9) Repeated cuts
10) Failure to recognise carotid occlusion
11) Stimulation of wound
12) Bleeding
13) Aspiration of blood
14) Release from the restraint while conscious
15) Hoisting while bleeding
16) Dressing cattle alive.

Inappropriate body support

The belly support or body squeeze crush is applied wrongly such that either the support is not sufficient to prevent the animal from collapsing in the box or the animal is lifted off the floor, both leading to pain, fear and distress. Lack of skilled operators, lack of body support in the restraining device, wrong pressure settings and faulty equipment are identified as the hazard origin.

Novelli et al. (2016) reported that the average time between restraint and neck cutting was 98 and 116 s in upright restraint and rotation to lateral recumbency, and these cattle struggled for on average 15 and 31 s, respectively.

Verhoeven et al. (2016) reported an average time to loss of consciousness of 109 s in cattle restrained in an upright position and of 49 s in cattle that were rotated to 90° or 180° during slaughter without stunning.

Excessive pressure

Pressure applied in the restraint is too high, leading to pain. Lack of skilled operator and faulty equipment are the origin.

Immobilisation of the head

Immobilisation of the head or stretching of the neck of animals is needed to perform slaughter without stunning (Figure 9).
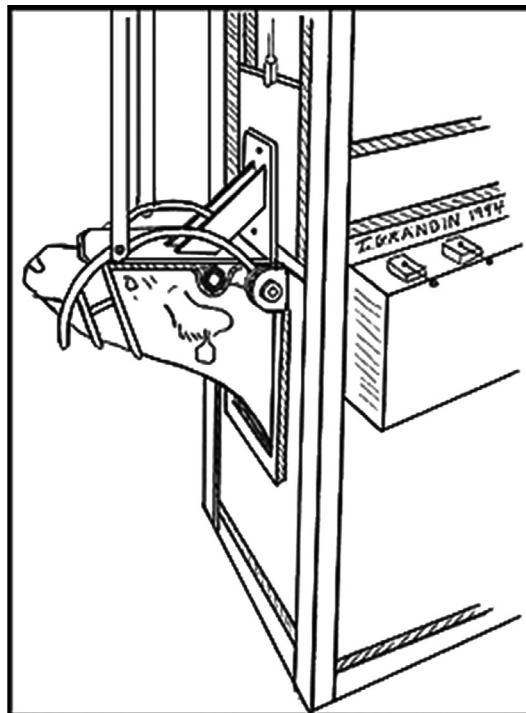

Figure 9: Illustration of an upright restraint used to perform slaughter without stunning (Source: Temple Grandin[28])

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[28] http://grandin.com/ritual/aspca.html

Rotation of the animal

Although cattle may be slaughtered without stunning in upright position, some prefer to rotate the animal and the degree of rotation in the purposefully designed restraint can vary from 45° to 180°. In a review of slaughter without stunning, Fuseini et al. (2016) identified rotation of cattle to be a common practice in many countries. In the EU, 78% of the cattle slaughtered without stunning is slaughtered in rotated positions (BoRest study report).

The percentage of struggling beef cattle was higher with the system where the animals are turned on the back (i.e. rotation by 180°) compared with the upright position or turned on their sides (Velarde et al., 2014). Similar results were reported by Novelli et al. (2016). Lambooij et al. (2012) evaluated rotating veal calves in the restraint by 90°, 120° or 180° and reported that rotation compromised veal calf welfare and should be avoided. However, no significant differences in terms of animal welfare outcomes between the groups of cattle that were restrained upright or rotated up to 180° were observed in a large study including 1,113 bovine animals of different categories in 18 slaughterhouses in six EU member states (BoRest study report). Also, an experimental study comparing upright, 90° and 180° restraint in dairy cows (Gerritzen et al., 2014) showed that restraining upright as well as rotation is stressful for cows. However, at the time of rotating animals showed more eye white than during upright restraint indicating an acute stress effect of being rotated. In the same study, it has been shown that repeated restraining and rotating becomes more stressful for the animal. Therefore, it can be argued that the negative experience is retained and that restraining by itself is aversive. Nevertheless, although distinct parameters such as white of the eyes or blood pressure showed differences between treatments, there was no overall indication that one treatment (upright, 90° or 180°) is significantly more stressful than the other.

Due to the variety of the situations found in slaughterhouses, the animal welfare outcomes depend more on the way devices are designed and used than on the position of the animals (upright or rotated). Furthermore, in a study by Verhoeven et al. (2016), it was observed that bleeding after the neck cut in upright supported restrained animals was hampered due to the animals losing balance and as a result leaning with the neck or the wound on the front of the restraint box. The result of the hampered bleeding observed in this study (Verhoeven et al., 2016) was a strong delay in the onset of unconsciousness.

Inversion

Cattle may be suspended from an overhead rail with a shackle sattached to one of the hind legs for the purpose of slaughter without stunning (e.g. in China, Gregory et al., 2012). In some countries, cattle may be hoisted first from an upright restraining pen with a shackle secured to a leg, inverted and lowered on to the floor until resting on the shoulder, the neck twisted and stretched, and finally neck cut is performed on the ventral aspect (Gregory et al., 2008). Inversion of cattle is a pre-requisite/common practice in some parts of the world.[29]

Hoisting

Cattle may be hoisted and suspended from an overhead rail with a shackle attached to one of the hind legs for the purpose of slaughter without stunning (e.g. China, Gregory et al., 2012). In the USA, about 10% of cattle and 50% of veal calves slaughtered without stunning following one method are subjected to hoisting before neck cutting.[26]

Casting

For casting, cattle are restrained by fastening a rope around their legs, tripped over to recumbency and manually restrained for the purpose of neck cutting. Cattle may be held in a restraining pen or in a wooden race for attaching casting ropes to the legs and upon release from the pen or race the cattle would be cast and restrained on the ground with ropes (for example in Indonesia, Gregory et al., 2012). In this process, the head of cattle may then be secured either with a rope or by hand, and the neck cut while the animal is in lateral recumbency with the neck twisted such that the ventral aspect is facing upwards. Traditional rope casting method in some countries uses ropes to trip the free-standing animals over and bring them down and is usually followed by trussing of the legs to avoid further movement. Normally, the animal is cast manually using a rope tightly fastened to the legs, while pulled by tail, and the head twisted by an operator and then pushed to fall down into lateral recumbency.

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[29] http://grandin.com/ritual/conservative.jewish.law.html

The neck is twisted and presented with the ventral aspect uppermost for the cut (Alam et al., 2019). Cattle restrained in this manner often struggle and attempt to right their heads indicating severe welfare consequences (Grandin, 1994).

Incomplete sectioning of carotid arteries

The prevalence of this hazard is reported to be up to 6% in cattle subjected to slaughter without stunning in a slaughterhouse (Gregory et al., 2008; Alam et al., 2019). See Section 3.3.1.1 for definition.

Repeated cuts

Neck cutting is performed by a sawing motion. Gregory et al. (2008) reported that the average number of cuts may vary between 3.2 and 5.2 depending upon the practice, and up to 60 swipes have been found. Alam et al. (2019) also reported similar prevalence. Each time the knife touches the surface of the wound the potential exists for further nociceptor activation (von Holleben et al., 2010). The origin of this hazard is identified to be lack of skilled operator and too short and /or blunt knife. Recently, Imlan et al. (2020) evaluated the effects of knife sharpness on EEG responses in cattle. The results showed a significant increase in the median frequency and total power of the EEG, the parameters indicative of pain and distress, in the animals slaughtered without stunning by cutting soft tissues in the neck at the first cervical vertebra. The increases were more significant in the group slaughtered using a knife that is normally used in slaughterhouses when compared with the group slaughtered with a patented sharp knife.

Failure to recognise carotid occlusion

Carotid occlusion or false aneurysms develop when the severed end of the carotid retracts within its surrounding connective tissue sheath, blood flowing from the severed end impregnates the adventitia, and the artery end becomes sealed as the adventitia swells with blood (Gregory et al., 2006; Gregory, 2009).

When the cuts were made at second to fourth cervical vertebrae, carotid occlusion formed as early as 7 s following slaughter without stunning, and on average they develop within 21 s (Gregory et al., 2012). In 6% of all the cattle, both the left and right carotid arteries stopped bleeding before 60 s had elapsed following the neck cut. In those cases, the average times to arrested flow in the first and second arteries were 11 and 27 s (range 7–20 and 12–55 s), respectively. Gregory et al. (2008) reported no differences in the prevalence of false aneurysms in arteries according to breed of cattle (Asian vs European), method of restraint (inverted vs lateral vs upright) or slaughter premises (casting on a slab vs upright restraint or rotary pen in abattoirs). As mentioned previously, cutting carotids at the first cervical vertebra reduced the prevalence of false aneurism (Gregory et al., 2012). The authors suggested potential reasons for the reduced likelihood of early arrested blood flow from false aneurysm formation when the cut is made at the C1 position are as follows. First, the common carotid artery has more branching at the C1 position and the risk of false aneurysms sealing all the severed branches may be lower than for sealing the main artery cut at the C2 to C4 position. Second, there may be less stretching of the artery at the C1 position when the chin is extended, and as a result when the arteries are cut at that position there is less retraction within the connective tissue sheath. This may reduce the potential for false aneurysm formation. Third, there may be less connective tissue around the carotid arteries at the C1 position compared to the C2 to C4 position, and so the opportunity for aneurysm formation would be lower at the cranial end. This study demonstrated that false aneurysms could form when the arteries were cut at the C1 position, but their frequency was 2.5 times lower compared to the C3 position. Therefore, neck cutting at C1 would minimise poor animal welfare outcome during slaughter without stunning (Abdullah et al., 2019).

Operator failing to recognise carotid artery occlusion due to lack of knowledge, skill and aptitude or monitoring procedures. Lack of skilled operator and monitoring of animals at key stages is origin of this hazard.

Stimulation of wound

Physical stimulation of the wound can occur during manipulation or massaging of the neck cutting wound to remove blood clots, by a second intervention or neck cut to improve bleeding quality or due to the contact with the restraining device.

Bleeding

Inducing unconsciousness through exsanguination, which is required by the method.

Aspiration of blood

Another welfare concern is aspiration of blood into trachea and blood splashing in the lungs of cattle subjected to slaughter without stunning in an upright restraint (Agbeniga and Webb, 2012). In this study, out of 170 animals examined after slaughter without stunning, 93% had blood lining the trachea, ranging from one to over 50%. Out of 141 animals stunned using a penetrating captive bolt, 97% had no blood lining the trachea while the remaining 3% had less than 10% blood lining the trachea. Furthermore, 65% of animals slaughtered without stunning had blood splashings ranging from 5% to over 50%, while only 0.7% of the animals subjected to preslaughter stunning had blood splashings in the lungs. In contrast, Gregory (2008) examined the upper respiratory tract in cattle for blood aspiration following slaughter without stunning through ventral neck incision and following captive bolt stunning plus sticking by gash method. In both slaughter methods, the cattle were held in the upright (standing) position during bleeding. Nineteen per cent of the cattle slaughtered without stunning and 21 % of the cattle that were stunned and then stuck had blood lining the inner aspect of the trachea. Thirty-six and 31 per cent had blood in the upper bronchi, respectively. It was concluded that blood aspiration occurs during slaughter, and so concerns about airway irritation from blood aspiration could be a concern in those animals that are not stunned or do not lose consciousness rapidly.

Gregory (2009) provided further details on the results of examination of bovine respiratory tracts for blood following Shechita without stunning, Halal slaughter without stunning, and captive bolt stunning with sticking. In all three methods, the cattle were in the upright (standing) position at the start of bleeding. Those that had not been stunned continued to breathe during the early part of bleeding while those that were stunned were not breathing. Nineteen per cent of the shechita, 58% of the halal and 21% of the stunned plus stuck cattle had blood lining the inner aspect of the trachea. Thirty-six per cent, 69% and 31% had blood in the upper bronchi, respectively. Ten per cent, 19% and 0% had fine bright red blood-tinged foam in the trachea, respectively. It was concluded that concerns about suffering from airway irritation by blood could apply in animals that are either not stunned before slaughter or do not lose consciousness rapidly while blood is present in the respiratory tract.

Release from the restraint while conscious

Cattle released from the restraining device before the onset of unconsciousness.

Hoisting while bleeding

Cattle released from the restraining device, shackled and hoisted before the onset of unconsciousness.

Dressing cattle alive

Same as in Section 3.3.1.1.

3.3.2.2. Prevention and correction of welfare consequences and their related hazards

In general, equipment used to control pressures applied during restraint should be regularly calibrated and maintained in good operational conditions.

Preventive measures for hazards occurring during restraint of cattle for slaughter without stunning include training of staff to acquire knowledge and skills necessary to perform various tasks associated with slaughter without stunning, including making adjustments to the equipment to optimise pressure applied in the restraint according to the size of the animal. Immobilisation of the head, rotation of the animal, inversion, hoisting and casting have no corrective or preventive measures. As a guide to good practice, animals should not be restrained if the operator is not ready to perform sticking or neck cutting. The operator should also be trained and certified with regard to skills required to animal handling and loading of animals into the restraining devices (von Holleben et al., 2010). Corrective measures for hazards occurring during restraint of cattle for slaughter without stunning (inappropriate body support, excessive pressure) include adjusting body support and pressure applied in the restraint to eliminate or minimise struggle.

Keeping the interval between rotation and neck cutting to the minimum is a corrective measure for rotation.

Pre-cut stunning is the only preventive measure for the welfare consequences connected with cutting. Preslaughter stunning of cattle with captive bolts is common in many countries where slaughter without stunning was the norm in the past; for example, Malaysia, Indonesia, Egypt, Saudi Arabia, the United Arab Emirates, Yemen, Tanzania (Fuseini et al., 2016). Penetrative captive bolt stunning has been accepted in these countries, as in many European countries, on the basis that cardiac activity continues in these animals (Fuseini et al., 2016) and bleed out is not impeded by the stunning method (Anil et al., 2006). It is also worth mentioning that competent authorities in some countries had demonstration programs (e.g. Italy, Salamano et al., 2013) leading to acceptance of preslaughter stunning of animals using reversible head only electrical stunning.

Further preventive measures for hazards occurring during bleeding of cattle without stunning include training of staff to acquire adequate knowledge and skills to use sharp knife that is long enough to suit the size of the animal (should be at least twice the width of the neck of the animal (von Holleben et al., 2010) and to bleed the animal in a single cut and to avoid repeated cuts or cutting with a sawing motion, to ensure both carotids are severed completely, monitor the rate of bleeding and recognise signs of carotid occlusion and monitor the state of consciousness life.

One way of overcoming poor welfare consequences originating from carotid occlusion could be to perform chest sticking, severing the brachiocephalic trunk, what is commonly used to kill camels according to religious traditions, but cattle are always exsanguinated by making a ventral neck incision (Fuseini et al., 2016).

Post-cut stunning immediately after the cut is mandatory in some countries (e.g. Austria, Australia, Denmark, Estonia, Finland) as a mitigation measure (Ferrari and Bottoni, 2010). In other countries, post-cut stunning is only applied if the animal is not rendered unconscious within a certain period of time (e.g. 40 s in The Netherlands). This requirement of 40 s is an arbitrary value based on the observation that most of the cattle are rendered unconscious within 40 s (von Holleben et al., 2010).

Corrective measure for hazards occurring during bleeding of cattle without stunning is the application of a post-cut stun without any delay.

3.3.2.3. Outcome table on 'Restraint for slaughter without stunning'

Table 31: Outcome table on 'Restraint for slaughter without stunning'

Hazard (these hazards apply to all cattle because they are conscious)	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Inappropriate body support (see Section 3.3.2.1)	Pain, fear and distress	Staff, equipment	Lack of equipment to support the body or wrong setting of the equipment Faulty equipment or/and lack of skilled operator	• Training of staff • Adjustment of equipment to optimal pressure according to the size of the animal	• Before neck cutting improve support • After neck cutting: post-cut stunning
Excessive pressure (see Section 3.3.2.1)	Pain, fear and distress	Staff, equipment	Faulty equipment or/and lack of skilled operator	• Training of staff • Adjustment of equipment to optimal pressure according to the size of the animal	• Adjust equipment to optimal pressure according to the size of the animal
Immobilisation of the head (see Section 3.3.2.1)	Pain, fear and distress	Staff, equipment	Requirement of the method	• None	• None
Rotation of the animal (see Section 3.3.2.1)	Pain, fear and distress	Staff, equipment	Requirement of some practice	• None	• Turn back the struggling animal • Keep to a minimum the time between rotation and neck cut
Inversion (see Section 3.3.2.1)	Pain, fear and distress	Staff, equipment	Part of the method/practice	• None	• None
Hoisting (see Section 3.3.2.1)	Pain, fear and distress	Staff, equipment	Part of the practice	• None	• None
Casting (see Section 3.3.2.1)	Pain, fear and distress	Staff	Part of the practice	• None	• None

ABMs: Escape attempts, vocalisations (pain, fear and distress), facial expression (pain, fear and distress)

3.3.2.4. Outcome table on 'Bleeding during slaughter without stunning'

Table 32: Outcome table on 'Bleeding during slaughter without stunning'

Hazard (these hazards apply to all cattle because they are conscious)	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Incomplete sectioning of carotids arteries (see Section 3.3.2.1)	Pain, fear, distress	Staff, equipment	Lack of skilled operators Blunt and/or too short knife	• Training of staff • Use of sharp knife • Correct size of the knife • Ensuring both carotid arteries are cut	• Post-cut stunning • Correct cutting of both arteries
Repeated cuts (see Section 3.3.2.1)	Pain, distress	Staff, equipment	Lack of skilled operators Too short and/or blunt knife	• Training of staff to avoid repeated cuts	• None
Failure to recognise carotid occlusion (see Section 3.3.2.1)	Pain, fear, distress	Staff, equipment	Lack of skilled operator Lack of monitoring	• Training of staff • Monitoring of bleeding	• Post-cut stunning • Removing of occlusion
Stimulation of wound (see Section 3.3.2.1)	Pain	Staff, equipment	Lack of skilled operators Physical contact with the open wound due to the restraint or to the manipulation	• Training of staff to avoid manipulating the wound • Adaptation of the equipment to avoid the physical contact with the wound • Post-cut stunning	• Post-cut stunning
Bleeding (see Section 3.3.2.1)	Pain, fear, distress	Staff	Method requires inducing death through bleeding of conscious animals	• Post-cut stunning	• Post-cut stunning
Release from restraint (see Section 3.3.2.1)	Pain, fear	Staff	Lack of skilled operator Lack of monitoring High throughput rate	• Training of staff • Slowing down the process • Monitoring of the state of consciousness before releasing	• Post-cut stunning
Hoisting (see Section 3.3.2.1)	Pain, fear, distress	Staff	Lack of skilled operator Lack of monitoring High throughput rate	• Training of staff • Slowing down the process • Monitoring of the state of consciousness before hoisting	• Post-cut stunning

Hazard (these hazards apply to all cattle because they are conscious)	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Dressing of cattle while still alive (see Section 3.3.2.1)	Pain, fear, distress	Staff	Lack of skilled operators Short bleeding time Incomplete section of both arteries Lack of monitoring of death before being dressed	• Training of staff • Ensuring animals are dead before being dressed	• None
Aspiration of blood into the trachea (see Section 3.3.2.1)	Pain, fear, distress	Inherent part of the method	—	• None	• Post-cut stunning
ABMs: Escape attempts, vocalisations (pain, fear and distress)					

3.4. Emergency slaughter: description and preventive measures

Emergency slaughter means killing of animals that are considered fit for human consumption but injured or have a condition associated with severe pain or suffering and there is no other practical possibility to alleviate this pain or suffering.

Emergency slaughter can be performed under three scenarios: i) animals that are unfit for transport, but fit for human consumption, may be slaughtered on the farm under veterinary supervision and carcasses transported to slaughterhouse for meat inspection; ii) animals deemed to be fit for transport may be transported to a local slaughterhouse for emergency slaughter; in this case, the farmer should organise with the food business operator and schedule immediate slaughter upon arrival; iii) animals that are found to be injured or immobile in the truck or lairage pen should be slaughtered in situ.

Under scenarios ii) and iii) animals are expected to arrive at the slaughterhouse, and it is important to ensure that their welfare is protected. The responsible person should ensure that the slaughterhouse has procedures, facilities and equipment for killing these animals outside of the normal slaughter line. The FAWC (2003) recommended that the slaughterhouse operator must ensure that procedures for emergency slaughter are clearly displayed at the unloading point so that any animal in obvious pain or distress on arrival at the slaughterhouse can be slaughtered or killed immediately.

Cattle with severe pain and suffering may arrive at the slaughterhouse, and emergency killing should be carried out while the animal is still on the transport vehicle. Similarly, cattle may become non-ambulatory due to injury or sickness in lairage and they may have to be humanely killed during lairage period. It is important to prevent other animals in the group trampling on the recumbent or immobile animal, and therefore, emergency killing may have to be performed first before attempting to move other animals from the pen. Conditions that will induce severe pain and suffering are, e.g. bone fractures, joint dislocations and open wounds, and animals that are disabled or fatigued.

The incidence and causes of cattle requiring emergency slaughter or killing at arrival or during lairage seem to vary widely. Assessments of culled cattle in holding pens at 21 slaughter facilities throughout the United States provided estimated overall prevalence of 1.15% (Smith et al., 1999) and 0.8% (Doonan et al., 2003) for non-ambulatory cattle during 1994 and 1999, respectively. It has been reported that, in 2001, 7,382 non-ambulatory cattle arrived at 19 slaughterhouses in Canada (Doonan et al., 2003). Approximately 90% of the cattle were dairy breeds, and 10% were beef breeds. In addition, the non-ambulatory condition reportedly originated during the transport process in less than 1% of the affected cattle; thus, in most cattle the condition originated while they were still on a farm.

Warren et al. (2010) collected information on approximately 50,000 animals transported by 1,363 trucks to slaughterhouses in Ontario, Canada. The duration of transport varied between 8 and 52 h. Of the trucks surveyed, 0.4, 4.8 and 0.2% contained i) non-ambulatory (unable to walk off the truck with or without assistance) or dead animals, ii) lame animals, and iii) animals needing assistance, respectively.

In the Czech Republic, Pistecova et al. (2004) monitored emergency slaughter due to immobility of cows, heifers, bulls and calves in a selected facility in the region of South Bohemia in the period between 1997 and 2002. The results indicated that the most common causes of emergency slaughter due to immobility was damage to the locomotor apparatus, and that the most common causes were injuries to the limbs, joint and claw inflammations, pelvic injuries and paresis of hind limbs.

Cattle may be killed using captive-bolt stunning immediately followed by bleeding or pithing to kill the animal. The captive bolt parameters and size of pithing rod should be appropriate for the size of the animal. The interval between stunning and bleeding or pithing should be as short as possible to prevent recovery of consciousness. If bleeding is preferred, the brachiocephalic trunk must be severed promptly and accurately. If firearm with free projectile is the method of choice, it is important to select low velocity ammunition that does not exit the skull of the animal or one that disintegrates in the skull of the animal.

3.5. Unacceptable methods, procedures or practices on welfare grounds

The mandate requests to identify unacceptable methods in terms of welfare. In this respect, the Panel agrees with Chapter 7.5.10 of the terrestrial code of the World Organisation for Animal Health (OIE, 2019) which defines 'methods, procedures or practices unacceptable on animal welfare grounds' in any species as follow:

1) Restraining methods which work through electro-immobilisation or immobilisation by injury such as breaking legs, leg tendon cutting, and severing the spinal cord (e.g. using a puntilla or dagger).
2) The use of the electrical stunning method with a single application leg to leg.
3) The slaughter method of brain stem severance by piercing through the eye socket or skull bone without prior stunning.'

The same applies for the methods of restraint that are prohibited and listed in EC Regulation 1099/2009:

a) Suspending or hoisting conscious animals.
b) Mechanical clamping or tying of the legs or feet of animals.
c) The use of electric currents to immobilise animals without stunning or killing them under controlled circumstances, in specific any electric current application that does not span the brain.

In addition, the Panel has serious concerns about the following practices as they will induce severe welfare consequences:

- Unloading or moving severely injured cattle or those unable to move independently.
- Use of painful stimuli to move animals (e.g. use of electric goads).
- Lack of drinking water or inappropriate drinking systems at lairage.
- Lack of space at lairage for all animals to lie down at the same time.
- (Rope) casting of cattle for restraint.
- Slaughter without stunning.

Furthermore, here are no documented scientific data on the effectiveness of using a hard object such as a hammer, club or a metal pipe to induce unconsciousness. However according to expert opinion, this method to deliver a percussive blow to the head is prone to a high failure rate thus leading to severe welfare consequences.

These practices should be avoided, re-designed or replaced by other practices, leading to better welfare outcomes.

Most of the hazards originate from staff and therefore the Panel considers the lack of skills or lack of training of the staff working in the slaughtering of cattle a serious concern regarding animal welfare.

3.6. Specific hazards and preventive measures related to selected types of animals or species

Unweaned calves

Young animals with a higher metabolic demand and lower fat and energy reserves are more susceptible to cold stress (Fisher et al., 2009; Mader, 2014). Depending on duration of transport, unweaned calves are also more likely to experience hunger. They should therefore not be put in lairage but be slaughtered as soon as possible after arrival at the slaughterhouse.

Lactating cows

About one third of dairy cows is removed from the herds per year. The most common reasons for culling are too low productivity, infertility, lameness and mastitis (Edwards-Callaway et al., 2019). Welfare problems arising from cull cow slaughtering arise from the fact that most of the cull cows are lactating, that depending on the country they may be transported long distances and that even when fit for transport, their health state may be compromised to a certain extent (Edwards-Callaway et al., 2019; Stojkov et al., 2018; Langford and Stott, 2012). In a study of 6,152 of long haul journeys in North America, cull cattle and calves were more likely to die and become non-ambulatory during the journey than feeder cattle (steers and heifers before finishing). Therefore, calves and cull cattle suffer most from transport, and their welfare is more likely to be compromised compared to feeders and fat animals.

Lactating cattle are more sensitive to heat stress and water deprivation (Silanikove, 2000). When milking is omitted, engorged udders can affect mobility (impeded movement) and comfort (Flower et al., 2006). Lactating dairy cows should therefore be slaughtered as soon as possible after arrival.

Slaughtering of pregnant cows

Pregnant cattle are more sensitive to heat stress and water deprivation than non-pregnant cows (Silanikove, 2000).

Based on the available scientific evidence, it cannot be determined with certainty whether livestock fetuses are capable of conscious perception. Using the available scientific literature and expert Opinion, EFSA AHAW Panel (2017) concluded on the capacity of livestock fetuses to experience pain and other negative affect using an approximate probability scale. The respective outcomes are summarised as follows:

1) It is very likely to extremely likely (i.e. with 90–100% likelihood derived from expert knowledge elicitation) that cattle fetuses in the last third of gestation have the anatomical and neurophysiological structures/correlates for experiencing pain and/or other forms of discomfort. 2) There are two different possibilities whether fetuses perceive negative affect. It is more probable that the neurophysiological situation does not allow for conscious perception (with 66–99% likelihood) because of brain inhibitory mechanisms. There is a lower probability that livestock fetuses can experience negative affect (with 1–33% likelihood) arising from differences in the interpretation of the fetal EEG, observed responses to external stimuli and the possibility of fetal learning. 3) Since all slaughtering procedures involve a maternal circulatory collapse and rapid fetal hypoxia, it is unlikely to very unlikely (i.e. with 1–33% likelihood) that changes/responses occurring during stunning and bleeding of the dam are associated with pain or other negative affect in the livestock foetuses (EFSA AHAW Panel, 2017).

Therefore, irrespective of the stunning method used, the most relevant hazard for fetuses of this developmental stage is killing of the dam during the slaughter process. A set of scenarios and respective preventive or corrective actions for both the assumptions that livestock fetuses might or might not perceive pain or other negative affect (see point number 2 in the previous paragraph) are provided in Figure 10.
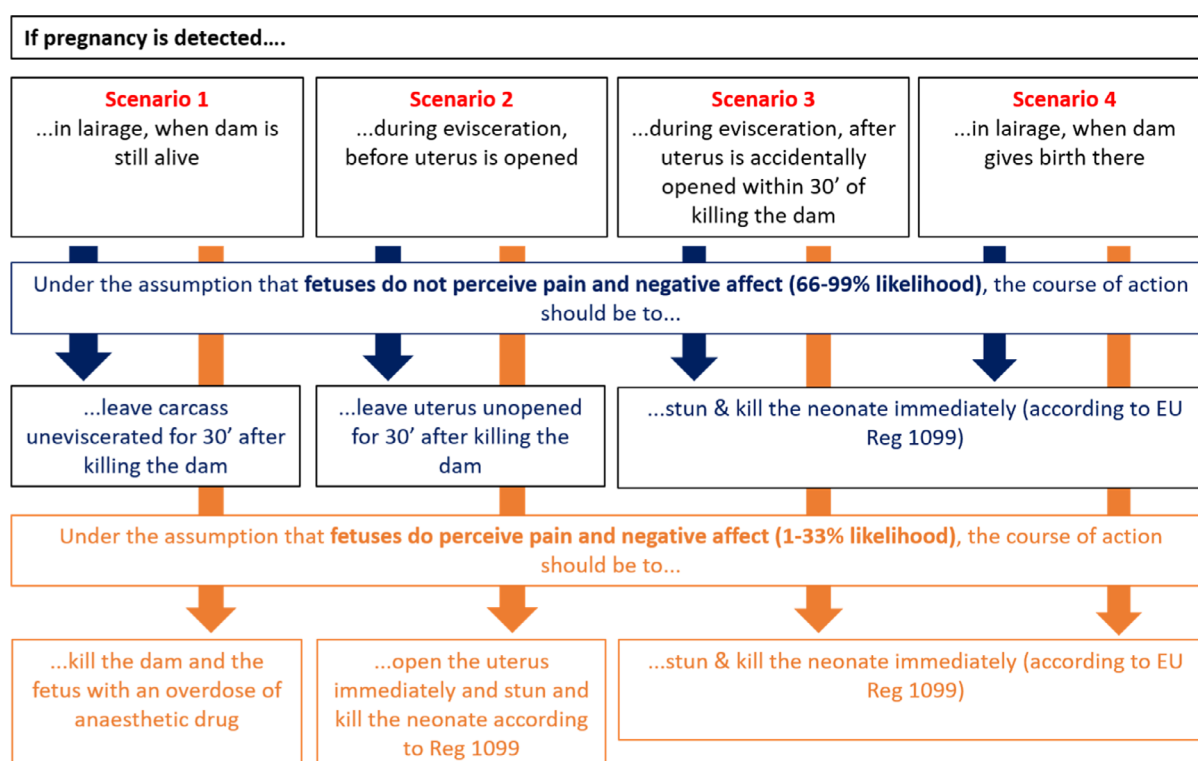

Figure 10: Scenarios and respective courses of action as regards handling of the fetus/neonate under different assumptions regarding the neurophysiological situation of the fetus (modified after EFSA AHAW Panel, 2017)

Breeding bulls

Adult breeding bulls are generally much larger and heavier (> 1,000 kg) than cows (500–800 kg depending on breed) or finished beef cattle (450–750 kg depending on breed and production system).

If in lairage, they should be kept separately. They require sufficiently sized passageways and stunning boxes to allow for proper restraint and correct positioning of the stunning devices. The bigger skulls and the larger thickness of the skull bones needs to be taken into account when selecting, e.g. bolt diameter, bolt length and cartridge power in captive bolt stunning.

<u>Horned animals</u>

In stable groups, the horn status itself is not necessarily related to bruising in cattle (Youngers et al., 2017). However, the presence of horns is one of the factors potentially contributing to bruises found in cattle carcasses (Mendonça et al., 2016). Bruising may occur at loading, during transport, but also after arrival at the slaughterhouse, e.g. during unloading or lairage. Horned cattle should not be mixed, e.g. during lairage, and the larger interindividual distance of horned cattle should be considered regarding space allowance provided in lairage.

It is worth noting that the standard width of raceways in cattle slaughterhouses is about 60 cm and this may not be adequate to move some breeds of cattle with laterally projecting long horns and for water buffaloes.

<u>Slaughtering of buffaloes</u>

In water buffaloes, dissipation of heat is more effective by panting than by sweating. The thermoregulatory system is however only efficient if shade or water (for wallowing) is provided (Koga et al., 1999). Nevertheless, the Upper Critical Temperature for buffaloes is with 36°C substantially higher than for cattle (ranging from 20°C to 32°C depending on the breeds) (Aggarwal and Upadhyay, 2013).

The level of human–animal interactions in water buffalo production systems can vary greatly (Napolitano et al., 2013). According to Grandin (2014a,b), extensively raised animals generally have an excitable temperament. This may complicate handling and impact on behaviour, e.g. during unloading or moving to the stunning box.

Passageways should be sufficiently wide, clean and not slippery (de la Cruz et al., 2018). Herding large buffaloes (> 600 kg) through narrow chutes designed for cattle has been shown to increase falls and collisions (de la Cruz-Cruz et al., 2014).

Shooting water buffaloes in the frontal position with a penetrative captive bolt is not always effective due to the massive frontal bones (Gregory, 2008). The frontal and the paranasal sinuses are wider in buffaloes when compared with cattle (Saigal and Khatra, 1977); e.g. the median distance from the frontal skin surface to the inner bone table is 7.4 cm in water buffaloes and 3.6 cm in cattle, respectively. In addition, these anatomical features vary markedly with breed, sex and age of buffaloes. Schwenk et al. (2016) reported that even specially designed captive bolt guns with a protruding length of 12 cm may not be considered adequate to stun water buffaloes irrespective of age and sex in frontal position let alone conventional guns with a bolt length of only 9 cm. Provided that the energy delivered is adequate, however, the diencephalon might be reached with these devices when used in an occipital position. This is due to the fact that the average distance from the frontal or occipital shooting positions to the thalamus as the target region in the brain (including the skin) was 143 mm vs. 105 mm in frontal position for water buffaloes and cattle, respectively, and 106 mm in occipital position for water buffaloes (this distance was not measured in cattle as shooting in this position is not practiced). Corresponding maximum values were 172 mm vs 121 mm in frontal position for water buffaloes and cattle, respectively (Schwenk et al., 2016). Thus, the use of penetrating bolts in occipital position with a protruding length of 12 cm might be considered to provide a solution to stun water buffaloes (Schwenk et al., 2016).

Gregory (2009) evaluated the efficacy of different captive bolt stunning positions (frontal, crown and poll) in water buffaloes with different captive bolt gun/cartridge combinations. They reported that buffalo bulls over 30 months old had an average skull thickness at the frontal position of 8 cm and when these animals were shot in the frontal position, they did not collapse after the first shot. Shooting in the crown position, 16–19 cm from the foramen magnum, produced a shallow depth of concussion with continued respiration and eyeball rotation post-collapse in some animals. In contrast, shooting buffaloes in the occipital position, 1–4 cm from the foramen magnum (Figure 11), can produce an effective stun. However, the depth of concussion can be shallow, especially in animals aged over 30 months, of which 25% showed signs of rhythmic breathing that began slowly at about 38 s after shooting, indicating that a short stun-to-stick interval is crucial to prevent the animals from recovering consciousness. In buffaloes shot in the occipital position, 79% had damage to the cerebellum, and 71% to the medulla and/or pons.
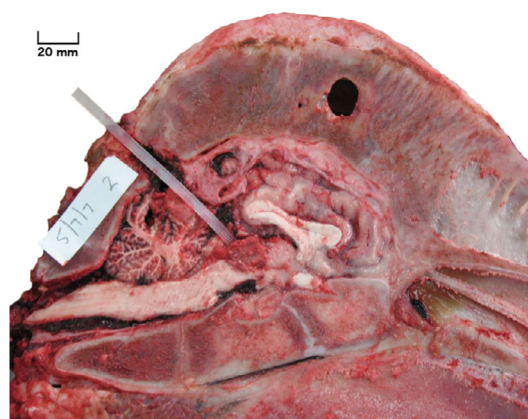
Figure 11: Example of a buffalo shot in the poll (occipital) position with the captive bolt entering into the occipital lobe and terminating in midbrain; about 10 cm travel of bolt and bone fragment. Left side: back of the head, right side: frontal direction (De la Cruz et al., 2018)

Nevertheless, the HSA (2018) has suggested that buffalo can be stunned in the occipital position using a heavy-duty contact-fired captive bolt gun fired using a minimum of 4 grain cartridge. The shot should be directed towards the nose, to direct the bolt through the cerebellum towards the mid-brain, by placing the muzzle of the captive bolt gun into the depression below the intercorneal protruberance and above the points of attachment of the Ligamenta nuchae.

When using firearms in buffaloes, the HSA (2018) recommends the ammunitions for stunning/killing of water buffalo and bison listed in Table 33.

Table 33: Type of firearm, ammunition and distance recommended for stunning/killing of water buffalo and bison (HSA, 2018)

Species	Slaughter site	Method	Distance
Buffalo	Field	243/0.275/0.308 rifle (JSP round)	10–30 metres whilst grazing
		12 bore shotgun (birdshot)	Close quarters
	Slaughterhouse	12 bore shotgun (birdshot)	Close quarters
		0.32 humane killer/0.38/0.357 pistol	Close quarters
Bison	Field	0.243/0.275/0.308 rifle (JSP round)	10–30 metres whilst grazing
	Slaughterhouse	0.38/0.357 carbine (semi-wadcutter)	1–2 metres whilst still in transport container

According to Glardon et al. (2018), bullet deformation has a strong impact on the outcome. Light 9 mm Luger or 0.38 Spl bullets as well as large deformable 0.44 Rem. Magnum bullets should be avoided in favour of heavier 0.357 Magnum deformation ammunition.

Slaughtering of water buffaloes without stunning is complicated further because of the thickness of their skin, long horns and short neck which can make it difficult to perform a clean cut. This can extend the time required to perform the cut and result in incomplete severance of the carotid arteries, followed by stabbing, hacking and chopping motions with the knife, all of which increase the pain associated with this practice (Ahsan et al., 2014; Alam et al., 2019). Gregory et al. (2008) reported that this can be further complicated by the inability of operators to manually reposition the animal's head, because of its horns, to ensure adequate exposure of the ventral surface of the neck for cutting. This study showed that when the head cannot be repositioned correctly, the knife had to be stabbed into the side of the neck repeatedly, causing many cuts (Gregory et al., 2008, cited by de la Cruz et al., 2018).

Slaughtering of bison

Bison are flightier and more fearful of humans compared with cattle. They show a larger flight zone, strong herd instincts and have a more aggressive nature (Grandin, 2007; Galbraith et al., 2014; Rioja-Lang et al., 2019). The stress susceptibility as well as the risk of injuries and subsequent trim losses following handling and transport (McCorkell et al., 2013) is the reason why, both in North

America as well as Europe, bison are slaughtered on farm to a considerable extent (e.g. 9 out of 18 bison breeders in Europe; Vervaecke, 2017).

When animals are handled and/or transported, alleyways should have limited side visibility and bison should be moved in small groups, as they become stressed and agitated when they have to wait in single files. This is also the reason why they should be moved individually to the stunning box. The stunning box should have solid sides as well as a solid top to prevent bison from rearing and endangering workers (Lanier and Grandin, 2000).

In a survey of Vervaecke (2017), 53% of the breeders had their animals killed by fire-arm, 26% by cutting after captive-bolt stunning and 21% had allowed for slaughter without stunning. Captive-bolt stunning required in up to 40% of the animals re-stunning due to the thickness of the skull.

For animal welfare reasons, bison are typically stunned with firearms due to the thickness of the skull preventing proper stunning with a captive bolt. The combination of firearm and ammunition selected must achieve a muzzle energy of at least 300 ft-lb (407J) for animals (calves) weighing up to 400 lb (180 kg), and for animals larger than 400 lb, 1,000 ft-lb (1356J) is required (AVMA, 2013). According to Galbraith et al. (2014), rifles (calibres from 0.22 magnum to 0.223 and larger) are used (see also Table 33).

If firearm is the choice for killing bison, then a minimum of 1,356 J (1,000 feet-lb) of muzzle energy is required for euthanasia of yearlings, cows, and mature bulls (AVMA, 2020). This limits the firearm options to higher-calibre, centerfire rifles (eg, 30-30, 270, 30-06, and others). The majority of handguns produce muzzle energies well below 1,356 J (1,000 feet-lb) and would not be appropriate for euthanasia of mature bison. The preferred anatomic site for entry of a bullet is on the forehead approximately 2.5 cm (1 inch) above an imaginary line connecting the bottom of the horns. Ideally, the angle of entry should be perpendicular to the skull. Considering the thicker skin and skull encountered with water buffalo, the use of a high-calibre firearm is the preferred method of euthanasia under field conditions (AVMA, 2020).

Figure 12: Preferred site for shooting bison with firearms (AVMA, 2020)
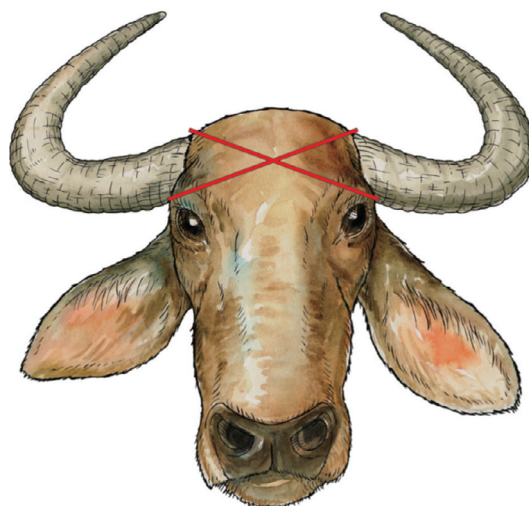
Figure 13: Preferred site for shooting water buffalo with firearms (AVMA, 2020)

3.7.   Assessment of uncertainty

On the possible inclusion of false-positive hazards, the experts were 95–99% certain that all listed hazards occur during slaughter of cattle (i.e. were truly existing hazards).

On the possible occurrence of false-negative hazards, the experts were 90–95% certain that at least one hazard was missing in the assessment considering the three criteria for the inclusion of methods and practices in this assessment. The three criteria were: a. all methods known to the experts that have technical specifications, b. methods currently used for slaughter of cattle and c. methods for which the welfare aspects are sufficiently described in the scientific literature.

Furthermore, when considering a global perspective (i.e. including all possible variations to the slaughter practices that are employed in the world and that might be unknown to the experts of the WG), the experts were 95–99% certain that at least one welfare hazard was missing. This is due to the lack of documented evidence on all possible variations in the processes and methods being practised (see Interpretation of ToRs on the criteria for selection of stunning methods to be included).

4.   Conclusions

This mandate asks EFSA to provide an independent view on the slaughter of cattle for human consumption, covering all parts of the slaughter process. The scientific Opinion focuses on the identification of hazards leading to negative cattle welfare consequences at slaughter. The hazards, their origins, preventive and corrective measures, welfare consequences and related animal-based measures have been identified on the ground of literature search and expert Opinion and takes into account the common slaughter practices that have been reported in the Opinion.

Not all the methods, procedures and practices for slaughter of cattle used worldwide are documented. Due to the lack of adequate description or scientific validation, a hazard analysis was not carried out for these methods, procedures or practices.

Outcome tables have been prepared to summarise the main results of this Opinion and include a concise presentation of all retrieved information.

4.1.   General conclusions

1) During the slaughter processes, cattle may experience negative welfare consequences such as heat stress, cold stress, fatigue, prolonged thirst, prolonged hunger, impeded movement, restriction of movements, resting problems, social stress, pain, fear and distress.
2) Consciousness is a prerequisite for cattle to experience pain, fear and distress. Therefore, animals that are ineffectively stunned, recover consciousness or those slaughtered without stunning, will be exposed to the hazards and experience the related welfare consequences. Pain and fear can be assessed indirectly by assessing the state of consciousness using specific ABMs at all stages.

3) During the slaughter processes, cattle may be exposed to several hazards, which could have a cumulative effect on welfare consequences (e.g. water deprivation, insufficient space allowance, and too high effective temperature will have a cumulative effect and exacerbate heat stress).

4) Exposure to some hazards might persist during all processes and phases until the cattle is rendered unconscious (e.g. food deprivation).

5) Other hazards might be present only during one phase, but the welfare consequence might persist during the successive processes and phases until cattle is rendered unconscious (e.g. pain due to inappropriate handling).

6) ABMs have been identified for the assessment of all the welfare consequences, except for prolonged thirst at the time of arrival and for prolonged hunger.

7) Most of the hazards identified are associated with lack of staff skills and training (inappropriate handling) and poor design, construction and maintenance of the premises. The Panel considers the lack of skills or lack of training of the staff working in the slaughterhouse a serious welfare concern.

8) The uncertainty analysis on the set of hazards for each process provided in this Opinion revealed that the experts were 95–99% certain that all listed hazards occur during slaughter of cattle. At the same time, the experts were 90–95% certain that at least one welfare related hazard is missing in this assessment according to the three criteria described in the Interpretation of ToRs (95–99% considering the worldwide situation). This is due to the lack of documented evidence on all possible variations in the processes and methods being practiced.

4.2.   Conclusions specific to Phase 1 – pre-stunning

1) The potential welfare consequences at arrival are thermal stress, prolonged hunger and thirst, fatigue, restriction of movement, and pain. The corresponding ABMs are panting, shivering, exhaustion, tachypnoea.

2) At arrival, ABMs can be assessed only from outside the truck and therefore this is only feasible for the animals at the sidewalls of the truck. If welfare consequences are identified for the visible cattle, it is plausible that other animals in the truck are also affected. If no welfare consequences are identified for the visible animals, this will not mean that animals that are out of sight are not affected by these welfare consequences.

3) Delayed unloading of animals will lead to persistence or exacerbation of the welfare consequences that originate from the farm or from transport (e.g. prolonged thirst, restriction of movement) and at the same time it may expose cattle to new hazards leading to additional welfare consequences (e.g. heat stress).

4) At unloading and during handling and moving of cattle, three welfare consequences that animals might experience are pain, fear and impeded movement. They can be assessed using the following ABMs: injuries, lameness, vocalisations, escape attempts, reluctance to move and turning back, slipping and falling.

5) Unloading severely injured cattle or those unable to move unassisted will exacerbate their pain and is considered a serious welfare concern by the Panel.

6) At lairage, the welfare consequences that cattle might experience are social stress, pain and fear, restriction of movement, resting problems, fatigue, thermal stress, prolonged thirst and hunger. These can be assessed using ABMs: panting, shivering, injuries, aggression at water trough, vocalisations, slipping and falling, tachypnoea, exhaustion, aggressive behaviour and mounting.

7) The Panel considers that, at lairage, lack of access to drinking water and lack of space for resting are welfare issues of serious concern, as they will prevent the animals to recover from transport or worsen the welfare consequences.

8) During handling to the restraining area, cattle might experience impeded movement, pain and fear. These can be assessed using ABMs: slipping, falling, escape attempts, vocalisation, injuries, reluctance to move and turning back.

9) The use of painful stimuli (e.g. electric goads) for handling and moving of the animals is considered a serious welfare concern by the Panel.

10) Rope casting of cattle as a restraint is considered a serious welfare concern by the Panel.

11) The excitable temperament of buffaloes demands additional care and skills during handling and moving of the animals.

4.3. Conclusions specific to Phase 2 – stunning

1) Consciousness is a prerequisite for cattle to experience pain, fear and distress. Therefore, animals that are not or ineffectively stunned or recover consciousness will be exposed to the hazards and related welfare consequences. Pain, fear and distress can be assessed indirectly by assessing the state of consciousness by specific ABMs (listed under the specific sections), which can be used at all key stages.

2) Effective mechanical (excluding firearms) and electrical stunning methods require restraint of the body and the head that per se may impose additional pain and fear. These welfare consequences will persist during the restraining period until successful stunning.

3) Ineffective captive bolt stunning is mostly due to wrong shooting position and direction and inappropriate stunning parameters (bolt length, velocity, power, etc.).

4) Inappropriate restraint of the head and lack of skilled operator can lead to wrong shooting position and direction of the captive bolt.

5) The pneumatically operated captive bolt guns are more effective than cartridge powered guns, especially in heavy bulls.

6) Non-penetrative captive bolt guns are less effective than penetrative captive bolt stunning methods.

7) Ineffective electrical stunning is mostly due to wrong placement of the electrodes, poor electrical contact, too short exposure time, inappropriate electrical parameters.

8) The duration of unconsciousness induced by head-only electrical stunning of cattle may not be sufficient to last until death occurs through bleeding.

9) Irreversible stunning methods (e.g. head-to-body electrical stunning) have the animal welfare advantage of eliminating the risk of recovery of consciousness and associated pain, fear and distress.

10) Captive-bolt stunning of water buffaloes using the frontal position is not always effective due to the thickness of frontal bones.

4.4. Conclusions specific to Phase 3 – bleeding following slaughter with or without stunning

1) The Panel considers bleeding of ineffectively stunned animals and those recovering consciousness following stunning a serious welfare concern, as it leads to severe pain, fear and distress. Pain, fear and distress can be assessed indirectly by assessing the state of consciousness and death by specific ABMs (listed under the specific sections).

2) Slaughter without stunning leads to severe pain, fear and distress due to restraint for the neck cutting and the cutting of soft tissues in the neck that will last until the onset of unconsciousness, which can be further delayed due to formation of aneurysm and carotid occlusion.

3) Chest sticking instead of neck cutting will avoid carotid occlusions, improve blood loss and reduce the time to the onset of death.

4) Formation of false aneurysm and carotid occlusion is prevented with head-to-body electrical stunning prior to neck cutting.

5. Recommendations

5.1. General recommendations

1) Design, construction and maintenance of the premises and handling facilities should be based on understanding how cattle perceive their environment and meet their welfare requirements (e.g. thermal comfort, comfort around resting).

2) Even in a well-designed and equipped slaughterhouse, training of staff is a key preventive measure to avoid hazards and mitigate welfare consequences: all processes of the slaughtering should be carried out by trained and skilled personnel. Staff should be trained to consider cattle as sentient beings, to have a good understanding of species-specific behaviour and to act accordingly during all processes.

3) The welfare status (based on the welfare consequences) of cattle should be assessed at each phase of slaughtering to prevent and correct hazards and mitigate negative welfare consequences.
4) The presence of hazards should be monitored by assessing the welfare consequences through ABMs.
5) When the use of ABMs is not feasible and the hazard is present, the animals are assumed to experience the related welfare consequences and should be treated accordingly.
6) A SOP should include identification of hazards and related welfare consequences, using relevant ABMs, as well as preventive and corrective measures.
7) The responsible person of the slaughterhouse should put in place actions to prevent the occurrence of hazards. Such measures should include:

   a) the inspection and maintenance of the facilities,
   b) training and rotation of the staff,
   c) appropriate settings and use of the equipment.
   d) be prepared to receive and perform the emergency slaughter of animals without delay

8) When a hazard is identified, it should be corrected without any delay.
9) Additionally, measures to prevent and mitigate the welfare consequences should be put in place.
10) Practices leading to serious welfare concerns should be avoided, re-designed or replaced by other practices leading to better welfare outcomes.
11) The ranking of the hazards according to the severity, magnitude and frequency of the welfare consequences for cattle at slaughtering should be performed in order to prioritise preventive and corrective measures and improve slaughtering of cattle.

5.2. Recommendations specific to Phase 1 – pre-stunning

1) Assessment of the welfare state of cattle at the time of arrival should be performed as an important first step in fulfilling animal protection at slaughterhouse.
2) At arrival, cattle should be unloaded as soon as possible to mitigate the welfare consequences experienced during transport or to prevent other welfare consequences occurring during arrival, including those that are not visible or that cannot be assessed.
3) If unloading is delayed for any reason, hazards inducing thermal stress (too high effective temperature, too low effective temperature) should be prevented (e.g. by providing showering or ventilation).
4) Cattle that are injured, show severe pain, signs of illness or those unable to move independently, should be inspected by a veterinarian and/or trained professional and, if necessary, a procedure for emergency slaughter should be applied as soon as possible to prevent further suffering of the animal.
5) The design, construction and maintenance of the unloading facility, and the aptitude and attitude of the staff should prevent animals from slipping and falling.
6) Cattle should be slaughtered after unloading without any delay. Keeping animals in lairage should be avoided or kept to a minimum.
7) In lairage, it is recommended to ensure all animals have access to water and protection from adverse weather conditions. Mixing of unfamiliar animals, particularly of horned animals, should be avoided.
8) In lairage adequate space should be offered to cattle to stand up, lie down, turn around and escape from aggressors. Space allowance should be calculated through the formula $A = k \times (BW)^{2/3}$, where A is the floor area covered by the cattle; k is a constant value that depends on the cattle posture and behaviour; and BW is the bodyweight of the individual animal. It is recommended to use a minimum k value of 0.0315, which should be increased according to the climatic conditions.
9) If the effective temperature is above the TNZ, showering or misting should be applied to cool down the animals and this can only be achieved through effective air movement.
10) Painful stimuli, such as electric goads, hitting with a stick, etc. should be avoided. Instead passive stimuli such as flags and paddles should be used.

5.3. Recommendations specific to Phase 2 – stunning

1) Optimum restraining of head and body is required to achieve effective stunning.
2) Restraining methods or practices which cause severe pain and fear should not be used.
3) Pain and fear associated with restraint should always be assessed by the use of ABMs.
4) Animals should not be restrained if the operator is not ready to stun them immediately.
5) Animals should not be stunned if the operator is not ready to bleed them immediately.
6) To avoid animal recovering consciousness, irreversible stunning methods are recommended.
7) When reversible stunning methods are used, bleeding should be applied without any delay to avoid recovery of consciousness.
8) To monitor stunning method efficacy, the state of consciousness of the animals should be checked at each of the three key stages – i.e. after stunning, just prior to sticking and during bleeding – using the suggested ABMs.
9) Animals ineffectively stunned or recovering consciousness should be stunned immediately with a backup method.
10) The use of non-penetrative captive bolt guns for stunning cattle should be avoided due to higher incidence of ineffective stunning and shorter duration of unconsciousness when compared with penetrative captive bolt stunning.
11) Water buffaloes should be stunned in the occipital position using a heavy-duty contact-fired captive bolt gun directed at the nose or using large-calibre firearms and deformation ammunition (e.g. 0.357 Magnum).
12) Bison should be stunned using high-calibre, centre-fire rifles (e.g. 0.30-30 Winchester)

5.4. Recommendations specific to Phase 3 – Bleeding

1) Chest sticking is preferred over neck cutting as it will prevent formation of false aneurysm and carotid occlusion and reduce the time to onset of death.
2) Recovery of consciousness following reversible stunning methods should be avoided by: i) prompt and accurate bleeding of animals ii) severing completely the brachiocephalic trunk, iii) making a sticking wound large enough to permit profuse bleeding leading to rapid death.
3) Death must be confirmed before carcass processing begins.
4) The person responsible for the assessment of unconsciousness should have the necessary knowledge and skills to differentiate between cessation of bleeding and impeded bleeding by the formation of aneurysm and occlusion of the carotid artery. Animals should be observed closely for the signs of occlusion and appropriate intervention must be applied immediately.
5) Since during slaughter without stunning all animals have to endure the welfare consequences resulting from remaining conscious during bleeding and therefore experience severe pain, fear and distress, slaughter without stunning should not be practiced.

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Abbreviations

ABM	animal-based measure
AHAW	EFSA Panel on Animal Health and Welfare
BW	body weight
DBT	dry bulb air temperature
ECoG	electrocorticogram
EEG	electroencephalogram
FAWC	Farm Animal Welfare Council
HALF	high-amplitude low-frequency waves

HSA	Humane Slaughter Association
LAPS	low atmosphere pressure system
LCT	lower critical temperature
MS	Member State
NCP	National Contact Point
OIE	World Organisation for Animal Health
RH	relative humidity
SCAHAW	Scientific Committee on Animal Health and Animal Welfare
SEP	somatosensory evoked potential
SPUC	single pulse of ultra-high electrical current
THI	temperature–humidity index
TNZ	thermoneutral zone
ToR	Term of Reference
UCT	upper critical temperature
VEP	visual evoked potential
WBT	wet bulb air temperature
WG	working group

Appendix A – Literature search outcomes

As described in Section 2.2.1, a literature search was carried out to identify peer-reviewed scientific evidence on the topic of 'slaughter of cattle' that could provide information on the elements requested by the ToRs, i.e.: description of the processes, identification of hazards, origins, preventive and corrective measures, welfare consequences and indicators).

To obtain this, firstly a broad literature search under the framework of 'welfare of cattle at slaughter' was carried out, and the results were successively screened and refined as described below.

Sources of information included in the search: Bibliographic database 'Web of Science'.

The search string was designed to retrieve relevant documents to 'animal welfare' during 'slaughter and killing' of 'cattle'. Restrictions applied in the search string related to the processes characterising 'slaughter and killing' (from arrival to bleeding) of animals, and the date of publication (considering only those records published after EFSA, 2004). No language or document type restrictions were applied in the search string.

Date of the search: 5th December 2019

Web of science search string	
Years 2004–2019	
	Category
Search terms	**Field searched**
TS= cows OR TS=cow OR TS= cattle OR TS= calf OR TS= calv* OR TS= bull OR TS="bos taurus" OR TS= bovine*	Topic
AND	
TS=slaughter* OR TS=kill* OR TS=stun* OR TS=captive bolt OR TS=captive-bolt OR TS=euthanasia OR TS=depopulation	Topic
AND	
TS=Arriv* OR TS=*load* OR TS=lairage* OR TS=handl* OR TS=mov* OR TS=restrain* OR TS=cut* OR TS=bleed* OR TS=conscious* OR TS=pain* OR TS=behav* OR TS=stress*	Topic
TS=Welf* OR TS="animal welfare"	Topic
Results: 397	
Results after screening: 45	

Refinement of literature search results

The search yielded a total of 397 records that were exported to an EndNote library together with the relevant metadata (e.g. title, authors, abstract). Titles and abstracts were firstly screened to remove irrelevant publications (e.g. related to species, productive systems, processes and research purposes that were out of the scope of this Opinion) and duplicates, and successively to identify their relevance to the topic.

Full text publications were screened if title and abstract did not allow assessing the relevance of a paper. The screening was performed by one reviewer, with support by a second reviewer in cases of doubt; publications that were not considered relevant nor providing any additional value to address the question were also removed. The screening led to 45 relevant records. Discrepancies were discussed between the WG members until a final subset of 19 relevant references was selected and considered in this assessment by reviewing the full papers. The final subset is reported in Table A.1.

Table A.1: List of publications relevant to 'slaughter of cattle' resulting from the Literature Search

ID	Reference
1	Abdullah et al. (2019)
2	Agbeniga and Webb (2012)
3	Chulayo et al. (2016)
4	Fuseini et al. (2016)
5	Gap-Don Kim et al. (2013)
6	Gibson et al. (2009a,b)

ID	Reference
7	Gibson et al. (2019)
8	Gregory et al. (2012)
9	Hemsworth et al. (2011)
10	Hultgren et al. (2014)
11	Johnson et al. (2015)
12	Lambooij et al. (2012)
13	Martin et al. (2018)
14	Mpamhanga and Wotton (2015)
15	Novelli et al. (2016)
16	Sandstrom (2009)
17	Terlouw et al. (2008)
18	Verhoeven et al. (2016)
19	Wotton et al. (2000)