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Welfare of sheep and goats at slaughter

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Abstract

The killing of sheep and goats 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 sheep and goats 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 sheep and goats); stunning (including restraint); and bleeding. Stunning methods were grouped into two categories: mechanical and electrical. Twelve welfare consequences that sheep and goats may experience during slaughter were identified: heat stress, cold stress, fatigue, prolonged thirst, prolonged hunger, impeded movement, restriction of movements, resting problems, social stress, pain, fear and distress. These welfare consequences and their relevant animal-based measures are described in detail in this Scientific Opinion. 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.

Keywords: small ruminants, slaughter, hazards, animal welfare consequences, ABMs, preventive/corrective measures

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Summary

The European Commission requested EFSA to provide a Scientific Opinion on the slaughter of sheep and goats.

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. rams, young lambs/kids) (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 concerns the killing of sheep and goats 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.

The stunning methods that have been identified as relevant for sheep and goats 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 percussive blow to the head and firearms with free projectiles. Electrical methods include head-only and head-to-body stunning.

In answering ToR-1, 40 hazards related to the welfare consequences applying from arrival of sheep and goats at the slaughterhouse until they are dead were identified. The majority of hazards identified in this opinion (39 of 40) have staff as origin, and hazards can be attributed to the lack of appropriate skills to perform tasks (e.g. inappropriate handling, use of wrong parameters for electrical methods) or to fatigue.

The mandate requested to provide definitions of qualitative or measurable (quantitative) criteria to assess performance (i.e. consequences) on animal welfare (ABMs; ToR-2) derived from these hazards; this ToR was addressed by identifying the welfare consequences occurring to sheep during slaughter and the relevant ABMs that can be used to assess qualitatively or quantitatively these welfare consequences. 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. Lists and definitions of ABMs to be used for assessing these welfare consequences have been provided in this Opinion.

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). Flowcharts, 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 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, actions to mitigate the welfare consequences caused by the identified hazards should be put in place.

To prevent sheep and goats to suffer from severe welfare consequences, a standard operating procedure (SOP) should be applied and should include identification of hazards and related welfare consequences, using relevant ABMs, as well as preventive and corrective measures.

At arrival, sheep and goats should be unloaded without delay and those showing signs of severe pain, signs of illness or those unable to move independently, should be inspected and a procedure for emergency slaughter should be applied without delay.

Keeping sheep and goats in lairage should be avoided, unless it benefits their welfare. If lairage cannot be avoided, animals should have access to water and protection from adverse weather conditions and lactating females should be milked to release the udder pressure. If milking is necessary, the milking interval should not exceed 12 h as prescribed in the EU Regulation on transport (EC Reg 1/2005). Mixing of unfamiliar goats, particularly of horned animals, should be avoided. Suckling lambs and goat kids are more susceptible when compared with adult animals to prolonged thirst and hunger. They are also more prone to cold stress and need additional protection in lairage. Therefore, suckling lambs and goat kids should be slaughtered without lairage. If slaughter is delayed, they need to be fed with suitable milk replacement at regular intervals.

During handling, sheep and goats might experience pain, fear and impeded movement. These can be assessed using ABMs: slipping, falling, escape attempts, vocalisation, injuries, reluctance to move and turning back. Sheep and goats can be handled and moved using lead animals of the same species. Dogs should not be used. When handled by operators, painful handling, such as lifting and dragging by horns or wool or one leg, hitting with a stick, etc., should be avoided. Instead, passive stimuli such as flags and paddles should be used.

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.

Head-only electrical stunning results in short duration of unconsciousness and therefore the onus of preventing recovery of consciousness, leading to poor welfare outcome, relies on the prompt and accurate bleeding. 4. In the light of the available scientific evidence at present, a minimum of 1.0 A is required to guarantee effective electrical stunning of all sheep and goats, including lambs and goat kids.

Ineffective captive bolt stunning is mostly due to wrong shooting position and direction and inappropriate stunning parameters. The use of non-penetrative captive bolt guns for stunning sheep and goats should be restricted to animals of less than 10 kg live weight.

Exposure to CO_2 at high concentrations (higher than 90% by volume) is considered a serious welfare concern by the Panel, because it is aversive and causes pain, fear and respiratory distress. Scientific evidence regarding the impact on welfare of the use of inert gases and CO_2 with inert gases is lacking; therefore, more research is recommended.

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.

Slaughter without stunning should not be practiced. The Panel considers this a serious welfare concern because it 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.

Certain animal categories like animals with heavy horns or a thick fleece or animals coming from extensive rearing systems should be handled with special care; specific measures for these situations are described in the text.

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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 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 and 2006. The EFSA provided additional opinions related to this subject in 2012, 2013, 2014, 2015 and 2017.

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.

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 Terms of Reference

This Scientific Opinion concerns the slaughter of small ruminants.

This Opinion will use definitions concerning the killing of sheep and goats, including the related operations, provided by Council Regulation (EC) No. 1099/2009 of 24 September 2009[1] 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 sheep and goats 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): (a) arrival, (b) unloading of animals from the truck until the lairage area, (c) lairage and (d) handling and moving to the stunning (or sticking) area. Because restraint of sheep and goats 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 sheep and goats following stunning and (b) the bleeding during slaughter without previous 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 sheep and goats 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.

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 sheep and goats in all 'types' of slaughterhouses (from industrial slaughterhouses with automated processes to on-farm 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.

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 sheep and goats 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 chapter 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 sheep and goats; in these cases, emphasis will be given to the relevant measures to prevent the hazards or to mitigate the welfare consequences.

[1] 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

Animals can experience welfare consequences only when they are conscious. This applies to all sheep and goats during the pre-stunning phase. In the stunning phase, sheep and goats 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, sheep and goats will experience welfare consequences in case of persistence of consciousness or if they recover consciousness 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 seizure) or suggesting consciousness (e.g. absence of tonic seizure) have been identified.

In this Opinion, distress – which can be defined as a conscious, negatively valenced, intensified affective motivational state that occurs in response to a perception that current coping mechanisms (involving physiological stress responses) are at risk of failing to alleviate the aversiveness of the current situation in a sufficient and timely manner (Mc Millan, 2020) – has not been included as a specific welfare consequence for Phase 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 severity of the latter, which are among the welfare consequences addressed in this Opinion. Therefore, distress was not listed 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 sheep and goats can experience when exposed to hazards will be reported. In this respect, the ranking of the identified hazards in terms of severity, duration 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. provision of adequate ventilation 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 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 chapter 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 subchapter '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 ruminants such as suckling lambs, goat kids, horned sheep and goats 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. Firstly, 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. Secondly, 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, redesigned 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 (LS) 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 chapter on Assessment).

2.1.2. Data from Member States and expert opinion

The data obtained from the literature 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, two main approaches were used to develop this Opinion: (i) literature search and (ii) expert opinion through WG discussion. These methodologies were used to address the mandate extensively (see relevant sections in the Assessment chapter) 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 sheep and goats 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.

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 221 references were retrieved and reviewed by the WG members to select potentially relevant references. This screening produced 90 relevant references. Discrepancies were discussed between the WG members until a final subset of 46 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 review 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 working group experts followed the risk assessment methodology from the EFSA's guidance on risk assessment in animal welfare (EFSA AHAW Panel, 2012).

Table 1: Example of the Structure of an outcome table

Hazard	Welfare consequence 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)					

Based on expert opinion through working group 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 sheep and goats. 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, chapters 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 Chapter.

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 small ruminant slaughter process (see Sections 3.1 to 3.3).
- HAZARD: The first column in each table reports all hazards pertaining to the specific process; the number of the Chapter 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).

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

<table>
<tr><th>Probability term</th><th>Subjective probability range</th><th colspan="2">Additional options</th></tr>
<tr><td>Almost certain</td><td>99–100%</td><td rowspan="4">More likely than not: > 50%</td><td rowspan="4">Unable to give any probability: range is 0–100%</td></tr>
<tr><td>Extremely likely</td><td>95–99%</td></tr>
<tr><td>Very likely</td><td>90–95%</td></tr>
<tr><td>Likely</td><td>66–90%</td></tr>
<tr><td>About as likely as not</td><td>33–66%</td><td rowspan="5"></td><td rowspan="5">Report as ‘inconclusive’, ‘cannot conclude’ or ‘unknown’</td></tr>
<tr><td>Unlikely</td><td>10–33%</td></tr>
<tr><td>Very unlikely</td><td>5–10%</td></tr>
<tr><td>Extremely unlikely</td><td>1–5%</td></tr>
<tr><td>Almost impossible</td><td>0–1%</td></tr>
</table>

- WELFARE CONSEQUENCES OCCURRING TO THE SHEEP AND GOATS DUE TO THE HAZARD: This column lists the welfare consequences to sheep and goats 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 (SOP).
- 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 measured on sheep and goats to assess the welfare identified consequences of a hazard.

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, 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 relates to 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.

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/bleeding 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 Chapter.

It is worth mentioning that, within the EU, unloading is considered to be part of the journey and is completed only when the last animal on the truck is unloaded.

The number of animals slaughtered varies greatly between slaughterhouses around the world, e.g. nearly 25,000 sheep were slaughtered per day during July 2021 in New Zealand.[2] This demands a great deal of planning and scheduling of the arrival of transport trucks and steady movement of animals from lairage/holding pens to the killing area.

The condition and management of animals before and during transport can have a cumulative effect on animal welfare at arrival. For example, rounding up and driving of sheep from the fields in large extensive production systems and long-distance transport through difficult geographical routes would have cumulative effect on welfare. In small sheep production conditions on the other hand, there can be a lack of appropriate installations for loading/unloading and deficiencies in the vehicle structure or equipment leading to poor welfare outcomes (Gallo et al., 2018).

Another potential source of poor animal welfare seems to be the marketing source, as welfare of sheep sold through livestock markets is considered to be poorer than for animals sold directly to abattoirs. The main welfare concerns for market-sold sheep include fatigue, fear, distress, prolonged hunger due to fasting, dehydration and pain due to injuries (Murray et al., 2000).

Although sheep and goats are often considered together as sheep and goats, there are distinct differences between the two species of animals in terms of their behaviour and temperament (AWC, 2020). Goats are more curious, bold and agile than most breeds of sheep. They are able to climb and balance and this, combined with their inquisitiveness, means they are able to escape pens that are designed to contain sheep. Goats are also usually taller than sheep and have longer legs, which has implications for whether the same handling and restraining systems may be used for both species. Goats are also less fearful of new experiences (neophobic) than sheep and will explore unfamiliar surroundings and investigate objects with their prehensile upper lip and tongue. In groups, goats display less consistent herding behaviour than sheep, and they are more independent and in general less fearful of humans (AWC, 2020). Sheep usually flee from approaching handler whereas goats may be familiar, or even aggressive towards the handler, in certain conditions.

3.1.2. Arrival

Arrival of animals 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.

In general, the welfare state of animals at the time of arrival at the slaughterhouse will be the cumulative effects of several steps associated with handling, penning, loading and transport to the slaughterhouse (Terlouw et al., 2008; Ekiz et al., 2012; Fernandez et al., 2018).

Transport involves mixing with other animals, novel experiences (new environment and people) and prolonged standing, often after periods of water and feed withdrawal (Collins et al., 2018). Therefore, depending on the conditions, transport constitutes a moderate to severe stress in animals, and the physiological stresses induced can be relatively long-lasting (Knowles et al., 1995). Some authors (Broom et al., 1996; Knowles, 1998) reported that loading the sheep on to the truck and the initial part of the journey are the most stressful steps of transport. Rearing conditions and production systems also have an effect on stress responses to handling on the farm. Animals reared under very extensive conditions are likely to be less habituated to human contact (EFSA AHAW Panel, 2014) and this may result in a bigger stress response during loading, that may persist at the time of arrival (Hall et al., 1998a).

[2] https://www.mpi.govt.nz/resources-and-forms/economic-intelligence/data/

A study carried out by Eriksen et al. (2013) in Norway indicated that lambs slaughtered at the conventional slaughterhouse had higher serum cortisol levels than lambs slaughtered on-farm with a mobile abattoir (with no transportation). Lambs at the conventional slaughterhouse displayed a higher frequency of vocalisations and showed more aggressive behaviour than lambs at the mobile slaughterhouse. The authors suggested that such behaviours may be induced by crowding and mixing of animal groups leading to social instability and formation of new hierarchy, and/or be due to other stressors, such as feed deprivation, novel environments or handling. These results clearly suggest that transport of animals to the slaughterhouse is stressful to them.

Behavioural evidence of stress in goats such as jumping and bleating is apparent, particularly at the start of the journey (within 10 min). Goats are also prone to trapping their feet, legs or horns, e.g. in gaps in the sides of vehicles, which can result in injuries. This could also occur in sheep. Aggression may be an issue during transport in goats and is exacerbated by close confinement; it is characterised by horn hooking and head butting. The risk of injury increases when horned goats are placed in crowded conditions. Goats prefer to stand parallel to the direction of travel, although body positions frequently change (Das et al., 2001). In situations of high stocking density, goats that fall may cause others to lose their footing and downed goats are trampled on.

The incidence of dead on arrival (DOA) can be used as the ultimate welfare outcome to assess the cumulative effects of on-farm handling and transport. Knowles et al. (1994a) reported a mortality of 0.007% in lambs transported directly from farm to slaughter (62 miles) in the south of England and 0.031% in those going through the auction market (199 miles). In Chile, mortalities of 0.1–0.13% have been reported at arrival of commercial loads of lambs at the slaughterhouses. These higher mortalities are associated with stressful procedures of rounding up in the fields, walking long distances to reach loading pens on the farm, longer distances (and time) travelled by the lambs, the low space allowances, bad roads, use of inadequate vehicles and untrained handlers (Gallo et al., 2018).

The prevalence of DOA in sheep and lambs can be high in hot weather conditions, especially if the trucks are overloaded. For example, the inspection records of Official Control Point in Southern Italy involving 60,454 sheep/goats travelling in long journeys in 225 trucks were analysed by Padalino et al. (2018). The data showed that the maximum mortality and morbidity rates for transport of lambs were 0.084% (average = 0.025%) and 0.019% (average = 0.010%), respectively, and reduced space allowance was associated with the poor welfare outcomes.

The welfare consequences that small ruminant might experience at arrival are thermal stress, restriction of movement, prolonged hunger, prolonged thirst and fatigue.

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

i) Mechanisms of thermal stress

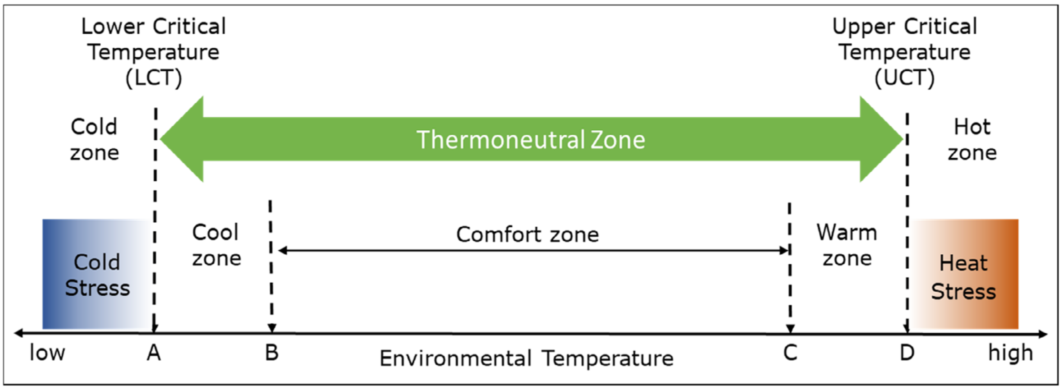
According to the EU factsheet on Transport Guide Extreme Temperatures,[3] heat stress can be caused during transport of sheep by hot weather conditions (high humidity), poor ventilation and overstocking.

Homoeothermic animals such as sheep and goats maintain internal body temperatures with minimal metabolic regulation within a range of ambient temperatures called the thermal neutral zone (TNZ). Within the TNZ, the basal rate of metabolic heat production is equal to the rate of heat loss to the environment. Homoeotherms adjust to the temperatures within the TNZ through different behavioural and adaptive responses requiring little energy expenditure (Moberg, 2000). Environmental temperatures can thus cause fluctuations in a homoeotherm's metabolic rate. This response is due to the energy required to maintain relatively constant body temperature above ambient temperature by controlling heat loss and heat gain. The degree of this response may vary not only according to the species and breed but also on the levels of insulative and metabolic adaptation.

According to Figure 1, the range of ambient temperature can be split in different zones regarding thermal comfort of the animals. To prevent thermal stress, the ambient temperature should remain in the TNZ, which is 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. Animals in the thermal comfort zone will have not experience cold or heat 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

[3] https://ec.europa.eu/food/sites/food/files/animals/docs/aw_platform_plat-conc_extreme-temp-factsh-sheep.pdf

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.



When the environmental temperature exceeds the threshold to the warm zone (point C in Figure 1), the animal will start activating strain responses (e.g. peripheral vasodilatation) but homoeothermy is still maintained, before UCT.

Figure 1: Schematic representation of Temperature and Thermal zones

When environmental temperature starts decreasing, animals will start activating strain responses and start to feel cold (from B to A in Figure 1). When the temperature reaches the LCT, they get outside the TNZ and the cold adaptation process is intensified to increase its metabolic rate to meet the demands for heat production. First, shivering will start to increase heat production (shivering thermogenesis) and is intensified as the animal goes deeper into the cold zone, with an increase of energy consumption. If the environmental temperature continues to decrease far below the LCT, and animals cannot maintain their homoeostasis, then hypothermia occurs. When the capacity for heat production is overloaded, homoeothermy is not maintained anymore, body temperature decreases and hypothermia starts, leading to death from cold in extreme cases (Gregory, 1998).

Evaporative heat loss for cooling starts when temperatures are above the TNZ, the UCT is reached. When the environmental temperature exceeds the UCT, the rate of heat gain and heat production become higher than the rate of heat dissipation (heat loss through evaporative cooling), resulting in hyperthermia.

When animals are exposed to their UCT and are not able to cope with or respond to these temperatures, heat stress begins and as a result, 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. Animals can show postural changes where it changes its body shape or moves and exposes different areas to the sun/shade, and through radiation, convection and conduction heat exchange occurs. Vasomotor responses allow control of the flow of blood between the periphery and the core to control heat loss from the surface of the body.

When the temperature continues to rise in the hot zone, coping mechanisms to maintain homoeothermy are unsuccessful, body temperature continues to rise and fitness can be impaired (hot zone in Figure 1). 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.

During transport, before arriving at slaughter, animals may face very adverse climatic conditions. When arriving at slaughter, 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 Pedernera, 2016). The longer the animals remain on the stationary truck before unloading, the more they can be submitted to thermal stress (Cockram, 2014). In the slaughterhouse situation, exceeding UCT or falling below LCT is considered as thermal stress. LCT and UCT in sheep and goats 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.

The susceptibility to heat stress (OSU, 2019[4]) may vary in sheep and goats due to several factors, in particular (i) presence of fleece, horn and age of the animal and (ii) skin colour.

Hair sheep (e.g. breed such as Morada Nova) cope with heat stress better than wool sheep, because in terms of heat loss, both non-evaporative and evaporative means are better (Correa et al., 2013). Fat-tailed sheep are also more heat tolerant. The European sheep breeds are usually the least heat adaptive because they tend to have shorter bodies and legs, short, thick ears, tight skin and dense fleeces. Horned animals dissipate heat better than polled (or disbudded) animals. It has been shown in cattle that in temperate breeds, the surface area of the vascularised inner core is reduced while the thickness of the outer keratin sheath is increased, which limits heat loss from the horns, as in colder climates loss of heat would be a risk to welfare (Picard et al., 1994).

The TNZ for sheep is reported to be between 12°C and 27°C (Marai et al., 2007; Sejian et al., 2017), although in hair breeds, the upper limit is considered to be 30°C (Neves et al., 2009). In the European context, according to the EU factsheet on Transport Guide Extreme Temperatures,[5] the TNZ for sheep varies with fleece and age:

- In lambs: the TNZ ranges from 14°C to 21°C;
- In fully fleeced sheep: the TNZ ranges from 0°C to 25°C (humidity > 80%) or 28°C (humidity < 80%);
- In shorn sheep: the TNZ ranges from 10°C to 29°C (humidity > 80%)/or 32°C (humidity < 80%).

In sheep hyperthermia, as defined by a rectal temperature of more than 40.5°C, has been reported in conditions of high humidity and air temperature of 33°C and 40°C, in sheep with fleece and shorn, respectively (Faucitano and Pedernera, 2016).

Wool can act as an insulator that prevents air flow over the skin and maintains heat in the body. Consequently, non-evaporative body heat dissipation mechanisms and sweating are ineffective in regulating body temperature in wool breeds (McManus et al., 2009; Titto et al., 2016). In addition, the number of sweat glands and the area they occupy are greater in hair breeds than in wool breeds, meaning sweating is a more effective body heat dissipation mechanism in hair breeds (McManus et al., 2011). Skin thickness is another phenotypic factor that causes inter-breed differences in thermoregulatory capacity; hair sheep have thinner skin than wool sheep, which favours dissipation (radiation and sweating) of core body heat through the skin (Titto et al., 2016).

Goats tend to tolerate heat better than sheep. Goats with loose skin and floppy ears may be more heat tolerant than other goats. Angora goats have a decreased ability to respond to heat stress as compared to sheep and other breeds of goats. It has been reported that long haired goats tolerate radiant heat better than short haired goats and that white or light brown goats do better than dark brown or black goats. Short haired black goats had lowest tolerance of radiant heat (Shinde and Sejian, 2013). Hair being relatively thin and short, it facilitates air flow across the skin allowing transfer of heat accumulated on the body surface to the environment by radiation or convection (Correa et al., 2013), or, more efficiently, by evaporation of sweat (McManus et al., 2011).

In goats, the TNZ is 12–24°C (Nikitchenko et al., 1988) and goat kids, especially suckling ones, are more likely to suffer thermal stress than adults, which may also apply to lambs. In addition, wet/dry weather conditions and wind speed are expected to affect thermal comfort. Holmes and Moore (1981) estimated the LCT for sheep and goats to be dependent on coat depth and wind speed. The LCT for goats with coat depth of 57 mm was estimated to be 9°C at wind speed of 1 km/h and 12°C at 7 km/h. The LCT for sheep with 30 and 60 mm coat depths was estimated to be 9°C at wind speed of 1 km/h; 16°C at 7 km/h; –4°C at 1 km/h and 8°C at 7 km/h. Based on these estimates, it was suggested that the goats with a coat of 57 mm deep are less resistant to cold conditions than sheep with a fleece of similar depth.

ii) Skin colour

Skin colour is known to affect the ability of shorn sheep to transfer excess body heat to the environment or vice versa (McManus et al., 2011; Titto et al., 2016). Light-coloured hair and skin in hair sheep allow them to have a lower heart rate, rectal temperature and respiratory rate compared to dark-coloured hair sheep (Fadare et al., 2012). This occurs because light colours reflect solar radiation, while dark colours absorb it; therefore, the darker the hair and skin colour the greater the body heat accumulation in dark-haired animals (McManus et al., 2009, 2011; Fadare et al., 2012). Similarly, it has

[4] https://u.osu.edu/sheep/2019/05/21/heat-stress-in-small-ruminants/

[5] https://ec.europa.eu/food/sites/food/files/animals/docs/aw_platform_plat-conc_extreme-temp-factsh-sheep.pdf

been reported that black goats had significantly higher respiratory rate than white goats, so as to eliminate extra heat accumulated due to their body colour. Acharya et al. (1995) reported that long haired goats tolerate radiant heat better than short haired goats and that white or light brown goats do better than dark brown or black goats.

Definition of 'Heat stress':

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

ABMs for 'Heat stress':

Clinical signs of heat stress in sheep and goats include continual panting, rapid breathing and an elevated rectal temperature (over 40.6°C) (Battini et al., 2014, 2016). This can lead to weakness and inability to stand that are characteristic of a heat stroke, which potentially leads to death. Observation of panting is considered to be the only feasible ABM for heat stress at arrival.

In general, increased respiration is an attempt to increase heat loss by evaporative cooling by the animal. The respiration rate can be recorded by counting flank movements per minute. Basal resting respiratory rate for sheep is between 20 and 38 breaths/min.

However, the resting respiratory rate of sheep may increase considerably if the animals are excited. The Australian Veterinary Association (AVA, 2018) submission on heat stress (during transport) in sheep categorised type of respiration as normal: 15–35 breaths/min, mild (increased respiration rate): 70–100, moderate (panting): 100–160 and severe (open mouth breathing with tongue out): 160–220.

The basal respiration rate in goats is 15–30 breaths/min. Goats will start panting, and the severity of heat stress according to panting rate is reported to be low: 40–60 breaths/min, medium: 60–80, high: 80–120 and severe: > 200 (Sarangi, 2018).

Panting score has been used as the easiest method of evaluating the impact of heat stress. This is because it only requires direct observation of the animal. Panting is known as sheep's response to increased environmental heat and by substantial increasing of respiratory rate. There are two phases of panting in sheep (Hales and Webster, 1967); rapid shallow panting and the slower deeper panting. An increase in both first and second phase panting is highly correlated with heat stress due to increasing ambient temperature and humidity (Bligh, 1959; Ames et al., 1971). Increasing respiratory rates with open mouth breathing are the first sign of panting (Hales and Webster, 1967); however, respiratory rate varies between individuals (Bligh, 1959).

In both sheep and goats, panting scores had shown significant positive correlation with Temperature Humidity Index (THI) and a significant negative correlation with wind velocity. The panting scores used for assessing heat stress in sheep and goats (Reddy et al., 2019 following Brown-Brandl et al. (2006) are: 0 = normal respiration, 60 or fewer breaths/min; 1 = slightly elevated respiration, 60–90 breaths/min; 2 = moderate panting and/or the presence of drool or a small amount of saliva, 90–120 breaths/min; 3 = heavy open-mouthed panting, saliva usually present, 120–150 breaths/min; and 4 = severe open-mouthed panting accompanied by protruding tongue and excessive salivation.

Battini et al. (2016) have used the following ABMs and scores to assess heat stress in dairy goats: 0 = normal respiration: the mouth is closed, the flank moves regularly (slightly visible) and the legs are frequently held near the body during lying; 1 = elevated respiration: from slightly to moderate panting with closed mouth, small amount of drool or saliva may be present, the posture is functional to heat dissipation, e.g. the neck is frequently extended, the legs may be held far from the body; 2 = panting: from heavy to severe open mouth panting, the mouth is open accompanied by protruding tongue and excessive salivation, the neck is frequently extended, the legs may be held far from the body.

Reddy et al. (2019) used the panting scores proposed by Brown-Brandl et al. (2006) for assessing heat stress in dairy heifers and reported that the panting scores recorded in India were significantly increased in both sheep and goat during the summer season, with highest values recorded during the end of May. It was also observed that during the peak summer season panting scores in sheep were significantly higher.

Panting is therefore proposed as an ABM for assessing heat stress (Table 3) and, considering the results described above, the Panel suggests panting can be defined as more than 60 breaths per minute. The number and proportion of animals showing panting should be assessed.

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

ABM	Description
Panting	Breathing with increased respiratory rate (more than 60 breaths/minute) sometimes accompanied by open mouth, drooling and tongue hanging out of the mouth (Brown-Brandl et al., 2006; Reddy et al., 2019).

Hazards leading to 'Heat stress':

1) Too high effective temperature.
2) Insufficient space allowance in the vehicle or truck.
3) Too long water deprivation.

Too high effective temperature

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

Complementary to the ABM described above, a Temperature-Humidity-Index (THI) can be used as an environmental measure to detect conditions that can lead to heat stress. For the calculation of THI, several different formulas have been proposed in literature 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:

$$\text{Formula A: THI} = 0.72\ (\text{WBT} + \text{DBT}) + 40.6.$$

Using this formula, temperature–humidity index 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).

Alternatively to Formula A, 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. Therefore, THI values can be calculated specifically for sheep using the following equation by Marai et al. (2007):

$$\text{Formula B: THI} = T - (0.31 - 0.31 \times RH) \times (T - 14.4).$$

where T is the dry-bulb temperature in °C and RH is relative humidity in %. Marai et al. (2007) defined four heat-stress categories: $THI < 22.2$ = absence of heat stress, $22.2 \leq THI < 23.3$ = moderate heat stress, $23.3 \leq THI < 25.6$ = severe heat stress and $THI \geq 25.6$ = extremely severe heat stress.

According to López et al. (2015), some breeds of woolly sheep can begin to experience heat stress (calculated with formula A reported above) at THI > 72, although investigation into heat-tolerant breeds (hair sheep) indicates it to begin at 82 units, with three heat stress levels: moderate (82–< 84), severe (≥ 84–< 86) and very severe (≥ 86). However, other authors indicate that hair sheep begin to show signs of heat stress at THI values between 78 and 79 units (Neves et al., 2009). Since hair sheep tolerate higher temperatures than wool sheep, it is probable that heat stress in any sheep breed begins at 78–79 units and not at 82 units. Hair sheep's greater tolerance to heat stress conditions is the result of genetic and phenotypic adaptations, as well as the activation of physiological, metabolic and endocrinological mechanisms. These aid in maintaining an adequate body water balance and normothermic conditions (38.3–39.9°C) at a low energy cost (Macías-Cruz et al., 2013, 2016). Several of the mechanisms activated by hair sheep in response to heat stress conditions are also activated by wool sheep, but the latter still exhibit greater increases in body temperature as ambient temperature rises (Romero et al., 2013). Therefore, the THI value, used to define thermal neutral zone, should be adapted according to the breed of the animals and the climatic conditions animals are subjected to.

Insufficient space allowance in the vehicle or truck

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 space requirement also depends on various other factors that include:

- Ambient conditions (environmental temperature, adequate ventilation, relative humidity),
- Ability of the animals to thermoregulate effectively (when THI is high – i.e. 84 or more – animals require more space for thermoregulation),
- 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 truck is stationary and without any mechanical ventilation.

Factors affecting space allowance include body weight, presence of wool and thickness of fleece, presence of horns, temperature and behaviour of animals during transport (SCAHAW, 2002).

According to Petherick and Phillips (2009), allometric equations of the form area = $kW^{2/3}$, where k = a constant and W = liveweight, can be used to estimate the space an animal occupies as a consequence of its mass. However, this relationship between space and liveweight is nonlinear.

Sheep attempt to maintain their balance independently and do not lean against each other during road transportation, and a lack of space makes it difficult for them to do this (SCAHAW, 2002). It has been suggested that high stocking densities can become hazardous because, in addition to causing thermal stress, they prevent sheep from making adjustments to their posture and position to maintain their balance in a moving vehicle (Knowles, 1998; Knowles et al., 1998). It has been reported that all the sheep lie down after about 4 h of transport given a space allowance equivalent to a k-value of 0.026 (Knowles et al., 1995; Cockram et al., 1996), which is very similar to a k-value of 0.027 for a lying sheep suggested by Baxter (1992). It has been reported that sheep lie down in increasing numbers in the first 5–10 h and tend to get up if the vehicle stops during long distance road transport in Europe (Knowles, 1998), indicating some degree of synchronous behaviour in this species.

However, sheep prefer to stand during rough journeys and poor road conditions (Ruiz de la Torre et al., 2001). The space allowance also affected suckling lambs' behaviour as the number of lambs lying down was highest when they had a space allowance of 0.25 m^2/lamb in comparison with 0.12 or 0.20 m^2/lamb (de la Fuente et al., 2012).

The SCAHAW (2002) reported that a space allowance of 0.31 m^2/head is required for a shorn sheep weighing 40 kg to lie down, which is equivalent to a k-value of 0.026. For journeys of less than 4 h duration, it recommended an area determined from the equation (formula 1):

$$\text{Formula 1: } A = 0.021W^{2/3}$$

where A is area in m^2, W is liveweight in kg.

Petherick and Phillips (2009) recommended that, if it is desirable for all animals within a pen or vehicle to be able to lie down simultaneously, then the amount of space needed per animal can be simply determined using the equation (formula 2):

$$\text{Formula 2: } A = 0.027W^{2/3}.$$

The latter equation (formula 2) is the most commonly used and recommended in this Opinion.

Data concerning the relationship between space allowance and heat stress for goats are scarce; however, data provided for sheep and lambs may be considered appropriate for goats as well.

Too long water deprivation

In general, a steady core body temperature of 39°C is maintained in sheep and goat. A common thermoregulatory mechanism that affects body fluid homoeostasis is evaporative cooling, by sweating and/or panting, to dissipate heat from the body when core temperature is elevated. However, these responses result in a reduction of total body water, thereby reducing blood volume and increasing the osmotic pressure of body fluids. While both panting and sweating are highly effective means of preventing core body temperature from increasing, unless the resultant body fluid losses are replaced by intake of water, hypertonicity, hypovolaemia and circulatory collapse can ensue (McKinley et al., 2017). Thus, exposure to heat stress will increase the amount of water required to maintain homoeostasis but also exacerbate the welfare consequence of prolonged thirst.

In seminomadic farming practices around the world, dry and lactating ewes may be exposed to different degrees of water deprivation, leading to stress due to dehydration. For example, Barbour et al. (2005) reported that significant immunosuppression occurred in lactating water deprived (no water provided) Awassi ewes in the period 9–18 days post initiation of thirst.

If no water is available in the vehicle, animals that are transported to slaughter experience prolonged thirst from the time they are deprived of water on farm until they have access to water in the lairage pens (if available).

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

At the slaughterhouse, all efforts should be in place to prevent animals from entering or staying in the hot zone, in which welfare is compromised or animals may die.

The physical environment experienced on the vehicle, in particular the thermal environment, is a major risk factor. Therefore, it is vital to ensure that ventilation regimes are effective in maintaining internal conditions that are as close to the thermal comfort of the animals.

Adequate and appropriate ventilation systems are essential because during journeys of any duration, weather conditions may change imposing varying thermal stress on the animals. Seasonal differences in weather conditions are also a risk in terms of thermal stress. Long journeys involving movement across climatic zones increases the risk of thermal stress (Consortium of the Animal Transport Guides Project, 2018).

Ventilation systems can be either free or forced systems. Free ventilation systems (natural or passive ventilation) are common in vehicles used for short (less than 8 h) journeys, whereas forced systems are a requirement for long journey vehicles. Frequent stops due to traffic or border controls in hot climates can lead to heating up the vehicle interiors resulting in heat stress. Similarly, metabolic heat production in animals within a stationary vehicle while waiting to be unloaded at the slaughterhouse can exceed external temperature contributing to heat stress (Cockram, 2014). To ensure adequate airflow in a stationary vehicle, the minimum space above the top of the head should be at least 15 and 30 cm in forced or passive ventilation system, respectively (SCAHAW, 2002). In hot weather and without shade in the arrival area, it is important to keep the vehicle moving or park at right angle to wind direction to ensure adequate airflow through the animals (Knowles, 1998) or kept the forced ventilation on.

In addition, ventilation is important in limiting the concentrations of ammonia from faeces and urine inside the vehicle (Fisher et al., 2002), and a concentration of above 45 ppm is reported to be aversive to sheep (Phillips et al., 2012). The space allowance provided in the vehicle should be adequate for the animals to thermoregulate, lie down and access water (when provided).

In case signs of heat stress like panting are observed at arrival or when sheep arrive with fleece on a warm day, animals should be unloaded with priority and cooled down.

Access of the vehicle to shade is another important aspect of managing heat stress. Good ventilation and air movement at arrival would help prevent or mitigate heat stress. According to the EU factsheet on Transport Guide Extreme Temperatures[3], the deck height should be sufficient to ensure correct ventilation inside the truck.

Definition of 'Cold stress':

When the temperature is below the LCT (Figure 1), animals 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.

ABMs for 'Cold stress':

Sheep and goats subjected to cold stress show shivering. If the cold persists, body temperature will drop and sheep become lethargic, recumbent (down on their chest or on their sides), the mucous membranes (pink lining of the mouth) will turn pale to white, and the legs feel cold.

Sheep and goats are considered to be hypothermic when body temperature drops under 37.5°C.

Clinical signs of hypothermia are (Erikson, 2018): initially sheep and goats will try to maintain their body temperature by shallow breathing in order to reduce the rate of respiration, shivering, seeking shelter and huddling together. The author has used the following ABMs and scale to assess cold stress: 0 = no sign: the hair coat is flat on the back, no sign of cold stress is visible, the posture is relaxed; 1 = hair horripilation: the hair coat is bristling on the back, the posture is not a distinguished trait; and 2 = shivering: the small ruminant is shivering, the posture may help to reduce heat loss, e.g. the back is arched, the head is held downwards, the whole body is stiff.

When sheep and goats are subjected to cold stress at arrival, they may show shivering behaviour on the vehicle. Observing all animals properly can be challenging. In case it is possible, the number and proportion of animals that are shivering according to the definition from Battini et al. (2014, 2016) showed in Table 4 can be taken as a specific ABM.

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

ABM	Description
Shivering	Rapid twitching of muscle groups anywhere on the body (Battini et al., 2014, 2016)

Hazards leading to 'Cold stress':

Too low effective temperature

Battini et al. (2014) reviewed literature concerning ABMs used for assessing via Welfare Quality protocol, including cold stress, in dairy goats on farms. Subsequently, Battini et al. (2016) evaluated the on-farm welfare assessment of thermal stress in dairy goats using THI ranges calculated according to Marai et al. (2001), THI = T − (0.31 − 0.31 × RH) × (T-14.4), where T is the dry-bulb temperature in °C and RH is relative humidity in %) as follows: cold = THI < 50; neutral = THI 50–65; and hot = THI > 65.

According to the EU factsheet on Transport Guide Extreme Temperatures[3], cold stress can be caused during transport of sheep by cold weather conditions, water ingress by rain or snow and overventilation. This is also valid for goats.

In sheep, heat stress is more common than cold stress. However, sheep that are transported in open top deck in high altitudes and during inclement weather conditions may be prone to cold stress. Lambs and recently shorn sheep (up to 10 days after shearing) are susceptible to wind chill and need to be transported in vehicles with enclosed fronts or provided with protection during weather that could cause heat or cold stress.

Rain and windy weather combined with temperatures below normal will lead to cold stress in young animals, especially newly shorn sheep without shelter, and death may occur in case of extreme hypothermia. The impact of the cold weather will depend on its duration, rainfall, wind speed and temperature; the 'wind chill' factor can double heat loss. Rainfall causes heat loss in two ways. First, any water evaporated from the skin will cool the body in the same way as sweat evaporation. Second, rain falling on the sheep, lodging briefly in the fleece and finally dripping off will remove warmth from the skin. The loss of a sheep's insulating fleece combined with the evaporative and thermal conductivity of rain falling onto skin, and finally the chilling influence of wind, all result in rapid hypothermia.

In addition, young animals are more susceptible to hypothermia as they have less fat reserve to mobilise. Losses can be substantial in newborn lambs following cold weather if precautions are not taken. Newly shorn sheep are also prone to hypothermia. The shorter the period after shearing in which exposure to cold stress occurs, the greater the risk of hypothermia. Recently, shorn sheep may only have about three millimetres of insulating wool remaining, which can cause up to a threefold increase in heat loss, compared to un-horned animals.

The same mechanisms of heat loss apply to goat, even though no publications is available.

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

According to the EU factsheet on Transport Guide Extreme Temperatures, in preparation for transport, it is important to consider that cold stress during transport of sheep can be prevented by: reduce space allowance if animals have more than the minimum allowed space (but without reducing it below the minimum), provide additional bedding or insulation and remove wet bedding after each trip (i.e. provide clean dry bedding for each journey), provide feed shortly before loading (to increase the metabolic heat production), adjust flaps or windows and use protective sheeting to protect all animals from rain/snow and wind chill. Make sure air circulation is not impeded, use side covers to block air movement through trailers. Be careful to maintain adequate ventilation, keep animals as dry as possible, avoid loading wet animals and, particularly for lambs, pre-warm vehicles by using heaters prior to loading. When driving, reduce ventilation from vent flaps. When stopping, reduce the opening of the vent flaps on the windy side and open on the other side, park in an area that provides protection from the wind, add extra weather boards to keep wind or freezing rain out. Make sure ventilation is kept adequate. Some of these measures can also be applied to cold stress in lairages and holding pens.

All mentioned measures also apply to goat transport.

Lambs and recently shorn sheep (up to 10 days after shearing) are susceptible to wind chill and should be transported in vehicles with enclosed fronts or provided with protection during weather that could cause heat or cold stress. Newly shorn sheep should not be transported if staple growth is less than 7 mm or if they have been shorn less than 24 h before start of journey (EU factsheet on Transport Guide Extreme Temperatures).

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

Small ruminant can be subjected to prolonged hunger since they are deprived from food for the time feed is removed on farm until their arrival on the slaughterhouse. Usually, feed is not provided to sheep and goats during transport.

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), as metabolic requirements are not met.

ABMs for 'Prolonged hunger':

There is no specific ABM to assess prolonged hunger of sheep and goats at arrival.

Hazards leading to 'Prolonged hunger':

1) Too long food deprivation

Pre-slaughter fasting of animals occurs routinely for various durations and it helps to empty the guts. There has to be a balance between meeting the needs of the slaughterhouse and maintaining good animal welfare practice. Lambs lose up to 0.4% of their live weight per hour during the first 24 h of fasting, partly due to emptying of gut contents. Carcass weight loss starts between 12 and 24 h of fasting, and over the first 48 h, it averages about 0.9% carcass weight per hour (Gregory, 1998).

Sheep are frequently subjected to feed deprivation for about 12 h before, and then during, transport and feed may be provided later in lairage. Extensively reared sheep in some countries may have to travel for thousands of km lasting several days before reaching slaughterhouses (Hogan et al., 2007; Gallo et al., 2018). An average live weight loss in sheep of 5.5 kg over 12 h compared with control group was reported by Cockram et al. (1999). In New Zealand, the period of pre-transport fasting can range from 3 to 12 h (Fisher et al., 2012).

Prolonged hunger results in inadequate biological functioning and it is an unpleasant emotional state (Kyriazakis and Savory, 1997). Since sheep will invest significant work to obtain food suggests that hunger generates a negative affective state that the animal seeks to alleviate (Verbeek et al., 2011). There is also supporting evidence from cognitive bias studies that the consumption of a food reward generates a positive affective state (Verbeek et al., 2014a), whilst physiological changes associated with hunger generate a negative state (Verbeek et al., 2014b). The effects of inadequate feed supply may also exacerbate the adverse effects of exposure to cold (Verbeek et al., 2012).

Kannan et al. (2000) reported that a 2-h transportation, combined with 18 h of feed deprivation, resulted in elevated cortisol levels and approximately 10% liveweight shrinkage in Spanish does. Alcalde et al. (2017) investigated the effects of 2 or 6 h of road transport on Spanish Blanca Celtibérica breed suckling goat kids, 30–36 days old weighing on average 10 kg, from 'high' and 'low' welfare farming systems. Blood samples were collected both on-farm and in the slaughterhouse. The results indicated that, regardless of its duration, transport caused significant effects on blood glucose, cortisol or creatine kinase, suggesting stress.

Animals subjected to prolonged hunger may be seen eating bedding materials, if provided on the vehicle or in lairage. However, bedding may not be provided and therefore eating bedding materials cannot be suggested as an ABM.

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

Keep transport distance and duration, and lairage time to the minimum. To prevent 'Prolonged hunger' the food should not be withdrawn prior to transportation, as suggested for cattle (EFSA AHAW Panel, 2020).

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

Definition of 'Prolonged thirst':

Thirst is defined as a longing or compelling desire to drink and is induced by both extracellular and cellular dehydration (Blair-West et al., 1994).

Prolonged thirst is defined as 'the animal has been unable to get enough water to satisfy its daily needs (5–10 litres per day), resulting in dehydration' (EFSA AHAW Panel, 2014; OSU, 2019[4]).

Sheep are prone to dehydration during long journeys and the metabolic stresses associated with handling and holding sheep on the farm before the journey have been reported to be as bad as the journey itself (Knowles et al., 1994a).

Thirst causes stress and also reduces food intake which, in turn, may lead to the welfare problems associated with prolonged hunger.

ABMs for 'Prolonged thirst':

There is no specific ABM feasible for use at arrival. For instance, sunken eyes can provide a useful measure of prolonged thirst, but it is not considered a feasible measure because the eyes of the animals are barely visible.

Hazards leading to 'Prolonged thirst':

Too long water deprivation (see Section 3.1.2.1 also)

Sheep are frequently subjected to water deprivation for about 12 h before, and then during transport. In the EU, they might be subjected to water deprivation for a maximum of 8 h (Reg 1/2005). Extensively reared sheep in some countries may have to travel for thousands of km before reaching slaughterhouses (Hogan et al., 2007; Gallo et al., 2018).

Knowles et al. (1993) found no evidence of dehydration in sheep during journeys of up to 24 h when ambient temperatures were not above 20°C. However, it has been reported that when ambient temperatures increased above 20°C for a large part of a long journey, there were clear indications that animals became dehydrated (Knowles et al., 1994b). Finally, it is worth noticing that the absence of dehydration does not mean that animals are not thirsty.

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

Sheep and goats should have access to water on the farm until they are loaded and in the vehicle, as already mentioned in the current EC 1/2005, when journeys are longer than 8 h.

Unload animals from the transport vehicle without delay and provide access to clean, cool, and fresh water in lairage is paramount to preventing thirst and heat stress in sheep and goats.

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.

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 and proportion of animals showing the two ABMs in Table 5.

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

ABMs	Description
Exhaustion	Conscious animals lying on the floor and not able to stand up (recumbency); reluctance to move if the animal is standing, but no signs of lameness such as repeated weight shifting or reluctance to bear weight.
Tachypnoea	Excessive rate and depth of breathing, e.g. > 60 per minute (Reddy et al., 2019).

Hazards leading to 'Fatigue':

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

Insufficient space allowance in the vehicle

To avoid fatigue at arrival animals should be able to lie down and space allowance should be calculated with the formula 2 detailed in Section 3.1.2.1.

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

The prevention and correction measures regarding the hazards 'Too high effective temperature' and 'Too long food deprivation' and 'Too long water deprivation' are described in Sections 3.1.2.1 and 3.1.2.2.

Hemsworth and Jongman (2017) also argued that welfare monitoring at each stage of the post-farm gate process is essential, together with provision of optimal thermal and spatial conditions in holding facilities and proper training for staff on handling sheep to safeguard animal welfare.

Very high stocking densities will prevent the animals from lying down (Cockram et al., 1996; Knowles et al., 1998) and this may cause fatigue and muscle damage, particularly during long journeys (Knowles et al., 1998). Also, at too high a stocking density the risk of heat stress increases, because the increased contact between animals will limit their ability to dissipate heat and at the same time will increase heat exchange between individuals (Schrama et al., 1996; Knowles et al., 1998).

Hall et al. (1998b) found higher plasma cortisol concentrations on sheep transported on rough journeys compared with sheep on smooth journeys. Ruiz de la Torre et al. (2001) compared the stress response and meat quality of sheep transported on smooth vs. rough roads. Lambs transported on smooth roads had a lower heart rate and lower plasma cortisol concentrations after 8 and 12 h than the lambs transported on rougher roads. Also, 24 h after slaughter the pH of the meat of the lambs transported on smooth roads was lower than that of the lambs transported on rougher roads, suggesting that the latter may have suffered muscular fatigue, leading to reduce muscle glycogen stores.

As the roughness of a journey depends on road conditions and driving style, both training of drivers and planning of the journey are essential to reduce the movement of the vehicle, and hence fatigue in animals.

In addition, space allowance should be adjusted according to:

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

The SCAHAW (2002) concluded that where journeys last for longer than 12 h, animals will become fatigued. More space should be allowed if a journey is longer than 12 h and if the climatic conditions are warm (EFSA AHAW Panel, 2011).

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

Definitions of 'Restriction of movement'

Restriction of movement: The animal is unable to lie down, stand up, have access to water and feed and escape from aggression from dominant animals.

ABMs for 'Restriction of movement'

At arrival, it is very difficult to see animals in the vehicle 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 (see Section 3.1.2.1 for the formula).

Hazards leading to 'Restriction of movement':

Insufficient space allowance in the vehicle or truck

Cozar et al. (2016) investigated the impact of transporting Merino lambs by road for 5.5 h over a distance of 334 km with three space allowances (0.16 m^2, 0.20 m^2 or 0.30 m^2) and provision of feed in lairage. Based on the results of physiological stress indicators, the authors concluded that, under the conditions of this study, a range of space allowance during transport between 0.16 and 0.30 m^2/lamb could be recommended without major changes on welfare physiological indicators. Teke et al. (2014)

evaluated the effects of two space allowances (0.20 and 0.27 m^2/lamb) during transportation of 55 Karayaka lambs (29 kg average body weight) over a distance of approximately 130 km and for the duration of 2 h 15 min. The results indicated that transportation with a space allowance of 0.20 m^2/lamb resulted in higher stress responses compared with a space allowance of 0.27 m^2/lamb. This is consistent to the Petterick equation (formula 2) for which the resulting minimum space allowance for lambs of this weight is 0.25 m^2 (see details in Section 3.1.2.1).

At arrival, movement of sheep are restricted until they are unloaded but minimal space allowance, such as calculated with formula 2, will allow them to stand up and lay down.

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 animals to the size of the compartment.

The Guide to good practices published by the European Commission for the transport of sheep provides a list of features to safeguard welfare of sheep (Consortium of the Animal Transport Guides Project, 2018). The livestock vehicles must be designed to ensure that sheep can rise from lying to a standing position without contacting overhead deck structures and allowing optimum ventilation. This table is consistent with the figures resulting from the Petterick equation reported in Section 3.1.2.1. It is to be noted that unshorn sheep and lambs of ≥ 26 kg with thick fleece should be offered around 25% more space than shorn sheep and, additionally, increased space is offered for long journeys (> 8 h). The recommended space allowances during transport of sheep are presented in Table 6.

Table 6: Space allowances recommended for sheep

Live weight (kg)	Fleeced sheep		Lamb and shorn sheep	
	Short journey (m^2)	**Long journey (m^2)**	**Short journey (m^2)**	**Long journey (m^2)**
< 20	–	–	0.21	0.27
21–30	–	–	0.28	0.36
31–40	0.39	0.51	0.34	0.43
41–50	0.45	0.60	0.35	0.50
51–60	0.51	0.67	0.40	0.57
61–70	0.56	0.75	0.44	0.63
71–80	0.61	0.82	0.48	0.69

According to Regulation EC 1/2005, long journeys are defined as journey that exceeds 8 h, starting from when the first animal of the consignment is loaded.

As it is not feasible to provide more space for the animals in the truck at arrival, the mitigation measures should be to unload the animals without delay 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 without delay.

The welfare consequences detected at arrival will be exacerbated if animals are not unloaded without delay.

3.1.2.6. Outcome table on 'Arrival'

Table 7: Outcome table on 'Arrival'

Hazard	Welfare consequence/s occurring to the animals 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 Too low space allowance	• Staff training • Increase space allowance • Scheduling to avoid hottest hours of the day for transport • Unload without delay following the arrival • Provide adequate ventilation to the truck at arrival • Protect from adverse weather conditions.	• Provide adequate ventilation or/and cooling systems • keep the vehicle moving • park at right angle to wind direction • park in the shade • prioritise unloading
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 without delay following the arrival • Provide adequate shelter to the truck at arrival place	• Provide protection when the animals are on the truck • Unload the truck without delay and bring the animals to a thermal neutral zone (with heaters)
Insufficient space allowance (See Section 3.1.2.1)	Restriction of movements, movements, 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 without delay

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Too long Food deprivation (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 without delay
Too long Water deprivation (see Section 3.1.2.1)	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 without delay

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

3.1.3. Unloading from the vehicle or truck

In high throughput sheep and goat slaughterhouses, animals are unloaded by using fixed ramps (in case the levels of the trucks can be adjustable in height) or hydraulically height adjustable ramps or elevators to meet the different deck heights of the trucks. Sheep have a very strong following behaviour. Handling during unloading is easier if it is carried out smoothly by exploiting the natural gregarious behaviour of sheep and let them move at their own pace. Extensively reared sheep may be fearful of close proximity to humans and tend to flee away from the handlers. A model or familiar sheep may be used to lead the entire batch during unloading (Miranda-de la Lama et al., 2014).

Goats are normally slaughtered in cattle or sheep slaughterhouses and they are unloaded using the existing facilities. This may include concrete ramps to which a vehicle carrying animals can reverse and unload. Goats' behaviour towards human handlers vary according to the husbandry systems and early life experience (Miranda-de la Lamaa and Mattiello, 2010). Habituation to humans by goats caused by frequent handling during daily activities plays a positive role in the quality of the human–animal relationships. For example, Mattiello et al. (2008) observed shorter avoidance distances in goats that were reared in small farms than in large modern farms, probably due to the closer relationships between the farmer and each individual goat on the small farm. Dam-reared goats exhibited greater avoidance distances from humans and were more fearful than that were human-reared goats (Lyons and Price, 1987). Le Neindre et al. (1996) found that young animals that were not exposed to human handling were more fearful and sometimes aggressive towards farmers/handlers. Lyons et al. (1988) concluded that genetic factors and early postnatal environments are responsible for individual temperament, including its attitude towards humans, which largely persists throughout the lifetime of the goat. In general, goats are more reactive than are sheep, because they are more aggressive. In this sense, when goats feel threatened or attacked, they tend to face the attacker, but sheep will usually flee. Understanding of this species-specific behaviour will help to improve operators' safety and animal welfare.

Sheep and goats are able to cope with steep unloading ramps. However, when the ramps do not have solid side barriers, animals may be pushed or jump over the edge.

The welfare consequences that small ruminant might experience during unloading are pain, fear and impeded movement.

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

Definitions of 'Pain' and 'Fear'

Pain is defined as an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage (Raja et al. 2020). 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).

ABMs for 'Pain' and 'Fear'

Sheep may show subtle signs of pain, while goats are intolerant of painful procedures (Kata et al., 2017). Goats will often bleat, while sheep may only exhibit tachypnoea, inappetence, grinding of teeth, immobility, or abnormal gait. Sheep, as a prey animal, tend to remain silent rather than vocalising during painful procedures (Stafford, 2014), however, vocalisation can be used to assess fear in sheep (e.g. social isolation; Hemsworth et al., 2011). Goats are more vocal animals than sheep, even if they are also prey animals.

In general, sheep in pain may show the following signs (Manteca et al., 2017): reduced feed intake and rumination, licking, rubbing or scratching painful areas, reluctance to move, grinding their teeth and curling their lips, altered social interactions and changes in posture to avoid moving or causing contact to a painful body area.

Goats and lambs may vocalise when they experience something aversive or threatening, and therefore it can be used as an ABM for fear. Goats fearful of humans might be aggressive towards handlers.

Slipping and falling 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. However, sheep tend to be less prone than cattle or goats to slipping.[6] More slipping in sheep is seen when the ramp angle is between 15° and 25°. When the internal ramp angle is steeper than this, they

[6] https://www.hsa.org.uk/downloads/publications/prevent-slips-and-falls.pdf

tend to stop at the top of the ramp and focus on where to place their feet instead of following-on rapidly as a group. The best approach with steep ramps is to avoid rushing the sheep once they have started to move off the vehicle.

Lameness can be detected during unloading by assessing if animals are not bearing weight on one or more limbs when standing or moving, reluctance to move and difficulty or inability to stand (Kaler and Green, 2008; König et al., 2011).

ABMs that are considered to be relevant for the assessment of pain and fear at unloading are presented in Table 8. Assessment of these ABMs can be done by counting the number and proportion of animals showing them.

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 (AWIN, 2015).	Fear
Lameness	Lameness is an abnormality of movement and is most evident whilst the animal is in motion (AWIN, 2015).	Pain
Reluctance to move	An animal that refuses to move when coerced by the operator or that stops for at least 4 s not moving the body and the head (freezing) (modified after AWIN, 2015).	Fear, pain
Turning around or moving backwards/turning back	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 AWIN, 2015).	Fear
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (Gregory, 1998; Faucitano and Pedernera, 2016).	Pain
Vocalisation	Bleating in goats and vocalisation in lambs (Goldberg, 2018).	Pain and fear
Grinding of teeth, curling of lips	Teeth grinding and/or curling of upper lip (Manteca et al., 2017; Goldberg, 2018).	Pain

Hazards leading to 'Pain and 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) Inappropriate handling.
2) Improper design, construction, and maintenance of premises.
3) Unexpected loud noise.

Inappropriate handling

It is considered inappropriate handling causing fear and/or pain when staff force the animals to get off from the truck too quickly or through non-adapted bridges and raceways; lifting them by fleece/wool or use of dogs to move them.

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

Attempts to escape due to fear of humans or dogs (in those countries where dogs are used, not in Europe as it is forbidden) may result in injury as animals may collide with fences, walls or pen fixtures and due to slipping and falling. Risk of injury through bunching and smothering is also a potential problem with extensively reared sheep.

Improper design, construction and maintenance of premises

In general, animal handling facilities should be designed to minimise stress and avoid causing injury during handling. A well designed, constructed and maintained unloading area can add to the speed and efficiency of unloading, consequently limiting the amount of stress on animals and risk to get injured.

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 or dogs barking. Noise can be continuous or sudden. The latter is defined here as 'unexpected loud noise'.

The auditory range of sheep is 125 Hz to 40 kHz with the most sensitive frequency a little higher than cattle and pigs at 10 kHz (Heffner and Heffner, 1992). Sheep appear to adapt to increased noise levels, particularly when these are relatively continuous, such as the noise of transport vehicles at around 60–90 dB(A), although they may show an initial rise in heart rate (Hall et al., 1998c). Kim et al. (1994) noted that sheep in lairage appeared more responsive to human vocalisation and to mechanical noise such as metal banging and hosing than to noises of animal origin (e.g. pig or cattle vocalisation or cattle fighting/mounting), but they did not record noise levels. Weeks (2008), Weeks et al. (2009) found mean sound levels from clanging gates and other fittings in 11 sheep lairages to be 76 dB(A) and they recorded sheep vocalisations at around 70 dB(A). Data concerning goats are not available.

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

Additional care is needed, including consideration for emergency slaughter on the truck, when dealing with severely lame animals. The veterinarian or the person in charge of animal welfare (animal welfare officer) should take necessary action to avoid further suffering in these animals.

Erian et al. (2019) suggested that knowledge can be improved in animal welfare training programs focused on animal welfare around transport and slaughter. Training of people handling animals in slaughterhouses to understand species specific innate behaviour and acquire necessary skills to move them with minimum of stress is essential to maintaining good animal welfare (Hemsworth et al., 2011).

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 : (i) use the flight zone and the point of balance principle (i.e. for the animal to move forward, the handler should be within the flight zone but behind the point of balance at the shoulder of the animal (see chapter 3.1.3 of the EFSA AHAW Panel, 2020 scientific opinion on cattle slaughter), (ii) use following behaviour and move animals in small groups (Faucitano and Pedernera, 2016). 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.

Clearly, positive handlers' attitude towards the animals on the farm has an impact on smooth unloading and movement within slaughterhouses, and adequate training to acquire knowledge and skills is vital to maintaining good animal welfare (Coleman et al., 2012).

Extensively reared sheep and goats may be fearful of close proximity to humans and tend to flee away from the handlers. Habituation to being handled by humans can reduce the stress response to loading and unloading. Hall et al. (1998a) also studied the effects of taming or habituation to handling on the responses of sheep to transport and showed that individual animals responded differently to taming and that those sheep, which responded most positively to taming, showed the least marked response during transport. Similarly, habituation to humans by goats caused by frequent handling during daily activities plays a positive role in the quality of the human–animal relationships (Miranda-de la Lama et al., 2014).

A leader or familiar sheep may be used to lead the entire batch during unloading (Miranda-de la Lama et al., 2014). Trained goats or sheep will lead conspecifics through stockyards or lairages (Hutson, 2014). A specialist lead sheep or goat should be used for different handling procedures. Training the lead animals will be easier if one leader is trained to unload trucks and another is trained to lead animals into lairage pens. In confined spaces such as trucks and small lairage pens at the slaughterhouses, lead animals are recommended, instead of dogs. Staff should not be shouting, and sources of unexpected loud noise should be identified and removed.

It is important that shadows that might frighten the animals are removed, and that the lighting in the unloading area/reception pen is good, as sheep are reluctant to move into dark places (Knowles, 1998).

Good design of facilities unitises natural species-specific behaviour of animals will reduce the amount of effort required from the operator. Handling systems should have floors made with non-slip surfaces and the sides of raceways should have no protrusions or sharp edges. Unloading bays should be designed so that fixed ramps are no steeper than 25°. The unloading area should be secure and provide a wide, clear, straight path from the vehicle to the pen where the animals are to be held. The facilities should not have any distractions. Raceways leading to lairage pens should be wide and straight to allow animals to be moved in groups. Where raceways contain corners, it is far easier to move animals through a system designed with curved bends rather than right-angled bends.

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

Definitions of 'Impeded movement':

Difficulty of movement resulting in slipping and falling.

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

ABMs for 'Impeded movement':

Animal welfare, as affected by impeded movement, can be assessed during unloading by recording the number and proportion of animals slipping and falling (AWIN, 2015) (see description in Table 9).

Table 9: ABMs for the assessment of 'Impeded movement' at unloading

ABMs	Description
Falling	Loss of balance in which parts of the body other than feet and legs are in contact with floor surface (AWIN, 2015).
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 (AWIN, 2015).

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 25° for sheep (Consortium of the Animal Transport Guides Project, 2018). When the ramp angle is steeper than this, they tend to stop at the top of the ramp and focus on where to place their feet instead of following-on rapidly as a group. In a general manner, goat are more prone to climb and steeper ramps might not be a problem for most of them. Unloading ramps should have solid sides and of sufficient height to prevent goats from jumping. Slips and falls occur mostly when concrete floors are wet with rain, urine or manure and it occurs especially when sheep and goats are running or turning.

Inappropriate handling

It is considered inappropriate handling causing impeded movement when staff move single animals since sheep are gregarious; force the animals to get off from the truck too quickly or through non-adapted bridges and raceways. Inappropriate handling might cause animals rushing and getting scared and then slipping and falling during unloading. Furthermore, inappropriate handling may result in flight leading to injury as animals may collide with fences, walls or pen fixtures and due to slipping and falling. Risk of injury through bunching and smothering is also a potential problem with extensively reared sheep.

The best approach with steep ramps is to avoid rushing the sheep once they have started to move off the vehicle.

Trying to unload downer animals from the truck is also considered inappropriate handling.

Catching, lifting or pulling of animals by the horn, skinfold, wool or fleece will have serious welfare consequences (Knowles, 1998) and may result in bruising (Cockram and Lee, 1991).

In addition, good practices for handling during unloading state (Consortium of the Animal Transport Guides Project, 2018):

- Enough time should be given to the animals during unloading so as to they can adapt to the new situation (light, odours, etc.). Attempting to rush sheep and goats during unloading can be a cause of injuries and poor welfare.
- Animals should be unloaded in the same social group as they were in before they were loaded onto the vehicle, and in accordance with the size of pen they are going into.

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

As corrective measures, the first step in improving animal movement is to correct mistakes that people make while handling and/or moving animals.

Positive handlers' attitude towards the animals on the farm has a beneficial impact on smooth unloading and movement within slaughterhouses, and adequate training to acquire knowledge and skills is vital to maintaining good animal welfare (Coleman et al., 2012).

In a general manner, it should be ensured there are no obstacles or distractions in the way that would make animals balk and turn back, impeding the flow. Sheep being gregarious animals will follow each other and they should be allowed unload without force, especially while unloading down steep ramps.

According to the Guide to Good Practices for the Transport of Sheep published by the Consortium of the Animal Transport Guides Project (2017-rev1 May 2018 (2018):

- The ramp should have a non-slip surface which is sufficiently resistant, with panels or sidebars high enough to prevent animals falling or escaping during unloading.
- Ramp inclines should be no more than 26° (which means that ramps should have a maximum height of 50 cm measured 1 metre before the end of the ramp). It is recommended to reduce the inclination during unloading, especially for lambs. A way to decrease the inclination of the ramp is to increase the ramp length.
- Ramps of more than 10° must have foot battens to stop animals slipping.
- The width of the unloading dock should be at least the width of the transport vehicle.
- The driver should ensure that the ramp and the vehicle are properly aligned with the unloading area, and that sheep cannot get trapped or injured by the gap between the ramp and the vehicle.
- Lifting platforms and upper floors shall have safety barriers so as to prevent sheep falling or escaping during loading and unloading operations.These preventive measures are considered valid for goats as well.

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

Table 10: Outcome table on 'unloading of animals from the truck'

Hazard	Welfare consequences occurring to the animals 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 • Use of leader sheep	• Instruct the operator to stop inappropriate handling • Implement staff rotation, or • Slaughter the animal without delay
Improper design, construction and maintenance of premises (See Section 3.1.3.1)	Pain, fear, impeded movement	Facilities	Too steep slope Lightin Slippery and/or dirty floor or ramp Absence of solid lateral protection Presence of a gap between the vehicle and the ramp	• Ensure maintenance of the area • Rebuild the unloading area to accommodate animal behaviour	• Clean the slippery floor or ramp • Provide sawdust or straw to make it non slippery • Slow down unloading process
Unexpected loud noise (See Section 3.1.3.1)	Fear	Staff	Staff shouting and making noise Dog barking	• Identify and eliminate the source of noise • Avoid dogs • Staff training • Avoid personal shouting	• None

ABMs: escape attempts (fear), lameness (pain), reluctance to move (pain and fear), turning back (fear), falling, slipping (impeded movement) injuries, vocalisations (pain, fear), grinding of teeth, curling of lips (pain)

3.1.4. Lairage

Lairage is the stage when animals stay in pens from after unloading up to the start of moving to go to the stunning or killing point. Lairage conditions *per se* can have their own impact on the welfare of small ruminant and can also exacerbate the welfare consequences originating from the hazards, the animals have been previously exposed to before reaching the lairage pens.

From a welfare point of view, animals should be slaughtered without delay after unloading to prevent exposure to prolonged stress (Knowles et al., 1998); however, 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. Differences in animal genetics, on-farm handling conditions, journey length, road and driving conditions, and conditions on the vehicles could explain the differences in the cumulative stress levels and recovery times in lairages reported in different studies (Liste et al., 2011; Liu et al., 2012; da Leme et al., 2012; Díaz et al., 2014; Yalcintan et al., 2018). Recovery in the lairage can occur only when animals have enough space, good climatic conditions, within a quiet environment (FAWC, 2003) and they are provided with water. They might also be provided with food in case they have to stay in lairage for longer than 12 h (EC Reg 1099/2009).

Space allowance given to each animal should be sufficient for it to lie down, get up, turn around and access resources such as water without hindrance. In addition, sheep and goats 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. Lairage facilities used for goats have often been designed for sheep or other species and as such may consist of pens constructed with bars rather than solid walls (AWC, 2020). Goats will tend to climb up on the bars and an assessment will need to be made of the risk for the goat in trying to climb over the pen sides. Premises with solid walls are better suited to handling goats and pen sides should be of a suitable height to prevent climbing. Floors and raceways, water drinkers and feeders if suitable for sheep will normally be suitable for goats. Lactating animals should be identified on arrival and have arrangements for milking should that be necessary to relieve the udder. If milking is necessary, the milking interval should not exceed 12 h as prescribed in the EU Regulation on transport (EC Reg 1/2005). These animals as well as those that are sick, unweaned, or that might have given birth recently or are at the end of pregnancy (in case they have been transported) should be prioritised for slaughter (AWC, 2020).

During transport, there is a requirement to separate goats of significantly different sizes or ages, sexually mature males from females, animals with horns from animals without horns, animals hostile to each other and tied animals from untied animals (AWC, 2020). It may be prudent to keep these categories of animals separately in lairage also. For example, Angora goats are horned and are separated in transit and slaughter. However, separation is not required where the animals have been raised in compatible groups, are accustomed to each other, where separation will cause distress or where females are accompanied by dependent young. The welfare consequences that sheep and goats might experience during lairage are social stress, pain and fear, thermal stress, prolonged hunger, prolonged thirst, fatigue and restriction of movement.

In extreme uncontrolled conditions, morbid animals can be seen at lairage.

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

Definitions of 'Social stress'

The animal experiences stress and/or negative affective states such as pain, fear and/or frustration resulting from a high incidence of aggressive and other types of negative social interactions, often due to hierarchy formation and competition for resources or mates.

Social isolation is stressful to sheep (Parrott et al., 1994) and good correlation exists between emotional reactivity profiles recorded during rearing and stress reactions during preslaughter handling (Deiss et al., 2009).

ABMs for ''Social stress'

Social stress can be assessed by observing the number and proportion of animals showing aggressive behaviours such as biting and, in goats, butting (Table 11).

Table 11: ABMs for the assessment of 'Social stress' at lairage

ABMs	Description
Aggressive behaviour	Can be expressed as aggression with contact, i.e. biting, butting, or aggression without contact, i.e. threat displays, chases, escapes (Miranda-de la Lama, 2005; Tölü and Savas, 2007).

Hazards leading to ''Social stress'

Mixing of unfamiliar animals:

Mixing of unfamiliar animals will lead to increased aggression.

For goats: Aggressive postures in goats can also include side-on locking of horns, butting the flank of another feeding goat, and ear biting. When a conflict between goats escalates, the typical aggressive behaviour involves one goat standing up on its hind legs, lowering its head, and striking it against its opponent's head.

For sheep: Hall et al. (1998a) observed that social mixing is less of a welfare problem for sheep than for other farm animals. Knowles (1998) reported that, when two groups of unfamiliar sheep are mixed and penned together, they stay as two groups.

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

Keep established groups of animals together and avoid mixing unfamiliar animals. Prioritise slaughter of aggressive animals or mixed groups.

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 3.1.3.1.

ABMs for 'Pain' and 'fear'

See Section 3.1.3.1.

Assessment of pain and fear at lairage, can be done by counting the number and proportion of animals showing the ABMs listed in Table 12.

Table 12: ABMs for the assessment of 'Pain' and 'Fear' at lairage

ABMs	Description	Welfare consequence
Injuries	Tissue damage (bruises, scratches, open wounds, broken bones, dislocations) (Gregory, 1998; Faucitano and Pedernera, 2016).	Pain
Vocalisation	Bleating in goats and vocalisation in lambs (Goldberg, 2018).	Pain and fear
Grinding of teeth, curling of lips	Teeth grinding and curling of upper lip in sheep (Manteca et al., 2017; Goldberg, 2018)	Pain

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) Novelty of the environment.
3) Unexpected loud noise (see Section 3.1.3.1).
4) Mixing of unfamiliar animals (see Section 3.1.4.1).

Improper design, construction and maintenance of premises

Proper design, construction and maintenance of lairage should be based on number of animals to be kept in lairage at any one moment (space allowance), which will depend upon the throughput rate, ventilation capacity required to provide thermal comfort to these animals, requirement to provide access to water and feed, drainage system to cope with the volume of faeces and urine to be removed and washing to maintain pens clean, lighting conditions to suit the animals and protection from inclement weather conditions. Failing to meet these basic requirements could result in poor outcomes.

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 adequate ventilation to maintain thermal comfort and 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.

Floors and raceways, water drinkers and feeders if suitable for sheep will normally be suitable for goats.

Novelty of the environment

The novelty of environment during preslaughter holding, and social isolation (a 15-min isolation with no visual contact) has been reported to be more potent stressors than feed deprivation in goats (Galipalli et al., 2004; Kannan et al., 2000, 2002, 2003).

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

Identify the source of pain and fear and implement appropriate measures.

It has been suggested (European Commission, 2017) that lairage pens can have both solid and open sides. Open sides allow sheep to see each other and, as a result, sheep will be calmer in the lairage. However, cross bars should be avoided for goats, as they might climb on them. Higher sides would also be required for goats than for sheep. Plastic walling could be used, which would contribute to reducing noise. Besides, plastic walling can also be mobile, and it would help to alter the arrangements to meet the needs of different categories of animal. Partitions can be used to keep distinct groups separate, or isolation pens for animals requiring special care.

According to the Preparation of best practices on the protection of animals at the time of killing (European Commission, 2017):

- Animals can move independently in well-designed slaughterhouses. As a result, they experience reduced stress. They are also easier to handle. The work of operators is greatly facilitated and made safer. Well-designed facilities also prevent animal injuries.
- Gates should be designed to facilitate the movement of the animals and to secure them in a given area. Therefore, it is important that gates do not allow animals to escape, or to become trapped. Gates should be properly maintained and kept in good condition.
- No sharp ends or pointed objects should intrude into passageways, ramps, or pens, because they could cause injuries to the animals. Drinkers can cause injuries unless they are incorporated into sides and walls.

According to the best practices on the protection of animals at the time of killing (European Commission, 2017), there are a variety of options to prevent or reduce sudden noises from the movement of animals and closing of gates.

i) Prevention of metal to metal contacts:

Identify metal to metal contact points in ramps, passageways, bridges and pens. Use rubber or another synthetic material on one of the surfaces.

ii) Use of sound reducing designs and materials:

Use plastic for the sides of ramps and gates to prevent noises. Ceilings can also be designed to prevent noises. Low ceilings are better than high ceilings in that respect, however low ceilings also mean reduced air flow and poor ventilation.

iii) Location of noisy activities and separations:

Where possible activities that make a lot of noise, such a truck washing, should be conducted at sufficient distance from the animals.

iv) Shape of the roof:

The shape of the roof may contribute to the noise level, particularly in the lairage. A gable roof (inverted V shape) will contribute to more noise in the lairage than a saw- tooth shaped roof. Saw tooth roofs can also be used to increase natural lighting.

Animals at lairage should be allowed to rest comfortably, without any disturbance. Do not allow any shouting or banging of paddles. Use flags instead.

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

Definition of 'Thermal stress'

For definition of heat and cold stress see Section 3.1.2.1.

ABMs for 'Thermal stress'

In lairage, counting the number and proportion of animals panting or shivering can be used to monitor heat or cold stress, respectively (Table 13).

Table 13: ABMs for the assessment of 'Thermal stress' at lairage

ABMs	Description	Welfare consequence
Panting	Breathing with increased respiratory rate (more than 60 breaths per minute) sometimes accompanied by open mouth, drooling and tongue hanging out of the mouth (Brown-Brandl et al., 2006; Stockman et al., 2011; Battini et al., 2016; Reddy et al., 2019).	Heat stress
Shivering	Rapid twitching of muscle groups anywhere on the body (Battini et al., 2014, 2016)	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).

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.

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

Passive ventilation in lairage may be adequate in temperate climate, but active ventilation would be necessary in hot and humid climatic conditions. It is also worth mentioning that any material used for partition between groups should not hinder air circulation, leading to thermal stress in animals in lairage.

Lairages must have natural or forced ventilation to protect animals from temperatures above thermo neutral zone, harmful levels of humidity and harmful levels of ammonia. Sheep and goats should have access to water all the time, and they should have access to feed and provided with suitable bedding material to ensure comfort around resting if lairage duration is expected to be longer than 12 h (overnight). Bedding material is also essential for lambs and goat kids in cold weather conditions to avoid hypothermia (Dalmau and Velarde, 2016) since they are very susceptible to cold stress.

It is also worth mentioning that wooled sheep should not be sprayed with cold water as this will prevent cooling. Air will not be able to pass through the wetted fleece.

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

Definitions of 'Prolonged hunger':

For definition see Section 3.1.2.2.

ABMs for 'Prolonged 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.

Hazards leading to 'Prolonged hunger'

1) Too long food deprivation (see Section 3.1.2.2).

Prolonged lairage time will extend the time of food deprivation. Kannan et al. (2000) reported that 18 h of feed deprivation resulted in a 10% live weight loss in goats. Earlier studies also showed that fasting sheep for 24 h resulted in about 7% live weight loss due to reduction in gut contents (Kirton et al., 1971; Chillard et al., 1995).

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

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

Keep transport distance and duration, and lairage time to the minimum possible. Provision of food is essential if animals are expected to stay in lairage for longer than 12 h (EC Reg 1099/2009). Greenwood et al. (2010) suggested that minimising transport and providing good quality food and water in lairage would benefit welfare of goat kids.

Animals subjected to cold stress during transport or in lairage would also need to be fed, if they are not expected to be slaughtered without delay.

Suckling lambs and goat kids should be slaughtered without lairage. If slaughter is delayed, feed them with suitable milk replacement at regular intervals depending upon the age.

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

Definitions of 'Prolonged thirst':

For definitions, see Section 3.1.2.3.

Water should always be available in the lairage and the supply system should be designed, constructed and maintained to allow easy access to all the animals. Suckling animals are particularly susceptible to dehydration if they have not learnt to drink from troughs. It is very likely that animals panting to thermoregulate will be exposed to further dehydration in lairage.

ABMs for 'Prolonged thirst':

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 number and proportion of animals showing the ABMs reported in Table 14.

Table 14: ABM for the assessment of 'Prolonged thirst' at lairage

ABM	Description
Increased aggression at water trough	Aggressive encounters (butting, pushing, chasing away) at the water trough
Increased water intake	Animals drink frequently large quantities of water

Hazards leading to 'Prolonged thirst'

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 animals to have easy access to clean water at all times will result in severe dehydration which is considered a serious welfare concern.

Increased respiration rate, sweating or panting due to stress will also lead to dehydration, increasing the demand for water. Exposure to situations that lead to heat stress during transport or in lairage increases demand for water mainly due to moisture loss through increased respiration, panting and sweating, and therefore, heat stress will exacerbate thirst. Preventing heat stress will help to prevent thirst.

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

Keeping transport distance and duration, waiting time upon arrival at slaughterhouse and lairage duration to the minimum are preventive measures. Access to clean, cool, and fresh water in lairage is paramount to preventing heat stress in sheep and goats. It has been reported[4] that, on-average, a sheep or goat under TNZ will drink 5–10 litres of water per day. Lactating females will drink even more water. A study conducted with 3-year old ewes showed that consumption of water is 9–11% of body weight in the winter and 19–25% during the summer. Another study showed that Merino sheep drank 12 times more water in the summer than winter when it was dry and temperatures exceeded 38°C.

In lairages, the water 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.

Knowles, 1998 showed that when lambs are deprived of water for a period of at least 20 h during transport, even at high ambient temperatures, they do not drink immediately when water is offered if the source is unfamiliar. Therefore, sources of water similar to most systems used on farms should be provided at lairage. In case animals do not drink for any reasons, they need to be slaughtered without delay.

3.1.4.6. 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':

Animals experiencing fatigue will show immobility, recumbency, exhaustion and tachypnoea (for detailed description, see Section 3.1.2.4).

Assessment of fatigue at lairage can be done by counting the number and proportion of animals showing the ABMs reported in the following Table 15.

Table 15: ABMs for the assessment of 'Fatigue' at lairage

ABM	Description
Exhaustion	Conscious animals lying on the floor and not able to stand up (recumbency) or unable to move when the animal is standing. 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.
Tachypnoea	Excessive rate and depth of breathing, e.g. > 60 per minute in sheep and goats (EFSA AHAW Panel, 2011; Reddy et al., 2019).

The SCAHAW (2002) concluded that where journeys last for longer than 12 h, animals will become fatigued. Teke et al. (2018) investigated the effects of three lairage period (0, 2 or 4 h) after a 30 km journey that took 30 min on unpaved road condition on stress responses in Karayaka lambs. The results suggested that lambs could be slaughtered after short time transport with a less resting period in lairage without adverse effect on welfare.

Hazards leading to 'Fatigue'

Fatigue can also be due to the following hazards:

1) Too high effective temperature (see Section 3.1.2.4).
2) Insufficient space allowance.
3) Too long food deprivation (see Section 3.1.2.2).

4) Too long water deprivation (see Section 3.1.2.1).
5) Mixing unfamiliar animals.

Insufficient space allowance

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

The space requirement in lairage for lamb weighing less than 25 kg is around 0.30 m^2 and for other categories 0.56 m^2 (Weeks, 2008). Unshorn sheep require more space than shorn sheep to facilitate thermoregulation (Knowles, 1998). If animals are lairaged at a high density, there will be less room through which each animal can dissipate heat, and the problem will be exacerbated if the animals are fully fleeced (Knowles, 1998). Observations of lairage by Kim et al. (1994) estimated 1 m^2 per sheep was required before most animals lay down. In overnight lairage, a significantly positive correlation was found between increased space allowance and the likelihood that over two-thirds of the group was observed lying resting.

Therefore, in lairage as well, the Petherick and Phillips (2009) equation (formula 2) is recommended to calculate the minimum space allowance in a pen.

Mixing unfamiliar goats

In goats, aggressive behaviours are performed frequently within familiar group in order to maintain social hierarchy and are expressed as biting, butting, or threat displays, chases, escapes; these agonistic behaviours increase when space allowance is reduced (Tölü and Savas, 2007). Mixing can lead to increased aggression and, as a consequence, feeding and resting times decrease (Andersen et al., 2008).

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 and 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 animal reserve is too low for its energy requirement.

As a corrective measure, when animals are suffering from fatigue in lairage, they should be given good conditions to recover and be slaughtered without delay. If they cannot move, are sick or injured, emergency slaughter should be performed.

Another preventive measure is to avoid mixing unfamiliar groups of goats. Prioritise slaughter of aggressive groups of animals.

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

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

Restriction of movement: the animal is unable to lie down, stand up, have access to water and feed and escape from aggression from dominant animals.

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 (see Section 3.1.4.6), in lairage, like in transport, animals should have space to lie down and get up without being in contact with other animals, able to turn around and access water without hindrance and move away from aggression. There is no specific feasible ABM at lairage for restriction of movement, 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 (see details in Sections 3.1.2.1 and 3.1.4.6).
2) Improper design, construction and maintenance of premises (see details in Section 3.1.4.2).

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

Provision of minimum space allowance derived following the equation provided by Petherick and Phillips (2009): $A = 0.027W^{2/3}$, is considered to be a preventive measure.

Preventive measures also include design, construction and maintenance of lairage facilities to suit the behavioural needs of sheep and goats and training of staff to avoid overstocking pens, keep familiar animals together and avoid mixing unfamiliar animals.

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 animals, 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 without delay in case their welfare is impaired.

3.1.4.8. Outcome table on 'Lairage'

Table 16: Outcome table on 'Lairage'

Hazard	Welfare consequence/s occurring to the animals 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 without delay • Move the animals to a warmer area
Too long food deprivation (See Section 3.1.2.2)	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 and during 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 without delay • Provide food

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Too long water deprivation (See Section 3.1.2.1)	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 without delay • Provide water
Unexpected loud noise (See Section 3.1.3.1)	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)	heat stress, fatigue, restriction of movements, resting problem	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)	Fatigue, fear, pain, social stress,	Staff and 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 without delay
Improper design, construction and maintenance of premises (See Section 3.1.4.2)	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	• Clean and dry the lairage area • Provide bedding

ABMs: panting (heat stress), shivering (cold stress), aggression at water trough, increased water intake (prolonged thirst), exhaustion, tachypnoea, (fatigue), grinding of teeth, curling of lips (pain), injuries (pain), vocalisations (pain, fear), aggressive behaviour (social stress)

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

Procedures for handling animals should be laid down in the premises standard operating procedure (SOP).

In general, animals may be subjected to stress by inappropriate handling and movement from lairage to the point of stunning (Ivanov, 2020). According to the AVMA (2016), raceways that are too wide result in sheep turning around and becoming caught beside each other. The appropriate width is 40 cm for sheep. Chute width may need to be adjusted for exceptionally large or small animals. Same width may be considered appropriate for goats. However, unlike sheep, goats may not be fearful of humans and wedge themselves in the raceways.

A head collar or lead rope might be appropriate for some goats, where this has been used previously on farm (AWC, 2020).

Sheep have a very strong following behaviour, and an operator may have difficulty holding a sheep to prevent it from joining others. This behaviour can be beneficial to handling them in large numbers to maintain a continuous flow. As mentioned previously under unloading, the use of trained leader (judas) sheep can facilitate movement of sheep from lairage pens into the restraint. A common practice in some countries is for one operator to select a sheep and pull it towards the race leading up to the restraint, whilst another operator drives the rest of the group from behind. This kind of handling procedure is stressful for the lead sheep (Gregory, 1998).

Sheep are sensitive to distractions, such as moving or shiny objects and shadows, in the raceways and they will balk (Grandin).[7]

In general, goats are less fearful of humans and they are also used to close human contact on the farm. Therefore, handling and moving them from lairage to the point of killing can be done with minimum of stress and relative ease. Goats exhibit fewer fright responses and tend not to bunch up like sheep. The human interaction that goats are used to can result in a degree of 'stubbornness' and those handling them should be aware of this.

The welfare consequences that small ruminant might experience during handling and moving to the stunning points are impeded movement, pain and fear.

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

Definition of Impeded movement:

Difficulty of movement resulting in slipping and falling in the passageways leading from lairage to the point of stunning.

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

ABMs of 'Impeded movement'

Animal welfare, as affected by impeded movement, can be assessed by recording animals slipping and falling (AWIN, 2015). The assessment can be done by counting the number and proportion of slips and falls per animal (see description in Table 17).

Table 17: ABMs for the assessment of 'Impeded movement' during handling and moving of the animals

ABM	Description
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 (AWIN, 2015).
Falling	Loss of balance in which parts of the body other than feet and legs are in contact with floor surface (AWIN, 2015).

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 of the raceways to restraining point.

[7] https://www.grandin.com/RecAnimalHandlingGuidelines.html

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

Improper design, construction and maintenance of premises

In well-designed facilities, animals can move independently; as a result, they experience less stress, they are also easier to handle, the work of operators is greatly facilitated and made safer and also prevent animal injuries.

Passageways with obstacles, distractions and right angles are not conducive to easy handling and movement of animals. Wet and dirty floors lead to slips and falls.

Inappropriate handling:

This will happen if the handling is not appropriate; then animals might experience impeded movement, not going smoothly into the raceway, slipping, falling and eventually hurting themselves.

If animals have been injured previously, e.g. during transport or during a fight in lairage, or are suffering from lameness, impeded movement can be worsened.

Inappropriate handling such as wool pulling or dragging by skin fold or horns causes severe pain and therefore is considered a serious welfare concern.

The use of dogs for handling and moving of animals is a serious welfare concern.

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

According to the best practices at killing published by Directorate-General for Health and Food Safety (European Commission 2017), flooring must be non-slippery and kept clean in order to prevent injuries and have an effective drainage system to avoid puddles in the raceways. Passageways should allow animals to move in groups and have no sharp turns or right angles. No sharp ends or pointed objects should intrude into passageways. Also, animals may not move calmly, if they are distracted by people, noise or objects and they may stop moving forward or turn back. To avoid distractions and facilitate animal movement, passageways should have high solid sides; flooring in the lairage and in passageways should be made from the same material; drains should not be placed across passageways but at the side; shadows and reflections on the floor should be avoided; draughts blowing in the faces of the animals should be avoided; people should not block passage or within the field of vision of the animals. The layout of the slaughterhouse should allow operators to move without interrupting the animals.

As corrective measures, the first step in improving animal movement is to correct mistakes that people make while handling and/or moving animals. Training employees and stopping obvious handling mistakes will make it possible to determine if the problems with handling and movement in a particular slaughterhouse are due to people making mistakes or to a default in the design and/or maintenance of the raceway. Detection of distractions by viewing the passageway at animal level is the best option.

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

Definition of 'Pain', 'Fear':

For definition see Section 3.1.3.1.

ABMs of 'Pain', 'Fear':

See Section 3.1.3.1.

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

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

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

The most critical point of handling and moving sheep at slaughter is to coerce animals with mob instinct to form a single file. Grandin proposed a system for moving sheep with two gates that continuously revolve (Figure 2). A funnel shaped entrance will work well for sheep and the half circle crowd pen takes advantage of the natural tendency of sheep to go back to where they came from.

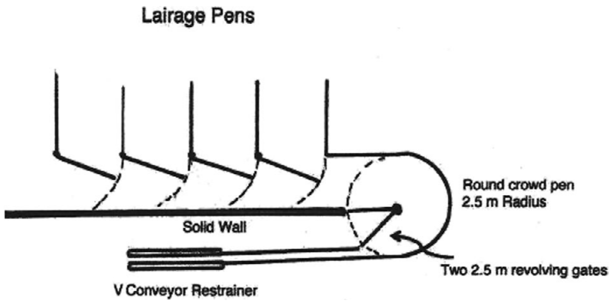


Figure 2: Illustration of crowd pen used for sheep and goats (Grandin, 2018[8])

In this design, the revolving gate 1 is secured alongside the solid wall of the lairage as shown in the figure above to allow animals from the lairage pen to enter the circular crowd pen. When sufficient number of animals are let into the crowding pen, the lairage gate is closed and the revolving gate is used to move animals in the circular crowd pen to enter the raceway leading to the V conveyor restrainer. The revolving gate 2 at the entrance to the raceway can be used to block the entrance to the raceway, if necessary.

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

It has been suggested (European Commission, 2017) that passageways should have a constant width sufficient for two animals to move forward side by side. Alternatively, passageways may be designed with two single rows separated by a barred, open side in the middle that enables one animal to see the other on its side. The width of the passageway may be reduced into a single file to enter the stunning equipment. Well-designed passageways can facilitate the transition of sheep and goat from a large passageway into a single row before restraining and stunning.

A crowd pen may also be used to move groups of sheep and goats from lairage pens into passageways (European Commission, 2017). A crowd pen, also known as a 'forcing pen', consists in a circular space, generally a full half-circle. It has two solid gates: one remains static, while the other is moved by an operator to push animals into the single race/the entrance to the restrainer. In order to be effective, the race should not appear as a dead-end. It should be straight or bend only after a sufficient length of race. Otherwise, the animals will not enter willingly into the single race.

[8] https://www.grandin.com/design/chute.ramp.race.design.html

3.1.5.3. Outcome table on 'Handling and moving of the animals to the stunning or killing area'

Table 18: Outcome table on 'Handling and moving of the animals to the stunning or killing area'

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Inappropriate handling (See Section 3.1.4.2)	impeded movement, pain, fear	Staff, equipment, facility	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 • Use a leader sheep	• Correct staff to discontinue inappropriate handling
Improper design, construction and maintenance of premises (See Section 3.1.4.2)	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
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 • Use a leader sheep	• Correct staff to discontinue forced movement of animals • Allow time for animals to move spontaneously

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Unexpected loud noise (See Section 3.1.3.1)	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 (fear, pain), reluctance to move (pain, fear), escape attempts and turning back (fear), slipping and falling (impeded movement)					

3.2. Description of 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.

Restraint:

Restraint means the application to an animal of any procedure designed to restrict its movements in order to facilitate effective stunning and killing. Restraining methods used in slaughterhouses are common to both mechanical and electrical stunning methods used for sheep and goats.

Sheep and goats are in many cases slaughtered in the same slaughterhouse using the same restraining devices. Restraining facilities in slaughterhouse will vary depending on the throughput. Some abattoirs may use group stunning pens, where several animals are held in a pen and the operator may restrict the movement of an animal prior to stunning. These are variable in design and consideration must be given to ensuring that there are facilities that allow the size of the pen to be reduced in order to deal with small numbers of animals. In other slaughterhouses animals are usually restraint in specially designed restraining devices like V-type restraining boxes, central track restrainer or V-shape moving conveyor. The restrain devices should be adjustable to the size and type of animal. Since sheep and goats have different anatomy, e.g. goats have longer legs and narrower girth than sheep, the restraint needs to be adjusted to suit the type of animal. Furthermore, goats will also attempt to climb. Manual head-only electrical and captive bolt stunning of sheep and goats in small groups, without any form of physical restraint, is practiced in low throughput slaughterhouses in some countries. Ideally, when animals are stunned in the groups, a small group of animals may be confined in a stunning area and one operator would perform stunning, and another operator would shackle, hoist and bleed the stunned animals. The Food Standards Agency in the UK (FSA, 2017); has produced best practice guidelines. Similarly, the Humane Slaughter Association (HSA[9]) also published Best Practice Guidelines for so called 'Group-Stunning Systems'. In those systems, even though the system is called 'group stunning', animals are stunned individually.

Another method involves holding a group of sheep and goats (typically 10–15) in a crowd pen and move them one at a time into a stun-pen in order to manually restrain, stun and bleed them (Figure, 3; European Commission, 2017). The size of the stun-pen will vary but should not permit too many animals to be held in it and will often include a crowding gate which allows the size of the stun-pen to be reduced such that, as the number of animals declines, there is less room for the remainder to move away from the operator.

9 http://www.hsa.org.uk/downloads/publications/group-stunning.pdf

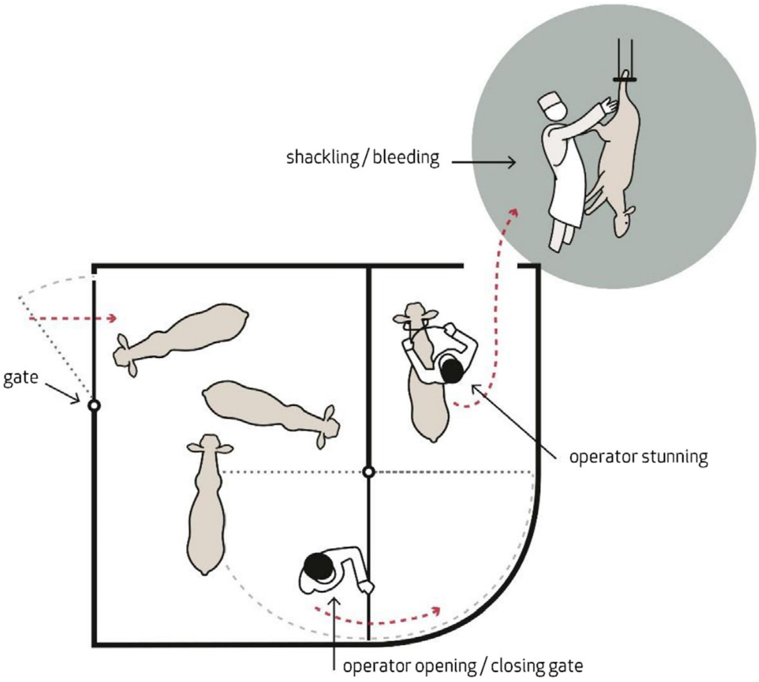


Figure 3: An illustration of stunning of sheep in or near the group (European Commission, 2017)

Several types of mechanical restraints are also used for stunning individual sheep and goats either manually or automatically in high throughput slaughterhouses. Illustrations of central track restraining system is shown in Figures 4 and 5 (European Commission, 2017). In these restraining systems, the stunned animals are dropped on to another conveyor and the unconscious animals are manually shackled, hoisted and bled.

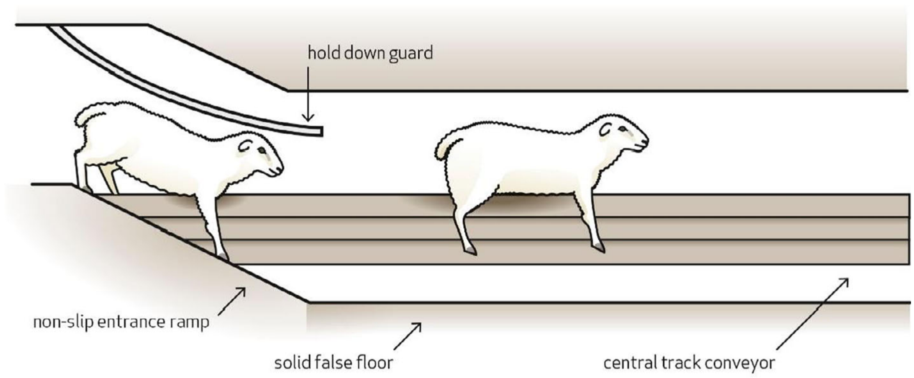


Figure 4: Sheep entry into a central tack restraint (European Commission, 2017)

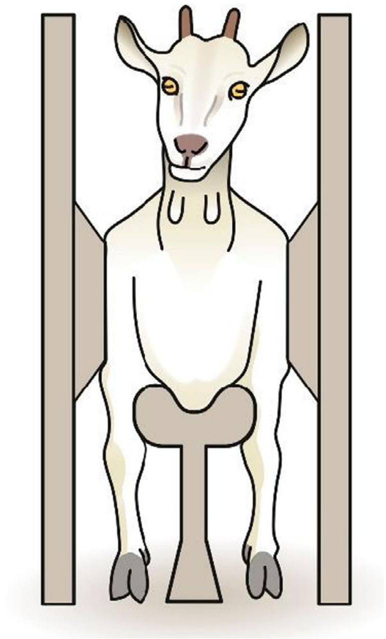


Figure 5: Goat restrained in central track restraint (European Commission, 2017)

Some slaughterhouses may use V-restrainers for sheep and goats (Figures 6 and 7; European Commission, 2017). Animals are loaded into V-shaped restraining conveyors that carry them to the point of electrical or mechanical stunning. The stunned animals are dropped on another conveyor and then shackled, hoisted and bled.

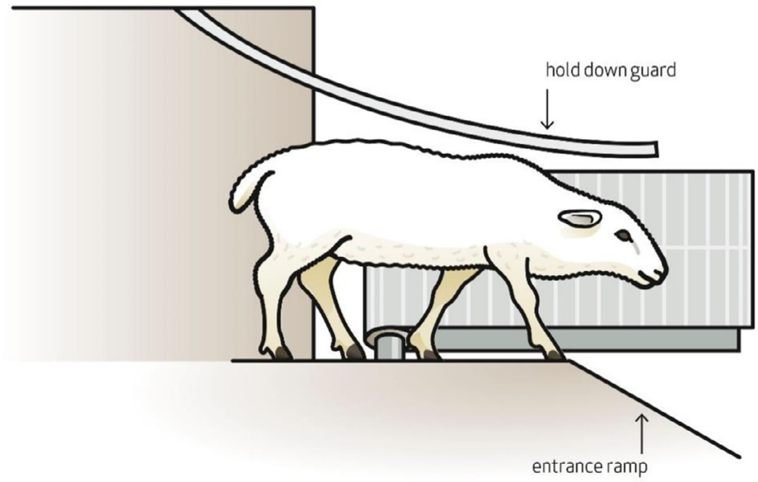


Figure 6: Sheep entry into a V-restraint (European Commission, 2017)

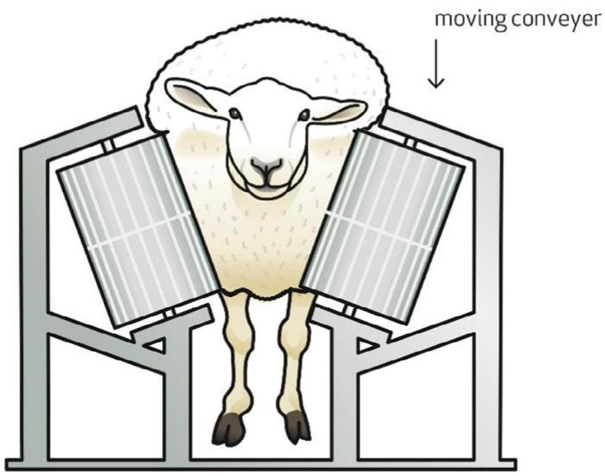


Figure 7: Sheep restrained in V-shaped conveyor (European Commission, 2017)

In this kind of restraints, the width of the conveyors and the slope of the loading system need to be adjusted to suit the size of the animal in order to avoid 'cliff edge' visual perception by the animal, thus ensuring good welfare.

The V-shaped restraint, when designed for sheep, may not always be suitable for goats depending on the design because goats have longer legs and narrow girth than sheep (AWC, 2020).

In Europe, for slaughter without prior stunning sheep and goats must be mechanically and individually restrained (EC 1099/2009 art. 15). However, sheep and goats are restrained using several procedures and these will be addressed under the Section 3.3.2, Bleeding without stunning.

Stunning

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 sheep and goats 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, percussive blow to the head or firearms with 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 3.2.2.1). Head-only electrical stunning can be performed in combination with or immediately followed by passing an electrical current through the body to induce fibrillation of the heart or cardiac arrest (head-to-body stunning 3.2.2.2).

In addition, Rodríguez et al. (2016) investigated the feasibility and animal welfare implications of using high concentrations of carbon dioxide (90% CO_2 by volume in air) for stunning lambs. In this study, changes occurring in the middle latency auditory evoked potentials (MLAEPs), recorded as a part of the EEGs, were used to determine the time to loss of consciousness and behaviour, i.e. head shaking, sneezing, gasping and gagging, was used to ascertain the aversive reactions and stress of induction of unconsciousness in lambs weighing 19–25 kg. Each animal fitted with recording devices was loaded into a dip-lift system and lowered into a chamber such that the animals were exposed progressively to a final concentration of 90% CO_2 in 66 s. The results indicated that the average time to loss of consciousness was 48 s. During the period of induction of unconsciousness, lambs exhibited head shaking and sneezing, gasping and increased respiration rate. Based on these results, the authors concluded that these behaviours occurring when the animals are conscious, is evidence that induction of high concentration of CO_2 anaesthesia is not immediate and lambs may suffer from fear, pain and/or stress. The presence of these behaviours clearly indicates aversion to exposure to 90% CO_2. Owing to this, stunning with CO_2 at high concentration (90% by volume in air) is considered a serious welfare concern.

There are no published data concerning the animal welfare implications of using concentrations lower or higher than 90% and therefore no conclusions could be drawn. Similarly, the Panel is not aware of research on other gas mixtures on sheep and goats.

Independently of the specific stunning methods, the identified welfare consequences for Phase 2 (stunning) are pain and fear. Therefore, differently from previous chapters, these two welfare consequences are presented below in Section 3.2.2 (pain and fear are presented together as they have same ABMs), while in the specific stunning methods sections only hazards and their management are presented.

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

Definition of 'Pain and fear':

'Pain' and 'Fear' are defined in Section 3.1.3.1.

During the stunning phase, animals 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 shackling, hoisting, and bleeding. Furthermore, recovery of consciousness might occur in effectively stunned animals if bleeding was delayed or was not properly carried out, i.e. blood vessels supplying oxygenated blood to the brain are not completely cut or bleeding was impeded.

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 number and proportion of 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
Vocalisation	Bleating in goats and vocalisation in lambs (Goldberg, 2018).	Pain, Fear
Struggle or escape attempts	Animals struggle or try to escape due to inappropriate restraint (modified after AWC, 2020 and European Commission, 2017)	Pain, Fear
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (Gregory, 1998; Faucitano and Pedernera, 2016).	Pain
Grinding of teeth, curling of lips	Teeth grinding and curling of upper lip in sheep (Manteca et al., 2017; Goldberg, 2018)	Pain

3.2.3. Electrical stunning

There are two types of electrical stunning used for sheep and goats: (1) head-only electrical stunning and (2) head-to-body electrical stunning. While the process description is given separately (see 3.2.3.1 and 3.2.3.2, respectively), the hazards, animal welfare assessment and management, as well as the outcome table are commonly presented for both types of 'electrical stunning'.

3.2.3.1. Head-only electrical stunning

Head-only electrical stunning is based on the principle of passing an electric current of enough magnitude through the brain of the animal that induces a generalised epilepsy (see for details EFSA, 2004). The electrodes or stunning tongs can be applied manually or mechanically. The effectiveness of head-only electrical stunning depends upon factors including (i) the stunning electrodes (tongs) should be ideally placed on either side of the head, between the eyes and base of the ears, such that they span the brain (ii) the amount of voltage (V) used in the stunner must be high enough to break the electrical resistance offered by the presence of fleece/wool and various tissues between the two electrodes; (iii) the amount of current (Amps) delivered to the brain must be enough to induce immediate onset of epilepsy; and (iv) the duration of current application. In addition, the waveform of the current (sine wave alternating current (AC) or pulsed direct current (DC)) and frequency of the current also determine the welfare outcomes.

Effective head-only electrical stunning induces immediate loss of consciousness that is characterised by immediate collapse of the animal and tonic immobility during exposure to the stunning current. Immediately after exposure to the current, animals show tonic seizure followed by clonic seizures, indicative of generalised epilepsy. Typically, during the tonic phase animals are in a state of tetanus and stretch out their fore- and hind- legs under the belly, breathing is absent, and the eyeballs are fixed or rotated into the socket (Figure 8; European Commission, 2017). The tonic phase is followed by the clonic phase which manifests with kicking of legs, paddling or galloping movements (Gregory, 1998; Velarde et al., 2000; EFSA AHAW Panel, 2013a). Reflexes that would require brain control are also abolished during generalised epilepsy, e.g. the palpebral (elicited by touching eyelashes or inner or outer canthus of the eye), corneal (elicited by touching the cornea) and pupillary reflexes and response to painful stimuli (EFSA AHAW Panel, 2013a).

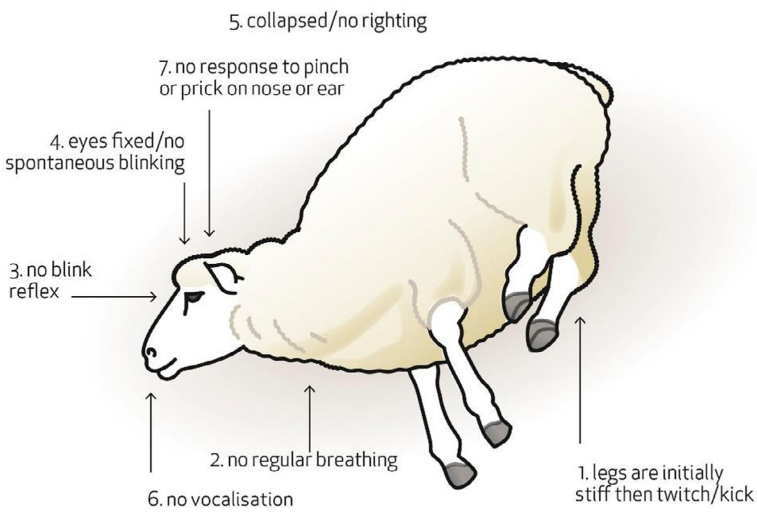


Figure 8: Physical signs (ABMs) of loss of consciousness following head-only electrical stunning in sheep and goats (European Commission, 2017)

Effective head-only electrical stunning must be followed by bleeding within 8 s (EFSA, 2004). Bleeding should be ideally performed during tonic phase (see Section 3.3 Bleeding for details). Effectively stunned animals can recover consciousness rapidly following the termination of generalised epilepsy manifested as tonic–clonic seizures and it begins with the resumption of spontaneous breathing (Velarde et al., 2002). Any animal showing spontaneous breathing should be re-stunned or a back-up method should be applied immediately to prevent recovery of consciousness. In group stunning situations, the delay between stunning and bleeding becomes more critical, because there could be a considerable delay between stunning and bleeding of the last animal in the group if only one operator performs the process of stunning, shackling, hoisting and bleeding of animals.

In sheep and goats, the stunning tongs or electrodes should be placed between the outer corners of the eyes and the base of the ears on either side of the head (Figure 9).

Head-only electrical stunning with minimum currents of as low as 0.343–0.485A has been reported to be effective in lambs (Velarde et al., 2000). Llonch et al. (2015) also reported that head-only and head to body electrical stunning with 0.3, 0.5 and 0.7 A induce effective stunning similar to 1.0 A in lambs and kid goats.

This study was submitted to EFSA for an assessment whether effective stunning could be achieved at lower current intensity. The study was not considered adequate for a full welfare assessment of the suggested change in current intensity, because it did not fulfil the eligibility criteria and the reporting quality criteria defined in the EFSA guidance on the assessment criteria for studies evaluating the effectiveness of stunning interventions that was in place at that time[10] (EFSA AHAW Panel, 2013b).

[10] EFSA guidance 2013 has been revised in order to permit innovation of new or modified stunning methods.

In addition, a previous guidance provided by the Humane Slaughter Association (HSA, 2000) recommended 1.0A for sheep and goats and 0.6A for lambs and goat kids but changed to 1.0A for both the categories in their more recent updated guidance on electrical stunning of red meat animals (HSA, 2016a). This is probably due to the fact the pioneering studies into head-only electrical stunning of sheep clearly demonstrated (by analysing EEGs and neurotransmitters released in the brain as a consequence of electrical stunning) that a minimum of 0.2 s application of 1.0A was found to be necessary to induce epileptiform activity in the brain indicative of immediate onset of unconsciousness and sustained period of unconsciousness that outlasts the time to onset of brain death due to exsanguination (Cook et al., 1995, 1996).

Berg et al. (2012) also investigated the effect of head-only electrical stunning of lambs in two separate trials. In the first trial, lambs were stunned with 0.6, 0.8, 1.0 and 1.25 A delivered using a 50 Hz sine wave AC for 10.5 s and, in the second trial, lambs were stunned with 1.25 A for 3 or 14 s. In both trials, the effectiveness of head-only electrical stunning was ascertained using corneal reflex, eye movement, rhythmic breathing, head righting reflex and kicking during tonic phase. Based on the results, the authors concluded that lowest current level resulted in unsatisfactory stun in majority of the animals and short stun duration increased the risk of poor stun quality. In this regard, the stun quality was judged to be poor in 6.5, 11, 29 and 53% of animals that were stunned with 1.25, 1.0, 0.8 and 0.6 A, respectively. The stun quality was also judged to be poor in 6% and 33% of animals that were stunned for 14 and 3 s, respectively. These results clearly demonstrate that stunning of lambs with a current of 0.8 or 0.6 A will result in ineffective stunning in a significant proportion of animals, and the outcome will be worse when the stun duration is short, i.e. 3 s.

In the light of available scientific evidence at present, a minimum of 1.0 A is required to guarantee effective electrical stunning of all sheep and goats, including lambs and goat kids. This is because the probability of ineffective stunning increases when the current level is lower than 1.0 A, especially due to the presence of wool and misplaced head electrical stunning tongs (Berg et al., 2012). Based on the European Commission factsheet (European Commission, 2017), we suggest minimum currents 1.0 A for stunning sheep and goats, delivered using 150–400 V, for at least 2 s. However, immediate onset of unconsciousness that persist until death should always be confirmed based on ABMs (see Section 3.2.3.4).

Figure 9: Head-only electrical stunning of sheep (European Commission, 2017)

In certain EU countries there is also a manual method of head-only electrical stunning of goat kids that is very similar to the method used for rabbits. In this method, a pair of 'V' shaped electrodes mounted on the wall is used. An operator takes out a goat kid from the transport crate and uses one of his hands to support under the belly of the animal and uses another hand to hold and press the animal's head against the stunning electrodes. The speed of the line can be up to 300–600 goat kid/hour. The electrical parameters used are: 50 Hz, 300 V, 1.0 A, applied for 1.5 s.

3.2.3.2. Head-to-body electrical stunning

Head-to-body stunning can be performed using a single current cycle in which electrodes are placed on either side of the head to induce unconsciousness and a third electrode is placed on the body, close to the position of the heart to induce cardiac ventricular fibrillation (Figure 10), which is more common in high throughput slaughterhouse. On the other hand, a two current cycles application may be used which involves head- only electrical stunning first and then immediately followed by a second current application across the chest (behind the elbow) to induce cardiac ventricular fibrillation (Figure 11).

Irreversible stunning of animals by head-to-body application of an electric current eliminates the chances of recovery of consciousness and stun-to-bleed interval is not critical anymore. Therefore, this method is considered to be better on animal welfare grounds. For this to occur, head-to-body stunning should always be performed using a 50 Hz sine wave alternating current (AC), as higher frequencies do not induce cardiac ventricular fibrillation. The cardiac arrest cycle should be applied without delay, and within 15 s after the head-only stun. Unconsciousness must be confirmed in animals before the application of cardiac arrest current cycle.

Figure 10: Head-to-body electrical stunning of sheep with single current cycle (Source: HSA)

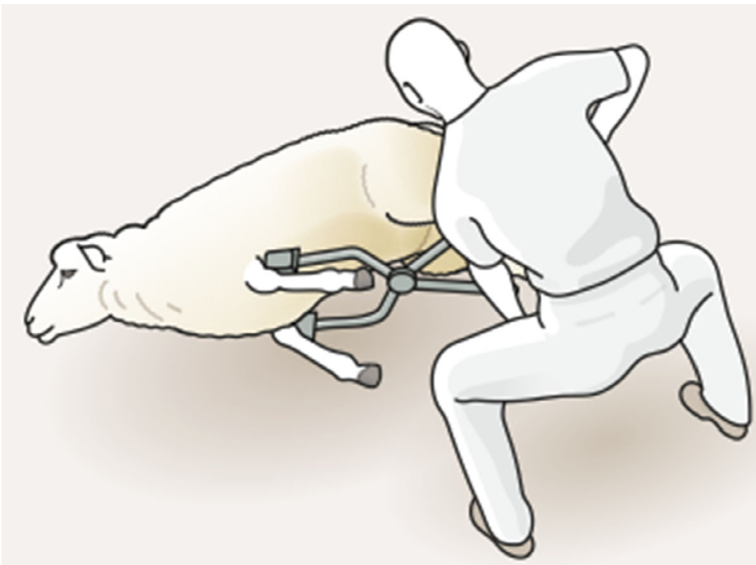


Figure 11: illustration of the application of electrodes on the chest to apply the cardiac arrest current cycle in sheep rendered unconscious first by head-only electrical stunning (European Commission, 2017)

The amount current applied in European slaughterhouses vary between 1.0A and 1.3A, and for Voltage between 220 and 400 V (European Commission, 2017). The duration of head-only electrical stunning varies between 3 and 8 s, and 3–15 s for the application across the chest.

Effective head-to-body electrical stunning is characterised by tonic seizure during exposure to the stunning method. After exposure, animals may have convulsions comparable as the ones described for head-only electrical stunning. The convulsive movements will change to paddling movements and relaxation and loss of muscle tone recognised by drooping ears and limp legs. Breathing is absent and eyes are fixed or rotated in their sockets. Corneal and palpebral reflex are abolished and reaction to pain stimuli are absent during the period of unconsciousness (see process description head only electrical stunning).

However, during manual stunning involving two electric current cycles method, the time interval between the two applications is critical. Head-only electrical stunning leads to immediate collapse of the animal and onset of tonic–clonic seizures and these may impede with the application of second current cycle across the chest to induce cardiac ventricular fibrillation. Therefore, additional care should be taken to apply the second cycle before the effectively stunned animals recover consciousness, which can be recognised first from the resumption of spontaneous breathing.

3.2.3.3. Hazards identification for 'Electrical stunning'

Hazard leading to 'Pain and Fear'

1) Inappropriate restraint.
2) Wrong placement of the electrodes.
3) Induction of cardiac arrest in conscious animals.
4) Poor electrical contact.
5) Too short exposure time.
6) Inappropriate electrical parameters.

Inappropriate restraint:

Manual application of head-only electrical stunning of animals in a group situation may be difficult as animals, especially sheep, tend to group together and goats being more agile might jump if not properly restrained. They hide their heads under each other. As a result, application of the tongs can be difficult, which can lead to misplacement of the stunning tongs or pre-stun shocks. This means that the lack of restraint can be a hazard for poor application of the stunning method.

Excessive pressure applied to sheep and goats during mechanical restraint could lead to pain and fear. Restraining goats in V-type restraint designed for sheep can be problematic, when the restraint device cannot be adjusted to the size of the goats. Stunning animals when crowded in a group increases the risk of the animal close to the one being stunned receiving electric shocks, leading to pain and fear.

Wrong placement of the electrodes:

Correct placement of the stunning electrodes on animals with horns can be difficult. During head-to-body stunning with a single current cycle, the head electrodes may be 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. During manual stunning, animals may struggle and move their heads if there is a delay between the placement of electrodes and pressing the button to switch on the stunning current, leading to slipping of stunning electrodes resulting in inadequate or failure to stun. Factors leading to wrong placement of the electrodes are variation in the size of animal/presence of horns, inadequate restrain of the animals and malfunctioning of the equipment in case of automated restraint/stunning systems.

Orford et al. (2016) evaluated three placements of electrodes in a sheep slaughterhouse: in front of the ears, in line with the ears and behind the ears and towards the upper neck; and all the electrode positions were found to be satisfactory provided a minimum current of 1.0A was delivered. Berg et al. (2012) reported that 33% of lambs that were judged to be ineffectively stunned had incorrect stunning tong placements.

Velarde et al. (2000) investigated head-only electrical stunning of sheep with 250 V delivered for 0.2 s using 50 Hz sine wave AC. In this study, electrical stunning was performed by using pair of tongs with button shaped flat, round electrodes, used two electrode positions: between the eyes and base of the ears on either side of the head (frontal position), or behind the ears on the occipital condyle on either side. The results showed that the proportion of successfully stunned animals was statistically significantly higher in the animals stunned with the tongs in a frontal position than in those stunned with them in a caudal position. The interval between stunning and return of sensibility to pain was affected significantly only by the position of the tongs, being longer in animals with them in a frontal position than in those with them in a caudal position. Based on these results, the authors recommended tong position is between the eyes and the base of the ears on both side of the head, preferably on wet skin.

Induction of cardiac arrest in conscious animals

Another hazard related to pain during to head-to-body stunning will be if the second current cycle spans the heart in conscious animals, due to ineffective head-only electrical stunning or recovery of consciousness due to a prolonged interval between the two electrical cycles.

Poor electrical contact:

The electric contact between the animal and stunning electrodes is not sufficient to facilitate current flow necessary to achieve immediate stunning. Good electrical contact with the skin may be difficult due to hair/fleece. For example, Orford et al. (2016) developed a 5-point scale to assess the extent of wool covering over the head in sheep and its effect on the head-only electrical stunning.

The electrical stunning electrode used in this study had one pin in each to penetrate the wool cover. The results of this study showed a trend of lower amount of current being delivered due to increasing wool cover and current applied to individual sheep also decreased steadily during stunning application due to build-up of dirt and operator fatigue.

The effects of the presence or absence of wool and wet or dry electrodes were evaluated by Velarde et al. (2000). The results showed that the proportion of successfully stunned animals was statistically significantly higher in the animals stunned with wet electrodes than in those stunned with dry electrodes and also in the animals without wool than in those with wool.

Electrical contact on the animal may be interrupted due to lack of or inappropriate restraint, leading to ineffective stunning causing pain and fear.

Too short exposure time:

It occurs when the duration of exposure to the electrical current is too short to result in epileptiform activity in the brain and/or cardiac arrest in all animals. In unrestrained animals, the contact between the stunning electrodes and the animal may be lost due to the fact the initial current flow caused the collapse of the animal and the operator fail to maintain continuous electrical contact.

Inappropriate electrical parameters:

The electrical parameters (current, voltage and frequency) are not adequate to induce immediate loss of consciousness and/or death; i.e. less than 1.0A delivered using more than 50Hz). Berg et al. (2012) reported that the stun quality was poor in 6 and 33% of animals that were stunned for 14 and 3 s, respectively, suggesting that stun duration is a key factor especially, i.e. less than 1.0A delivered using more than 50 Hz).

Several factors can contribute to this hazard (see Outcome Table in Section 3.2.3.6). 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.

Berg et al. (2012) reported that the percentage of ineffectively stunned lambs increases considerably when the stunning current is lowered below 1.0 A (i.e. 6.5, 11, 29 and 53% of animals were ineffectively stunned at 1.25, 1.0, 0.8 and 0.6 A, respectively).

Induction of cardiac arrest during head-to-body electrical stunning can be achieved by using a 50-Hz sine wave AC only and use of higher frequencies will fail to induce cardiac arrest.

3.2.3.4. Assessment of animal welfare (ABMs) for 'Electrical stunning'

During restraint, the welfare consequences are pain and fear. If the stunning is ineffective or if the animals recover consciousness, the welfare consequences are pain and fear due to the 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 cutting both carotid arteries and during bleeding.

The assessment of the state of consciousness leads to two possible outcomes: outcomes of consciousness and outcomes of unconsciousness (EFSA AHAW Panel, 2013a). Ideally, no animal should remain conscious due to ineffective stunning or recover consciousness following stunning; however, it is possible that some animals are conscious in case they were exposed to these hazards listed above.

ABMs related to consciousness were selected in a previous opinion (EFSA AHAW Panel, 2013a) and are described in full in the table below (Table 20). Assessment of state of consciousness during stunning can be done by counting the number and proportion of animals showing the ABMs described in Table 20.

Table 20: ABMs for assessment of 'State of consciousness' after electrical stunning (EFSA AHAW Panel, 2013a)

ABMs	Description
Posture	Effective head-only electrical stunning will result in immediate collapse or loss of posture in animals that are not restrained or prevented from doing so. Ineffectively stunned animals, on the other hand, will fail to collapse or will attempt to regain posture after collapse (EFSA AHAW Panel, 2013a).
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.
Corneal reflex	The corneal reflex is elicited by touching or tapping the cornea. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus. Unconscious animals may also intermittently show a positive corneal reflex (EFSA AHAW Panel, 2013a).
Palpebral reflex	The palpebral reflex is elicited by touching or tapping a finger on the inner/outer eye canthus or eyelashes. Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus (EFSA AHAW Panel, 2013a).
Vocalisations	Conscious animals may vocalise (bleating in goats and vocalisation in lambs, Goldberg, 2018), and therefore purposeful vocalisation can be used to recognise ineffective stunning or recovery of consciousness after stunning. However, not all conscious animals may vocalise (EFSA AHAW Panel, 2013a).
Spontaneous blinking	Conscious animals may show spontaneous blinking – the animal opens/closes eyelid on its own (fast or slow) without stimulation - 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 (EFSA AHAW Panel, 2013a).

These ABMs were therefore included in the following flowchart for head-only electrical stunning (Figure 12), including toolboxes of ABMs to be used at three key stages to monitor the state of consciousness. It is to be noted that these ABMs are not selected based on sensitivity and specificity and therefore they are not ranked in order of reliability. 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, 2013a). In case outcomes of consciousness are observed in key stage 1, then an intervention should be applied (i.e. a backup method). After application of a back-up method, the monitoring of unconsciousness according to the flowchart, 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.

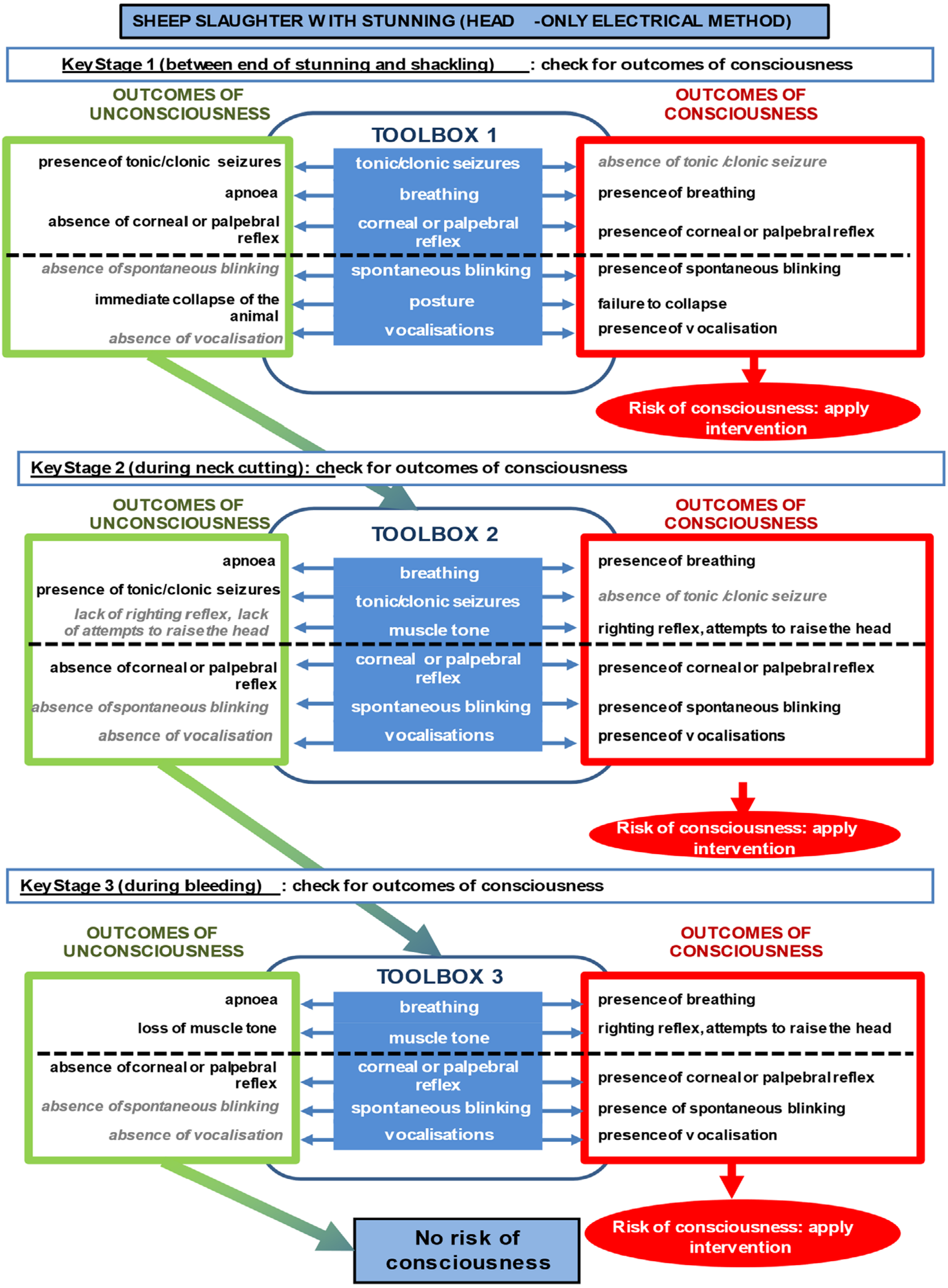


Figure 12: Flowchart for monitoring electrical stunning methods of sheep and goats (EFSA AHAW Panel, 2013a)

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

Pain and fear during restraint and application of 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 and bleeding 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. The use of too much pressure, shouting, hitting or lifting by horns or wool of the animals during handling to form a single line raceway or to load into a restraint will lead to pain and fear.

According to the best practices at killing published by the Directorate-General for Health and Food Safety, (European Commission 2017), sheep and goats can be stunned in a stun pen without restraining them. For efficient throughput, it is best operated by at least two people. The flow of animals is managed by gradually narrowing the pen (funnel) with a barred gate at the end. Ensure the stun pen is of a size that allows easy stunning, shackling, and hoisting. Two sheep might be housed in a pen of 3 m^2 or 5–7 sheep in a pen of 6 m^2.

In mechanical restraints, animals should be held firmly and presented to the operator to perform effective stunning. However, all parts that press against the animal should be equipped with pressure limiting devices that automatically prevent excessive pressure from being applied on the animal.

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. It is also important to note that the restraint should be adjusted to suit animals of different sizes and weight range to minimise pain and fear. Duration of restraint should be as short as possible. 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.

Restraints used for goats should have a supporting metal frame underneath and the operator will need to ensure that there is adequate clearance for the goats' legs below the conveyer and that goats are correctly supported. If it is considered that the V-restrainer is not suitable for restraining goats, then the premises SOP must reflect this and provide guidance on an alternative process for restraining goats (AWC, 2020). It is important to make sure the restraining system does not press excessively against the animal and causes discomfort.

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

The 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 maintenances of the equipment is essential to prevent hazards that might lead to ineffective stunning. Orford et al. (2016) recommended that stunning electrodes may be modified to increase the area of contact with the head by increasing the number of pins, which would help maintain the impedance to current flow at low levels and water jets should be focussed towards to the point of contact between the stunning electrodes and the head of the animal.

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.

Several factors influence the welfare outcomes of electrical stunning (European Commission, 2017): good placement of the tongs can be difficult on animals with horns and on sheep with woolly heads. Use electrodes with pins or with wet pins for woolly animals would help to overcome the problem. Alternatively, one can remove wool from the area where the electrodes will be positioned on the animal. In contrast with the EC/2017, literature suggest wetting the area with water (especially salted water) can also increase electrical contact. Ensure the tongs are the correct size for the animal. Ensure the tongs are not corroded. Keep them clean at all times. There should not be any delay between the stunning electrode placement on the animal and switching on the electric current. Some animals, especially goats, may be too active. They may require individual restraining to enable good positioning of the tongs. Stunning tongs should not be used as an aid to move animals.

In case outcomes of consciousness appear after stunning, an appropriate back up stunning method should be applied without delay to mitigate the welfare consequences.

3.2.3.6. Outcome table on 'Electrical stunning'

Table 21: Outcome table on 'Electrical stunning'

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
(Inappropriate) restraint (See Section 3.2.3.3)	Pain, fear	Staff, equipment, facility	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 3.2.3.3)	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
Induction of cardiac arrest in conscious animals (See Section 3.2.3.3)	Pain, fear	Staff	Ineffective stunning or prolonged interval between the two current cycles	• Ensure effective of stunning • Apply cardiac arrest current cycle without any delay	• Re-stun the animal
Poor electrical contact (See Section 3.2.3.3)	Pain, fear	Staff, equipment	Lack of skilled operators Poorly designed, constructed and maintained equipment Intermittent contact Burning of the wool	• 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 • Wetting of the fleece/wool	• Use of a back-up method

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Too short exposure time (See Section 3.2.3.3)	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
Inappropriate electrical parameters (See Section 3.2.3.3)	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 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, grinding of teeth, curling of lips (pain, fear), signs of consciousness after stunning (as a prerequisite for experiencing pain and fear)

3.2.4. Captive bolt stunning

Captive bolt stunning induces immediate loss of consciousness and sensibility in animals through concussion of the brain upon the impact of the bolt on the skull. The neurophysiological basis of brain concussion and the consequences of structural damage occurring to different regions of the brain are well documented in the scientific literature (EFSA, 2004).

3.2.4.1. Penetrative captive bolt stunning

Penetrative captive bolt powered by cartridge is the most commonly used method to stun sheep and goats. The gun powder content (strength) of the cartridge 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. 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.

Sheep and goats have extremely variable skull morphology particularly with regard to the presence, size and internal complexity of the frontal sinuses (AWC, 2020). These are air-filled paranasal spaces, located within the expanded frontal sinuses which occasionally extends up into the horn-cores (Farke, 2010). It has been suggested that the enlarged frontal sinuses of horned sheep and goats may be an adaptation for head-to-head combat and that these structures may have a shock absorbing function – protecting the brain from impacts to the horns (Farke, 2008). The sinuses are defined by two layers of cortical bone: one at the outer table of the skull (the 'external cortex') and one forming part of the surface of the endocranial cavity ('internal cortex'). Bony struts (usually numbering between four and six on each side in goats, with a typical thickness of 1 mm or less) may divide the sinuses into a series of interconnected chambers. Comparative morphological analysis suggests that relative frontal sinus size and complexity, as well as ramming behaviour, has a strong phylogenetic component (Farke, 2010). Both sheep and goats have an extensive frontal sinus that occupies the entire frontal bone, but the sinuses are less prominently strutted in goats compared to sheep (Farke, 2010). Particularly in older males and horned goats the sinuses may absorb the energy from a non-penetrative captive bolt device or reduce the depth of penetration of the bolt into the brain when a penetrative captive bolt stunning device is deployed. Both could result in reduced effectiveness of the stun (Cooney et al., 2012). Collins et al. (2017) demonstrated using adult goat cadavers and assessment of the effects of firing penetrating captive bolt using gross pathology and CT and MRI scans that penetrative captive bolt (PCB) can be effectively used to induce brain trauma potentially sufficient to result in stunning and unconsciousness of live goats. Plummer et al. (2018) evaluated the use of penetrative captive bolt (Cash Special captive bolt pistol, 0.25 calibre yellow cartridge; Accles and Shelvoke Ltd, Sutton Coldfield, West Midlands, England) in adult goat cadaver and anaesthetised goats. The shooting position used in this study was as recommended by AVMA (2016) as presented in Figure 16. The results of this study showed consistent disruption of the midbrain and thalamus in all goats. Immediate cessation of breathing followed by a loss of heartbeat in all 10 of the anesthetised goats.

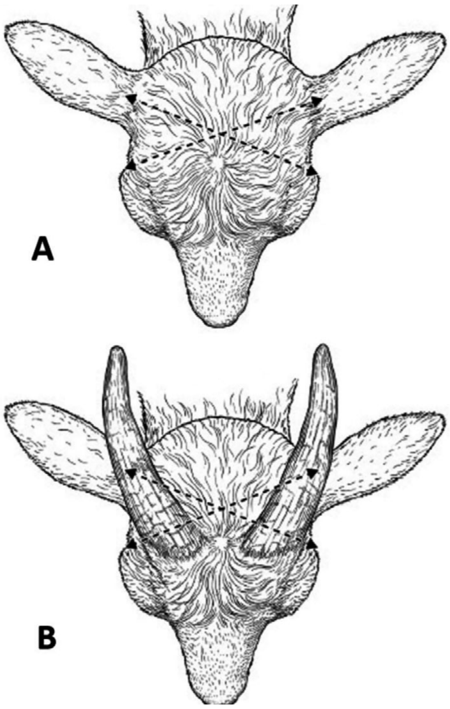


Figure 13: Schematic depictions of the method for determining the proper anatomic site for shooting of a polled goat (A) and horned goat (B) by use of a firearm or captive bolt device by Plummer et al. (2018)

In Figure 13, the optimal shooting site represents the intersection of two lines, each of which is drawn from the lateral canthus of one eye to the middle of the base of the opposite ear.

The correct position for stunning sheep depends on whether the animal is polled (hornless) or horned. For polled sheep, the muzzle of the captive bolt stunner should be placed on the highest point of the head, and on the midline, aiming straight down (Figure 14; HSA, 2016b).

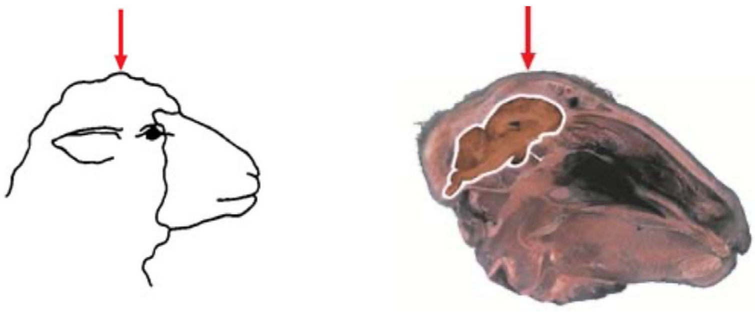


Figure 14: Ideal captive bolt shooting position for polled sheep (HSA, 2016b)

For horned sheep and goats, the muzzle of the stunner should be placed on the mid-line, behind the ridge between the horns, and aimed towards the base of the tongue (Figure 15; HSA, 2016b).

Figure 15: Ideal captive bolt shooting position for horned sheep and goats (HSA, 2016b)

The Humane Slaughter Association (HSA, 2016b) advices that for captive bolt stunning of all goats the bolt should be placed behind the bony mass on the mid-line and aimed towards the base of the tongue, irrespective of whether they have horns or not (Figure 16). Collins et al. (2017) also suggested a shot position slightly more caudal (back of the head) would be effective.

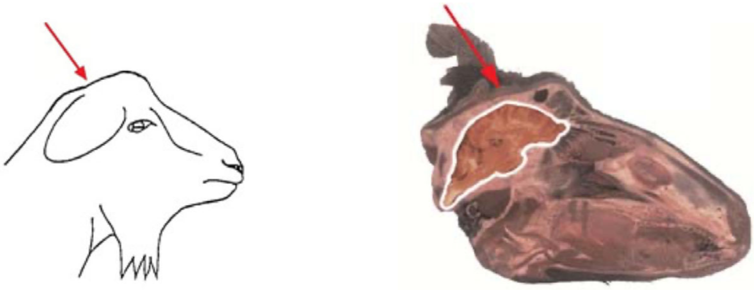


Figure 16: Ideal captive bolt shooting position for goats (HSA, 2016b)

According to the AVMA euthanasia guidelines (2020; Figures 17 and 18), for polled sheep or goats (A), PCB should be placed perpendicular to the skull over the anatomic site identified as slightly caudal to the poll (the crown or the highest point on the head) at the intersection of two lines drawn from the outside corner of each eye to the middle of the base of the opposite ear. Alternatively, a site located on the dorsal midline of the head, which corresponds with the external occipital protuberance of the skull, may be used. When using the site associated with the external occipital protuberance, the PCB should be placed flush with the skull at the external occipital protuberance while angling or aiming the muzzle of the PCB toward the mouth. Panel B indicates direction of the shot (Based on observations in goats by Collins et al., 2017 and Plummer et al., 2018).

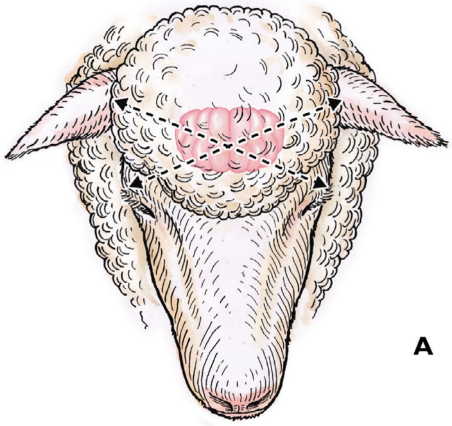


Figure 17: Penetrative captive bolt shooting frontal position for polled sheep and goats (AVMA, 2020)

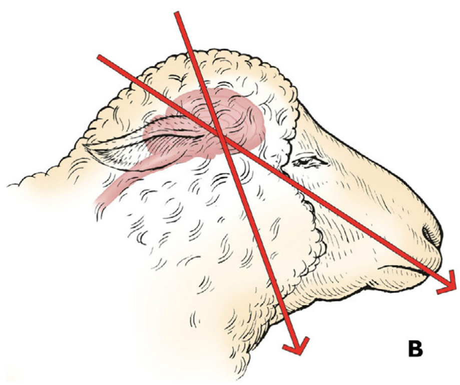


Figure 18: Penetrative captive bolt shooting lateral position for polled sheep and goats (AVMA, 2020)

According to the AVMA, 2020 (Figure 19), for horned sheep or goats (A), PCB should be placed perpendicular to the skull over the anatomic site identified as slightly caudal to the poll (also known as the crown or the highest point on the head) at the intersection of two lines drawn from the outside corner of each eye to the middle of the base of the opposite ear (based on observation by Plummer et al., 2018). Alternatively, a site located on the dorsal midline of the head, which corresponds with the external occipital protuberance of the skull, may be used. When using the site associated with the external occipital protuberance, PCB should be placed flush with the skull at the external occipital protuberance while angling or aiming the muzzle of the PCB toward the mouth, which is critical (based on Collins et al., 2017). Panel B indicates direction of shooting.

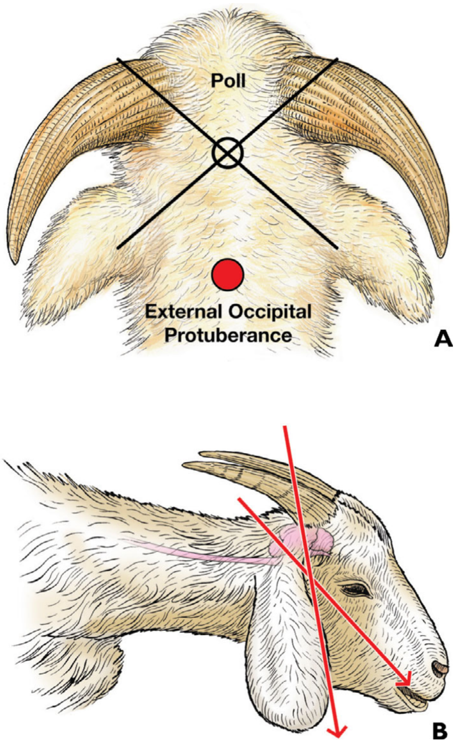


Figure 19: Penetrative captive bolt shooting position for horned sheep and goats (AVMA, 2020)

3.2.4.2. Non-penetrative captive bolt stunning

As described previously, adult sheep and goats have a unique morphological skull feature that will reduce the effectiveness of stunning with the non-penetrative captive bolt and therefore it is not widely used. In Europe, non-penetrative captive bolt can be used to stun ruminants weighing less than 10kg live weight (EC 1099/2009).

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.

Non-penetrative captive bolts (non-PCB) are mainly used to stun/kill neonatal lambs and goats (Grist et al., 2018a,b), however, they have been evaluated on adult animals as well (Sutherland et al., 2016; Collins et al., 2017).

Grist et al. (2018a) concluded, based upon behavioural indicators of brain death, that the Accles & Shelvoke CASH Small Animal Tool (CPK 200) is an effective single shot euthanasia device for neonate lambs, provided the shot position on the midline at the back of the head with the chin tucked in (Figure 15) and a 1.25-grain cartridge is used.

Grist et al. (2018b) concluded that the use of the CASH Small Animal Tool (CPK 200) can be recommended for euthanasia of neonatal goat kids when fired on the midline between the ears, with the chin tucked into the neck (Figure 16) is used in conjunction with a 1 grain cartridge.

Collins et al. (2017) demonstrated using adult goat cadavers and assessment of the effects of firing non-penetrative captive bolt as in Figure 14 directed towards the mouth (Cash Special captive bolt pistol, 0.25 caliber yellow cartridge; Accles and Shelvoke Ltd, Sutton Coldfield, West Midlands, England) and using gross pathology and CT and MRI scans that non-PCB can be effectively used to induce brain trauma potentially sufficient to result in stunning and unconsciousness of live goat kids.

According to the AVMA (2020; Figure 20) The preferred shooting position in neonatal lambs and kids is with the muzzle of the non-PCB on the midline behind the poll (i.e., between the ears) with the chin tucked into the neck (Sutherland et al., 2016).

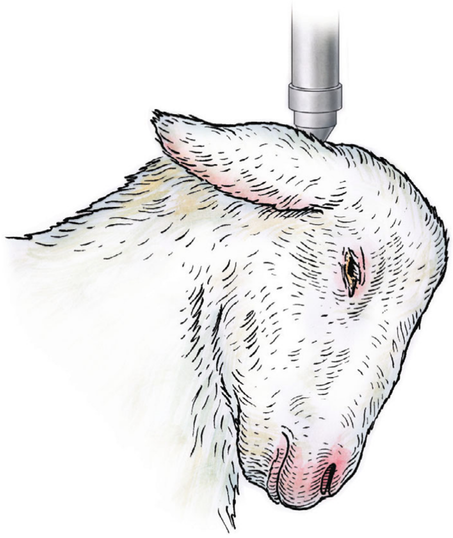


Figure 20: Non penetrative captive bolt stunning shooting position for neonatal lambs and goat kids (AVMA, 2020)

3.2.4.3. Hazard identification for 'Captive bolt stunning'

During the restraining, the welfare consequences are pain and fear. Indeed, after the captive bolt application, if the stunning is ineffective, the welfare consequences are pain and fear due to consciousness.

The hazards identified during this process are:

1) (Inappropriate) restraint: As described under electrical stunning (see Section 3.2.3.3).
2) Incorrect position and direction of the shot.
3) Incorrect captive bolt parameters

<u>Incorrect position and direction of the shot</u>:

Firing captive bolts in incorrect position or in the wrong direction can result in ineffective stunning leading to pain and fear.

Gibson et al. (2012) investigated in detail the pathophysiology of penetrative captive bolt gun injuries that result in incomplete concussion (e.g. lack of evidence suggestive of unconsciousness) in horned and polled (hornless) sheep. In this study, polled ewes and rams were shot on midline at the highest point on the head whilst aiming towards the throat. Horned ewes and rams were shot on midline between the base of the horns just caudal to the nuchal crest whilst aiming towards the back of the throat. The animals were shot once, with either the industry recommended gun/cartridge combinations or with higher powered combinations after the failure to induce irrecoverable concussion leading to death. Immediately after shooting, all animals were observed for clinical signs of insensibility and/or return of sensibility, including the presence or absence of immediate collapse, righting reflex, rhythmic breathing, jaw muscle tension, heart beat (palpation of the chest), corneal reflex, palpebral reflex, eyeball rotation, pupil dilatation, nystagmus and leg kicking. Recordings were taken for 5 min after shooting or, if the heart was still beating, they were continued until the onset of cardiac arrest. Any sheep that displayed signs of possible recovery after shooting were euthanised with an overdose of intra- venous pentobarbitone sodium (Euthatal, Merial Animal Health Ltd, Harlow, UK).

The results of the study by Gibson et al. (2012) indicated that rams (10%) were more likely to show signs of incomplete concussion than ewes (2%), and horned animals (8%) more likely than polled (3%). Sixteen percent of horned rams had signs of incomplete concussion. Inaccuracy of the shot assessed during post-mortem examination was associated with incomplete concussion: 100% of animals that showed signs of incomplete concussion were found to have been shot incorrectly. Seventy-nine % of incomplete concussion cases were associated with the bolt missing the brain entirely. Bad marksmanship (37%) and cases where the bolt missed the brain (15%) were more common in horned rams than polled rams and ewes (horned and polled).

In addition, the average bolt penetration depth in the head was largest in polled rams (71 mm) and lowest in polled ewes (66 mm). Rams (horned 12 and polled 11 mm) had significantly thicker skulls than ewes (horned 7 and polled 8 mm) and had a thicker skin tissue pad above the skull at the site of bolt penetration. The skin tissue pad was 5, 7, 16 and 21 mm thick in polled ewes, horned ewes, polled rams and horned rams, respectively. These results suggest that the anatomical predisposition needs to be taken into account in selecting shooting position.

During the restraining, the welfare consequences are pain and fear. After the captive bolt application, if the stunning is ineffective, the welfare consequences are pain and fear due to consciousness.

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 will occur 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 by the manufacturer (HSA, 2016a,b).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.

3.2.4.4. Assessment of animal welfare for 'Captive bolt stunning'

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 or unconsciousness.

Signs of effective captive bolt stunning include immediate collapse, absence of righting reflex, absence of rhythmic breathing, absence of jaw muscle tension, absence of corneal reflex, absence of palpebral reflex, absence of eyeball rotation, presence of pupil dilatation, absence of nystagmus and presence of leg kicking (Gibson et al., 2012). This suggestion is based on the observation that there are significant associations between incomplete concussion and failure to collapse, rhythmic breathing, positive corneal and palpebral reflex, and tight jaw. Gibson et al. (2012) also reported that animals which were irrecoverably stunned with a penetrative captive bolt also went into a period of convulsive hind-leg kicking which lasted for between 7 and 487 s. In these animals, the median time to cardiac arrest (suggestive of death) was 108, 100, 100 and 85 s for polled ewes, horned ewes, polled rams and horned rams, respectively. Eyeball rotation is often the first sign of potential incomplete concussion. In addition, incompletely concussed animals show either rhythmic breathing or failure to collapse and/or positive corneal and palpebral reflexes, tight jaw muscles and eyeball rotation.

ABMs related to pain and fear during restraint and loading into restraining device are escape attempts, vocalisations, injuries, grinding of teeth, curling of lips, reluctance to move and turning back. For descriptions see Table 8 in Section 3.1.3.1.

ABMs related to pain and fear after stunning are the signs of consciousness (Table 22). The same signs of consciousness that are in the flowchart for head-only electrical stunning (see Figure 12 in Section 3.2.3.3) were retrieved from the scientific literature and are therefore suggested for captive bolt stunning (Figure 21). Assessment of state of consciousness during stunning, can be done by counting the number and proportion of animals showing the ABMs described in Table 22.

Table 22: ABMs for assessment of 'State of consciousness' after captive bolt stunning (from EFSA AHAW Panel, 2013a)

ABMs	Description
Posture	Effective stunning will result in immediate collapse or loss of posture in animals that are not restrained or prevented from doing so. Ineffectively stunned animals, on the other hand, will fail to collapse or will attempt to regain posture after collapse (EFSA AHAW Panel, 2013a).
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.
Corneal reflex	The corneal reflex is elicited by touching or tapping the cornea. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus. Unconscious animals may also intermittently show a positive corneal reflex (EFSA AHAW Panel, 2013a).
Palpebral reflex	The palpebral reflex is elicited by touching or tapping a finger on the inner/outer eye canthus or eyelashes. Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus (EFSA AHAW Panel, 2013a).
Muscle tone	Stunned animals will show general loss of muscle 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 indicate ineffective stunning, as effectively stunned animals will exhibit fixed eyes.
Vocalisations	Conscious animals may vocalise (bleating in goats and vocalisation in lambs, Goldberg, 2018), and therefore purposeful vocalisation can be used to recognise ineffective stunning or recovery of consciousness after stunning. However, not all conscious animals may vocalise (EFSA AHAW Panel, 2013a).
Body movement	Ineffectively stunned animals and those recovering consciousness will show 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	Conscious animals may show spontaneous blinking – the animal opens/closes eyelid on its own (fast or slow) without stimulation - 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 (EFSA AHAW Panel, 2013a).

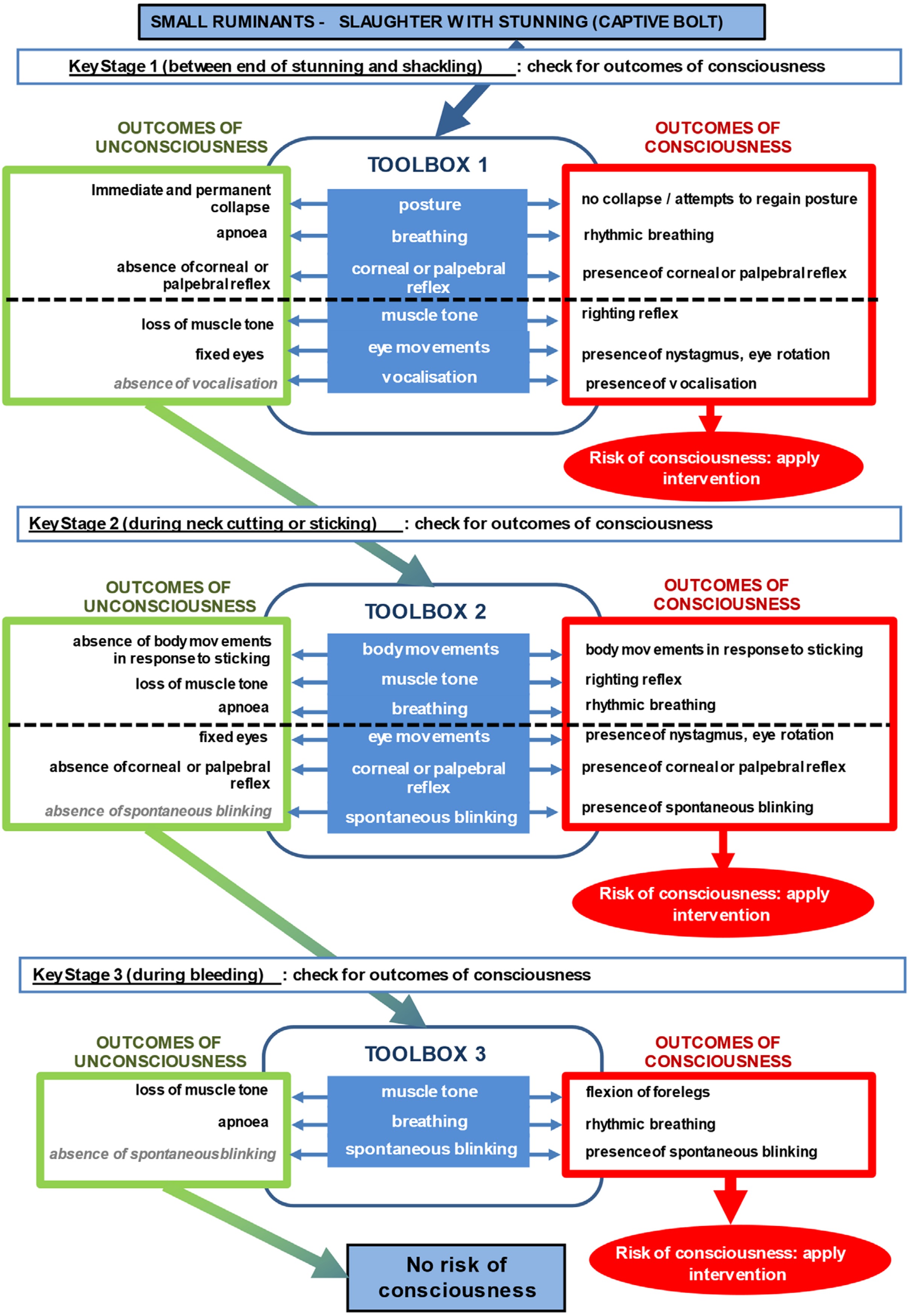


Figure 21: Flowchart for captive bolt stunning in sheep and goats

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

Preventive and corrective measures of welfare consequences due to restraint reported under electrical stunning would also be appropriate for captive bolt stunning.

Pain and fear during restraint and application of the 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. To prevent pain, mechanical restraint should suit the size of the animal. Most of the restraints used in small ruminant 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. 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 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.

3.2.4.6. Outcome table on 'bolt stunning'

Table 23: Outcome table on 'Captive bolt stunning'

Hazard	Welfare consequence/s occurring to the animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
(Inappropriate) restraint (See Section 3.2.3.3)	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 3.2.3.3)	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 3.2.3.3)	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, grinding of teeth, curling of lips (pain, fear), signs of consciousness after stunning (as a prerequisite for experiencing pain and fear), injuries (pain)

3.2.5. Percussive blow to the head

Percussive blow to the head followed by a killing method is used for neonatal sheep and goats (up to 5 kg live weight).

According to the HSA (2017), there are two variations of this method:

- Hold the animal by the back legs and deliver a firm blow to the back of the head with a blunt instrument, e.g. an iron bar or hammer.
- Hold the animal by the back legs and swing it through an arc to hit the back of its head with considerable force against a solid object, e.g. a brick wall or metal stanchion.

In both procedures, it is essential that the blow is delivered swiftly, firmly and with absolute determination to provoke severe damage to the brain and the immediate unconsciousness. If there is any doubt that the animal has not been killed effectively, the blow should be immediately repeated (HSA, 2017). However, the percussive blow may not always be effective in producing death and should be followed by bleeding or a secondary killing procedure such lethal injection, without any delay.

Successful induction of brain concussion manifests as immediate collapse of the animal, onset of apnoea (absence of breathing) and onset of a tonic seizure, which can be recognised by the animal's head being extended, hind legs rigidly flexed under the body and fixed eyes. Afterwards, clonic convulsions of variable intensity are an expected result of an effective stun. Ineffective or unsuccessful percussive blow to the head can be recognised by the failure to collapse, the presence of breathing (including laboured breathing) and in extreme cases, vocalisations.

To be effective it must involve a single blow to the correct position on the cranium of enough force to produce immediate depression and severe damage to the brain. If insufficient kinetic energy is delivered to the cranium, there is the potential for incomplete concussion, leading to pain and fear. To ensure death, manual blunt force trauma shall be followed as quickly as possible by a bleeding procedure, either by cutting the throat from ear to ear to sever both carotid arteries and both jugular veins or by inserting the knife into the base of the neck towards the entrance of the chest to sever all the major blood vessels where they emerge from the heart. Alternately, intravenous injection of saturated solution of KCl or $MgSO_4$ may be given to unconscious animals

In neonatal sheep and goats, the manual delivering of a blow to the forehead with a hard object or hitting the head towards a hard surface is entirely manual processes and prone to error. It requires a level of skill that most stockpersons and veterinarians would be unlikely possess if they infrequently perform the procedure. Consequently, the probability of achieving an immediate and humane killing in all cases is low. This method is less reproducible between animals and there is significant risk of causing incomplete concussion, and therefore, it is not recommended as an on-farm slaughter method.

In the event that percussive blow is not being effective in producing death it should be followed, without any delay, by a back-up method.

3.2.5.1. Hazard identification for 'percussive blow to the head' leading to 'Pain and fear'

Hazards are:

1) Restraint
2) Inversion
3) Incorrect application of blow to the head

<u>Restraint:</u>

The delivery of a blow to the forehead with a hard object requires the immobilisation of the animal and its head. Manual restraining of the neonates may carry the risk of fear and pain.

<u>Inversion:</u>

Manual blunt force trauma might be performed by holding the animal in an upside-down position and swinging the animal's head towards a hard surface or delivering a blow to the head using a hard object. This position and movement will cause fear and pain.

<u>Incorrect application of the blow to the head:</u>

If animals are not hit on the frontal–parietal bones, the method will fail to induce immediate unconsciousness and will cause severe pain. Lack of skilled operators, operator fatigue and poor restraint, and wrong choice of the tool to deliver the blow can lead to incorrect application of blow to the head.

3.2.5.2. ABMs for assessment of percussive blow to the head

ABMs related to pain and fear during restraint are vocalisation and escape attempts.

ABMs related to pain and fear after application of the blow to the head are the signs of consciousness and death. The same signs of consciousness and death that are suggested for penetrative bolt stunning can be used.

ABMs for assessing death in sheep and goats are (European Commission, 2017): no spontaneous movement, limp/permanently collapsed body, no response to pinch/prick on nose/ear, no noise/ panting, no breathing, dilated pupils, bleeding stopped, no heartbeat. Assessment of state of consciousness during stunning, can be done by counting the number and proportion of animals showing these ABMs.

3.2.5.3. Prevention and correction of welfare consequences and their related hazards during delivery of percussive blow to the head

There are no preventive or corrective measures to the pain and fear caused by manual restraint and inversion as this is part of the killing method. Therefore, it is preferable to choose a different method like non-penetrative captive bolt. Non-penetrative captive-bolt devices have the advantage of reproducibility and less reliance upon operator ability in comparison with manually delivered blow to the head.

Recommended measures to prevent the incorrect application of blow to the head are staff training and rotation, use of appropriate tool (such as a hard metal pipe or a club) and delivery of accurate blow and adequate.

Training of staff to use of adequate procedures to monitor (un)consciousness will contribute to prevent and correct stunning failures.

Inadequate stunning should be corrected without delay by application of an adequate back up procedure.

3.2.5.4. Outcome table 'Percussive blow to the head'

Table 24: Outcome table on 'Percussive blow to the head'

Hazard	Welfare consequence/s occurring to animals due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s of hazards (implementation of SOP)	Corrective measure/s of the hazards
Restraint (See Section 3.2.4.1)	Pain, fear	Staff	Immobilisation of the animal and presentation of the head of the animal to the operator are required	Training staff to keep it as short as possible	None
Inversion (Section 3.2.4.1)	Pain, fear	Staff	Manually inverting animals for the application of the blow to the head	Avoid inversion of conscious animals	None
Incorrect application of the blow to the head (Section 3.2.4.1)	Pain, fear	Staff	Lack of skilled operators, operator fatigue, poor restraint, hitting in wrong place, insufficient force delivered to the head, wrong choice of tool to deliver the blow.	Staff training and rotation, delivery of the blow with accuracy and adequate force, use appropriate tool	Correct application of the method

ABMs: signs of consciousness (as a prerequisite for experiencing pain and fear), signs of life (as a prerequisite to recover consciousness), escape attempts (pain, fear), injuries (pain), vocalisations (pain, fear)

3.2.6. Firearm with free projectile

Firearms are not used to stun/kill sheep and goats in slaughterhouses.

According to the AVMA (2020) firearms recommended for euthanasia of adult sheep and goats include the .22 LR rifle; .38 Special, .357 Magnum, and 9 mm or equivalent handguns; and shotguns. Some prefer hollow-point bullets to increase brain destruction and reduce the chance of ricochet. However, operators are reminded that bullet fragmentation may substantially reduce the potential for brain destruction because of reduced penetration, particularly when used in large-horned adult rams. Shotguns or higher-caliber firearms loaded with solid-point bullets are preferred in these conditions. When firearms are used for euthanasia it is important that the gun never be held flush with the skull. Instead, the muzzle of the gun should be aimed in the desired direction and held no closer than 6–12 inches from the target. The optimal site for firing is on the intersection of two lines, each of which is drawn from the lateral canthus of one eye to the middle of the base of the opposite ear (Figure 13). Alternative landmarks that provide a very similar placement use the dorsal midline of the head at the level of the external occipital protuberance aiming downward toward the cranial most portion of the intermandibular space (Figure 14). Frontal shots, aiming at the foramen magnum, should be reserved for use only with gunshot and provide an alternate approach for heavily horned sheep and goats where the top of the skull may be too hard to access due to the horns.

3.2.6.1. Hazard 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 22.

<u>Incorrect position of the shot</u>

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.

<u>Inappropriate power and calibre of the cartridge</u>

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 animals. It is also important to follow manufacturer's instructions.

<u>Inappropriate type of projectile</u>

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.

3.2.6.2. 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 captive bolt stunning were retrieved from the literature and therefore are suggested here for firearm with free projectile (see Table 22 for description of ABMs of state of consciousness and flowchart in Section 3.2.3.4).

3.2.6.3. 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, 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 for appropriate selection of ammunition, accurate shooting and to use of 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.

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

Table 25: Outcome table on 'Use of firearm with free projectile'

Hazard	Welfare consequence/s occurring to sheep and goats due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Incorrect shooting position (See Section 3.2.5.1)	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 3.2.5.1)	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 3.2.5.1)	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)					

3.3. Description of Phase 3: bleeding process, welfare consequences and relevant hazards

Bleeding is carried out to drain the blood from the carcass.

In the process of bleeding following stunning, the effectively stunned animal is prevented from recovering consciousness during the slaughter process. In slaughter without stunning, bleeding results in gradual loss of consciousness and onset of death.

3.3.1. Bleeding following stunning

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 bleeding (sticking). It is expected that unconsciousness induced by stunning should last longer than the time between the end of stunning and bleeding and the time to onset of death due to blood loss following sticking together (Figure 22). The bleed out time should be long enough to allow for death to occur in animals, and death should be confirmed before carcass processing begins. The time to loss of brain responsiveness (brain death) is reported to be 14 s following bleeding (Gregory and Wotton, 1984).

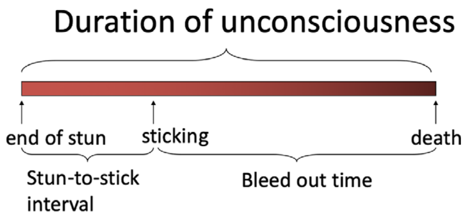


Figure 22: An illustration of the duration of stun-to-stick interval and bleeding (EFSA, 2004)

Bleeding of sheep and goat may be carried out by an incision made in the neck close to the head to ensure that both carotid arteries and both jugular veins are cut, i.e. a cut across the throat (Figure 23, cut position 2). An incision at the entrance to the chest can also be used (Figure 23, cut position 1).

The main sticking methods are: • Stab sticking: The knife is stuck in the neck ventral to the vertebral column where it should sever both common carotid arteries, which cannot be verified due to the small wound. • Gash sticking: The knife is stuck in the neck ventral to the vertebral column and moved ventral in order to cut all soft tissues including both common carotid arteries. • Full ventral cut: The knife cuts from the ventral part of the neck up to the vertebral column. This type of cut severs all blood vessels and other tissues lying ventral of the vertebral column (EFSA, 2004).

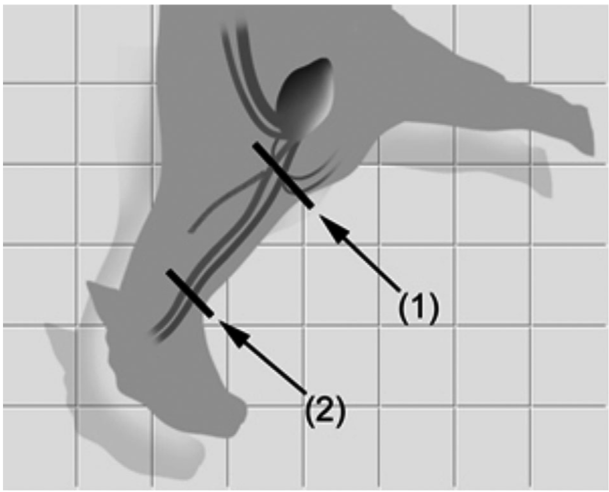


Figure 23: Cutting position for sheep and goats (HSA, 2016b), at the entrance to the chest (position 1) or across the throat (position 2)

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 3.1.3.1.

Distress can be defined as a conscious, negatively valenced, intensified affective motivational state that occurs in response to a perception that current coping mechanisms (involving physiological stress responses) are at risk of failing to alleviate the aversiveness of the current situation in a sufficient and timely manner (Mc Millan 2020).

The presence of consciousness due to ineffective stunning or recovery following stunning is a prerequisite to experiencing pain, fear, and distress.

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

The presence of consciousness during bleeding, leading to pain and fear, and distress can be recognised from the ABMs listed in the third key stage of the flowcharts (see flowcharts in Sections 3.2.2.4 and 3.2.3.4) which are reported in Table 26.

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

The assessment of state of consciousness and state of death can be done by counting the number and proportion of animals showing the ABMs described in Table 26.

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

ABMs	Description
Signs 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 recognised from the regular flank and/or mouth and nostrils movement.
Muscle tone	Conscious animals will not lose muscle tone. Ineffectively stunned animals and those recovering consciousness will show a righting reflex and attempts to raise the head. Loss of muscle tone can be recognised from the completely relaxed legs, floppy ears and tail, and relaxed jaws with protruding tongue.
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.
Corneal reflex	Corneal reflex is elicited by touching or tapping the cornea. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus. Unconscious animals may also intermittently show a positive corneal reflex.
Palpebral reflex	Palpebral reflex is elicited by touching or tapping a finger on the inner/outer eye canthus or eyelashes. Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus.
Vocalisations	Conscious animals may vocalise, and therefore purposeful vocalisation can be used to recognise ineffective stunning or recovery of consciousness after stunning. However, not all conscious animals may vocalise.
Signs of death	
Relaxed body	Complete and irreversible loss of muscle tone leads to relaxed body of the animal, which can be recognised from the limp carcass (EFSA AHAW Panel, 2013a)
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 the carotid arteries or of brachiocephalic trunk.
3) Sticking of conscious animals.
4) Dressing of animals 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. The maximum stun-to-stick interval can be calculated as follows: time of resumption of rhythmic breathing after electrical stunning minus time to loss of brain responsiveness after cutting both common carotid arteries and external jugular veins: 24.85–17 = 7.85 s (EFSA, 2004).

In commercial slaughterhouses, sticking of sheep and goats may be performed following shackling and hoisting the unconscious animals and moving it on an overhead rail to the bleeding area, or the unconscious animals may be manually lifted and hung on shackles prior to bleeding. Owing to this, there may be a delay between the end of stunning to sticking. Lack of a skilled operator, delayed shackling, hoisting and sticking of animals (e.g. when stunned animals convulse excessively) and positioning of the stunner too far away from the bleeding rail are therefore the origins of this hazard.

Incomplete sectioning of the carotid arteries or of brachiocephalic trunk

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

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

Sticking of conscious animals

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

Dressing of animals while still alive

Animals 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 brachiocephalic trunk or carotid arteries, 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 sheep and goats correctly as soon as they are 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 both carotid arteries, to ensure sticking wound is large and open 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 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 removed.

3.3.1.3. Outcome table on 'Bleeding following stunning'

Table 27: Outcome table on 'Bleeding following stunning'

Hazard	Welfare consequence/s occurring to sheep and goats 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 shortly after stunning?	• Re-stunning
Incomplete sectioning of the carotid arteries or brachiocephalic trunk (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 and carotid arteries • Ensuring brachiocephalic trunk is cut and carotid arteries • Ensuring the sticking wound is large enough to facilitate profuse bleeding	• Correct cutting of brachiocephalic trunk and carotid arteries
Sticking of conscious animals (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 Electro-immobilisation (in sheep)	• Proper stunning and short stun-to-stick interval • Training of staff to monitor consciousness	• Re-stunning before sticking
Dressing of animals 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 to monitor death • Ensuring death before dressing	• stop dressing and make sure the animal died before continuing if it is due to short bleeding time

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

3.3.2. Bleeding during slaughter without stunning

Considering the similarities in the anatomy and physiology of pain perception among the ruminant species (cattle, sheep and goat) it is more than likely that sheep and goats will also experience pain, fear and distress during the cut that will last until the animal is rendered unconscious through blood loss. (Johnson et al., 2014; EFSA AHAW Panel, 2020). Overwhelming international scientific opinion has long been that slaughter by neck incision of conscious animals causes pain. A series of studies in calves demonstrated that slaughter by ventral-neck incision is likely to be perceived as painful (Gibson et al., 2009aa,b). It is proposed that, as in cattle, non-stunned sheep and goats would experience pain in a similar manner (Johnson et al., 2014).

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 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).

Some papers stated that the low behavioural responses to the cut demonstrate that the cut is not painful (Levinger, 1995; Levinger, 1976). 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.

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 (von Holleben et al., 2010).

In goats and sheep, the brain is supplied principally by the common carotid arteries, via the maxillary artery which gives off dorsally directed rete branches. These branches link with the rete mirabile (Andersson and Jewell, 1956, Schummer et al. 1981). In these animals, the rete mirabile is less complex than in cattle with less side-to-side anastomosis (Baldwin, 1971). The left and right rete mirabiles connects to the arterial circle supplying blood to the entire brain. In goats the vertebral arteries communicate directly with the common carotid via the occipital arteries. However, unlike in cattle, there is no direct connection between the vertebral arteries and the rete mirabile (Figure 22; Baldwin and Bell, 1963). Andersson and Jewell (1956), reported that blood from the vertebral arteries make no contribution to cerebral perfusion in goats and only supplies the cervical spinal cord and posterior medulla (Andersson and Jewell, 1956; Baldwin, 1971).

It is also worth noting that although very slender vertebral rami entering at first cervical vertebra join the basilar as it goes over into the anterior median spinal artery, the major blood supply to the basilar artery comes from the internal carotid arteries (Gillilan, 1974).

Publication concerning slaughter without stunning of goats is scarce. As cited before (see Section 3.3.1), the average time to loss of brain responsiveness (brain death) in sheep is reported to be 14 seconds following bleeding (Gregory and Wotton, 1984; von Holleben et al., 2010) with 95% percent of the animals unconscious at 22s. It has been suggested that the reason for this short and narrower period for time to loss of consciousness in sheep compared to cattle is due to the differences in cerebral perfusion supply between the species, principally the contributions of blood from the vertebral arteries and the suggested lack of formation of false aneurysms (carotid ballooning) on the severed ends of the carotid arteries in sheep (Gregory et al., 2006).

However, Rodríguez et al. (2012) assessed brain activity in eight lambs during slaughter without stunning and its correlation with heart rate and the absence of physiological reflexes. Rhythmic breathing disappeared at an average (± SD) time of 44 ± 4.2 s after sticking (range 30–60 s). The corneal reflex disappeared at 116 ± 11.01 s (range 80–160 s) after sticking. Changes in brain activity occurred between 22 and 82 s after sticking (average 52 (± 20.2) s). Both brain activity and physiological reflexes revealed that when bleeding is performed, through a transverse incision across the neck without stunning, the time to onset of unconsciousness could be as long as 1 min. The authors suggested that the prolonged time to loss of consciousness compared to other authors' findings may be attributable to inefficient bleeding when lambs are slaughtered without head restraint in this study. The implication of this is that collapse of head on the neck cut wound impeded blood loss and delayed onset of unconsciousness.

Verhoeven et al. (2015) reported, on the basis of EEG changes, an average (SD) time of 15 ± 4 s for the onset of unconsciousness and 27 ± 8 s for the onset of an isoelectric EEG following slaughter without stunning of sheep. Interestingly, the time to cessation of regular breathing and abolition of eyelid reflex was found to be 27 ± 12 s and 59 ± 17 s (mean ± SD), respectively, after animals were considered unconscious on the basis of changes in the EEG and with isoelectric EEG, indicating that absence of regular breathing and eyelid reflex are distinctly conservative indicators of unconsciousness during slaughter without stunning of sheep. However, response to the threat reflex was lost before the onset of unconsciousness was observed on the EEG. The threat reflex is the involuntary blinking or withdrawal of the head in response to bringing a finger or hand with speed towards the eye of an animal.

In addition, only 7 out of 21 sheep had a positive threat reflex during exsanguination at an average of 7 ± 1 s post neck cut. Since sheep were considered unconscious at 15 ± 4 s post neck cut, absence of the threat reflex did not necessarily indicate unconsciousness. The authors suggested that the lack of correlation between the EEG criterion for unconsciousness and reflexes could be due to a massive stimulation of all sensory nerves after the neck cut, which can lead to a state of shock and distress (Gregory, 2005) disabling animals to respond to threat stimulus.

Velarde et al. (2014) reported the onset of unconsciousness appeared earlier when sheep were restrained manually on their sides (23.0 ± 2.20 s) than in animals hoisted before neck cutting (76.0 ± 3.44 s; animals hypotonic). In this example, an animal hoisted before neck cutting will suffer from pain, fear and distress longer than restrained animals.

Barrasso et al. (2020) reported that 16 out of 120 sheep subjected to slaughter without stunning showed signs of consciousness, i.e. positive corneal reflex (4) or rhythmic breathing (12) at 90 s after neck cutting. Four animals subjected to head-only electrical stunning followed by slaughter also showed rhythmic breathing at 90 s post cut. The authors concluded that permanence of the reflexes in slaughter without stunning could be reduced by introducing a reversible stunning method and the assessment of the animal's state of consciousness for longer time intervals than those commonly used is recommended.

Reversible pre-slaughter stunning of sheep is accepted by some religious authorities for Halal meat production (Khalid et al., 2015; Barrasso et al., 2020). Some other religious authorities, however, believe pre-slaughter stunning impedes with the blood loss and, since consumption of blood retained in the skeletal muscle is prohibited in Islam, are opposed to pre-slaughter stunning. In contrast with this belief, Anil et al. (2004) reported that the average blood loss (kg) occurring at 90 s (post cut) in sheep following slaughter without stunning, head-only electrical stunning and captive bolt stunning was very similar, i.e. 1.58, 1.62 and 1.53 kg, respectively, and these averages were not statistically different from each other. In addition, the average time taken to reach 90% blood loss was quickest in those animals that were electrically stunned. The slowest group to reach 90% blood loss was the no-stunning group. There were no significant differences between the groups. In addition, the rates of bleed out in sheep were very similar after slaughter without stunning and electrical or captive bolt stunning followed by bleeding (Table 28).

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 sheep after neck cutting (Anil et al., 2004)

Time (s) to:	Slaughter without stunning	Electrical stunning	Captive-bolt stunning	Statistical significance of differences between groups
25% blood loss	5.7	6.7	6.4	Not significant
50% blood loss (s)	14.1	16.4	16.3	Not significant
75% blood loss (s)	31.8	30.8	27.0	Not significant
90% blood loss (s)	55.8	50.9	53.3	Not significant

Khalid et al. (2015) reported that pre-slaughter head-only electrical stunning and post-cut head-only electrical stunning resulted in similar blood loss in comparison with slaughter without stunning, total blood loss expressed as percentage of body weight being 5.1, 5.1 and 5.2% respectively.

Clearly, evidence provided by Anil et al. (2004) and Khalid et al. (2015) does not support the notion that pre-slaughter stunning impedes with blood loss at slaughter.

In addition to the absence of differences in the bleeding rate in stunned and not-stunned animals, the throat cut involves major tissue damage which is likely to activate pain pathways in all animals. Therefore, 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 3.1.2.6. 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 homoeostasis (Carstens and Moberg, 2000, Moberg, 1987, NRC, 1992). In the case of slaughter without stunning, it is caused by extreme pain and fear experienced by the animals (Johnson et al., 2014). In addition, animals will experience fear and distress due to rotation and the inversion of conscious animals.

Sabow et al. (2016, 2017, 2018) examined the pain of the cut in conscious and minimally anaesthetised goats. They reported significant increases from baseline of EEG indices associated with noxious sensory input. The act of slaughter without stunning would therefore result in the goat experiencing pain.

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

Pain, fear and distress during restraint for slaughter without stunning can be recognised from the presence of escape attempts and vocalisations (Table 29).

Pain, fear and distress during slaughter without stunning can be assumed when there is the presence of signs of consciousness (until animal lose consciousness), using ABMs listed in the flowchart (EFSA AHAW Panel, 2013a) which is reported in figure 24 here below. From the presence of signs of unconsciousness, it is assumed the animal is not anymore suffering from pain, fear and distress.

The assessment of state of consciousness and state of death can be done by counting the number and proportion of animals showing the ABMs described in Table 29.

Table 29: ABMs for the assessment of 'Pain, fear and distress' during slaughter without stunning (EFSA AHAW Panel, 2013a)

ABMs	Description
Signs 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 recognised from the regular flank and/or mouth and nostrils movement.
Muscle tone	Conscious animals will not lose muscle tone. Ineffectively stunned animals and those recovering consciousness will show a righting reflex and attempts to raise the head. Loss of muscle tone can be recognised from the completely relaxed legs, floppy ears and tail, and relaxed jaws with protruding tongue.
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.
Corneal reflex	Corneal reflex is elicited by touching or tapping the cornea. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus. Unconscious animals may also intermittently show a positive corneal reflex.
Palpebral reflex	Palpebral reflex is elicited by touching or tapping a finger on the inner/outer eye canthus or eyelashes. Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus.
Vocalisations	Conscious animals may vocalise, and therefore purposeful vocalisation can be used to recognise ineffective stunning or recovery of consciousness after stunning. However, not all conscious animals may vocalise.
Signs of death	
Relaxed body	Complete and irreversible loss of muscle tone leads to relaxed body of the animal, which can be recognised from the limp carcass (EFSA AHAW Panel, 2013a)
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.

In addition, death should be confirmed before dressing and can be recognised by relaxed body, cessation of bleeding and dilated pupils. Impeded bleeding can be visibly seen from blood squirting out through the blood clot.

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

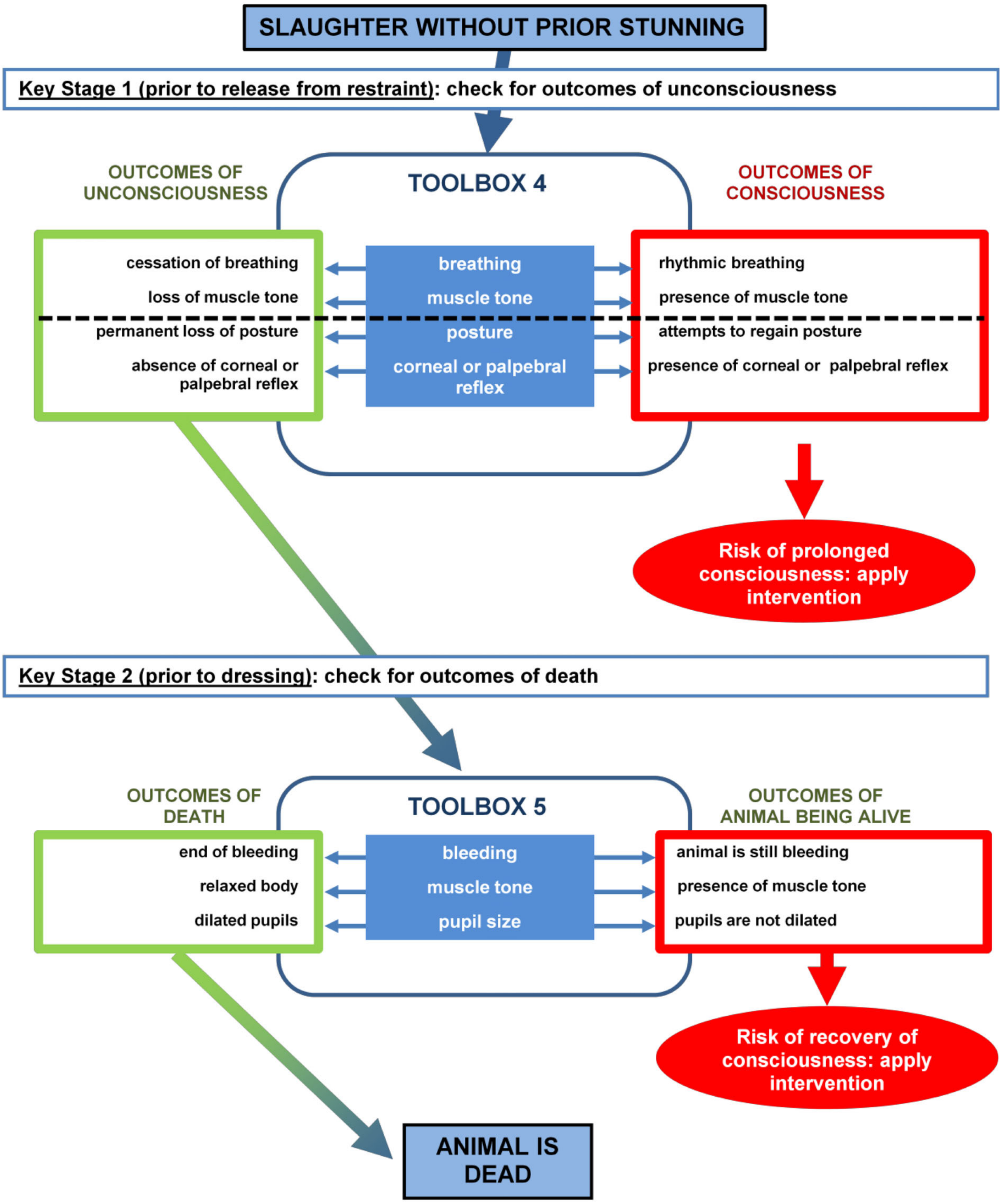


Figure 24: Flowchart including indicators for the monitoring of state of consciousness and death (EFSA AHAW Panel, 2013a)

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

1) Inappropriate body support (Restraint).
2) Excessive pressure (Restraint).
3) Immobilisation of the head (Restraint).
4) Rotation of the animal (Restraint).
5) Inversion (Restraint).

6) Hoisting (Restraint).
7) Bleeding to death.
8) Incomplete sectioning of carotid arteries.
9) Repeated cuts.
10) Stimulation of wound.
11) Aspiration of blood into the trachea.
12) Release from the restraint while conscious.
13) Hoisting while bleeding.
14) Dressing animals while still alive.

Inappropriate body support

The belly support[11] 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.

Excessive pressure

Pressure applied in the restraint is too high, leading to pain. Lack of skilled operator and faulty equipment are the origin[12]

Immobilisation of the head:

Immobilisation of the head or stretching of the neck of animals manually is needed to perform slaughter without stunning. This immobilisation is leading to fear and in certain cases pain in sheep and goats.

Mechanically operated chin lifts are used to stretch sheep and goats' necks to facilitate slaughter without stunning (Grandin, 2020). In case of inappropriate use, this will lead to pain and fear.

Rotation of the animal:

Sheep and goats may be rotated 90° or 180°, placed in a cradle and restrained manually for the purpose of slaughter without stunning (Velarde et al., 2014). As reported in EFSA cattle slaughter opinion, sheep and goats may be subjected to pain, fear and distress during rotation (EFSA, 2020).

Inversion

Inversion might be performed by holding the animal in an upside-down position. This position and movement will cause fear and pain.

Hoisting:

Animals may be hoisted and suspended from an overhead rail with a shackle attached to one or both of the hind legs for the purpose of slaughter without stunning.

Hoisting live and conscious sheep and goat upside down for the purpose of slaughter without stunning was common in some countries (Velarde et al., 2014).

Velarde et al. (2014) reported that the time interval between the application of restraint and neck cutting was longer when sheep were hoisted before neck cutting (45.0 $\pm$ 2.07 s) compared to when animals were turned mechanically (7.2 $\pm$ 0.32 s), or manually (3.2 $\pm$ 0.56 s) on their sides. In addition, the restraint to cut interval was longer in sheep mechanically turned on their sides than in those restrained manually.

Velarde et al. (2014) also reported that 60% of sheep that were hoisted and 67% of sheep that were rotated and restrained on their side struggled, suggesting pain, fear and/or distress.

Bleeding to death

The bleeding by itself will leading to hypovolaemia and hypoxia that will bring fear and distress until animals reach unconsciousness through exsanguination, which is required by the method.

Incomplete sectioning of carotid arteries

Failure to completely severe the two carotid arteries that supply oxygenated blood to the brain.

[11] http://grandin.com/ritual/small.sys.html
[12] http://grandin.com/ritual/evaluation.restraint.methods.kosher.halal.html

This hazard may lead to delayed onset of unconsciousness and onset of death. Lack of skilled operator and use of blunt or short knives are identified as hazard origins.

Repeated cuts

A cut performed to the neck while conscious is considered a hazard, since it will imply animals feeling pain, fear and distress. The more the number of cuts, the worse will be the welfare consequence.

Velarde et al. (2014) reported that the number of cuts performed during neck cutting differed between the restraining methods, it was higher in sheep slaughtered in the upright position (two) than in animals restrained manually on their sides (one).

Stimulation of wound

Physical stimulation of the wound by a second intervention to improve bleeding quality or to the wound being in contact with the restraining device. Stimulation of the wound will increase the perception of pain.

Aspiration of blood into the trachea

Aspiration of blood into trachea and blood splashing in the lungs of animals subjected to slaughter without stunning, as reported in cattle, is a welfare concern Gregory et al. (2009).

Release from the restraint while conscious

Animals released from the restraining device before the onset of unconsciousness. Slaughter without stunning requires restraint of animals until they are rendered unconscious through exsanguination. Release of the animals from restraint prior to loss of consciousness will lead to additional pain, fear and suffering due to animal falling down repeatedly.

Hoisting while bleeding

Animals released from the restraint and hoisted before the onset of unconsciousness.

Dressing animals while still alive

Animals 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 and lack of monitoring of death before dressing begins are hazard origins. The prevalence of this hazard is not known.

3.3.2.2. Prevention and correction of welfare consequences during bleeding following slaughter without stunning

Although direct evidence is lacking in sheep and goat, owing to the anatomical and physiological similarities between cattle and sheep and goats, the pain, fear and distress associated with slaughter without stunning is reported to be same, which can only be prevented by pre-slaughter stunning or corrected by the application of post cut stunning without delay (Johnson et al., 2014; EFSA AHAW Panel, 2020). Pre-cut stunning is the only preventive measure for the welfare consequences connected with cutting. Head-only electrical stunning of sheep and goats prior to halal slaughter is common in many countries (Nakyinsige et al., 2013; Farouk et al., 2014).

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

Preventive measures for hazards occurring during restraint of animals 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 animals 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 restraint rotation or inversion and neck cutting to the minimum is a corrective measure.

Further preventive measures for hazards occurring during bleeding of sheep and goats 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 carotid arteries are severed completely, monitor the rate of bleeding and recognise signs of poor bleeding and monitor the state of consciousness and life.

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

Table 30: Outcome table on 'Restraint for slaughter without stunning'

Hazard (these hazards apply to all animals because they are conscious)	Welfare consequence/s occurring to sheep and goats 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	• 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 • Adjust equipment to optimal pressure according to the size of the animal
Excessive pressure (See Section 3.3.2.1)	Pain, fear and distress		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 • 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		Inappropriate restraint of the head	• 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 • Adjust equipment to optimal pressure according to the size of the animal
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
ABMs: escape attempts, vocalisations (pain, fear and distress)					

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

Table 31: Outcome table on 'Bleeding during slaughter without stunning'

Hazard (these hazards apply to all animals because they are conscious)	Welfare consequence/s occurring to the sheep and goats due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Bleeding to death (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
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
Stimulation of the 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
Aspiration of blood into the trachea	Pain, fear, distress	Inherent part of the method	Bleeding while conscious	• None	• Post-cut stunning
Release from restraint while conscious (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 while bleeding (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 animals because they are conscious)	Welfare consequence/s occurring to the sheep and goats due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measures	Corrective measures
Dressing animals 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
ABMs: escape attempts, vocalisations (pain, fear and distress)					

3.4. Emergency slaughter

In general, animals that cannot be moved without causing them additional suffering should be killed humanely, wherever they are recognised during inspection. Typically, 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 FBO 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 Farm Animal Welfare Council (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 without delay.

Lameness is a major welfare problem in sheep; it can be due to various husbandry and farming practices, and severe lameness can be detected during unloading using ABMs: not bearing weight on one or more limbs when standing or moving, reluctance to move and difficulty or inability to stand (Kaler and Green, 2008; König et al., 2011). Severely lame animals should be killed on the truck using emergency slaughter procedures.

Animals 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 prevalence of emergency slaughter of sheep and goat is not reported in the literature. Penetrative captive bolts or head to body electrical stunning can be used to stun sheep and goats on the truck.

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:

- Slaughter without stunning.
- Sticking and bleeding of conscious animals.
- Painful induction of unconsciousness (e.g. 90% of CO_2).
- Unloading or moving severely injured animals or those unable to move independently without pain or to walk unassisted.
- Use of painful handling to move animals (e.g. lifting or pulling of sheep and goats by wool, skin fold or by horn).
- Use of dogs for handling and moving of animals.
- 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.

Furthermore, there 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 sheep and goats a serious concern regarding animal welfare.

3.6. Specific hazards related to types of animals or species (ToR 4)

During transport, there may be a requirement (e.g. in the UK) to separate animals of significantly different sizes or ages, sexually mature males from females, animals with horns from animals without horns, animals hostile to each other and tied animals from untied animals. However, separation is not required where the animals have been raised in compatible groups, are accustomed to each other, where separation will cause distress or where females are accompanied by dependent young (AWC, 2020).

Lactating goats and ewes should be identified on arrival and have arrangements for milking should that be necessary to relieve the udder.

Goats will tend to climb up on the bars and an assessment will need to be made of the risk for the goat in trying to climb over the pen sides or water troughs. Premises with solid walls are better suited to handling goats and pen sides should be of a suitable height to prevent climbing. It is important to ensure any such temporary fixtures are not hindering the airflow through lairage pens leading to heat stress.

Horned sheep and goats have an extensive frontal sinus that occupies the entire frontal bone, but the sinuses are less prominently strutted in goats compared to sheep (Farke, 2010). Particularly in older males and horned goats, the sinuses may absorb the energy from a non-penetrative captive bolt device or reduce the depth of penetration of the bolt into the brain when a penetrative captive bolt stunning device is deployed. Both could result in reduced effectiveness of the stun (AWC, 2020). Therefore, staff should have adequate knowledge and skill to choose the appropriate shooting position and direction in order to overcome these anatomical predispositions.

Similarly, the presence of horns in mature sheep and goats may hinder head-only electrical stunning tongs placement between the eyes and ears on either side of the head, and therefore, an alternative electrode placement position may be necessary. The operator should be able to decide the best electrode position that would span the brain.

In addition, good placement of the stunning electrodes can be difficult on sheep with woolly heads. Use of electrodes with pins or with wet pins for woolly animals may help to overcome this hazard. Alternatively, removal of wool from the area of the stunning electrode position should be considered.

Suckling lambs and goat kids require to be fed and provided with suitable bedding material in the lairage.

When goats are reared under an extensive management system, with little or no contact with the stockman, the behaviours that constituted a threat to the goats (slips, falls and jumps) were significantly higher during handling than loading due to fear. Overall, the result of the behavioural events per goat and time taken to unload each goat showed that the unloading procedure is less stressful than handling or loading (Minka and Ayo, 2007).

3.7. Assessment of uncertainty

Uncertainty related to the occurrence of false-positive and false-negative hazards was assessed (see methodology described in Section 2.2.4).

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. 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.

On the possible inclusion of false-positive hazards, the experts were 95–99% certain that all listed hazards occur during slaughter of sheep and goats (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 sheep and goats and c. methods for which the welfare aspects are sufficiently described in the scientific literature.

4. Conclusions

This mandate asks EFSA to provide an independent view on the slaughter of sheep and goats for human consumption, covering all parts of the slaughter process. The scientific opinion focuses on the identification of hazards leading to negative welfare consequences at slaughter for sheep and goats. 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 take into account the common slaughter practices that have been reported in the opinion.

Not all the methods, procedures and practices for slaughter of sheep and goats 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 all phases of the slaughter process, sheep and goats 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) During the slaughter processes, sheep and goats may be exposed to several hazards, which could have a cumulative effect on welfare consequences (e.g. water deprivation, insufficient space allowance, too high effective temperature will have a cumulative effect and exacerbate heat stress and fatigue).
3) Exposure to some hazards might persist along processes and phases until the sheep and goats are rendered unconscious (e.g. food deprivation).
4) Other hazards might be present only during one phase, but the welfare consequence might persist during the successive processes and phases until sheep and goats are rendered unconscious (e.g. pain due to inappropriate handling).
5) ABMs have been identified for the assessment of all the welfare consequences, except for prolonged thirst and prolonged hunger at the time of arrival as potential ABMs for these welfare consequences were not considered suitable for practical application.
6) Most of the hazards identified are associated with lack of staff skills and training (e.g. 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 slaughtering a serious welfare concern.
7) 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 sheep and goats. 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. 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 and restriction of movement. The corresponding ABMs are panting, shivering, exhaustion, tachypnoea.
2) At arrival ABMs can be only assessed from outside the truck, and therefore, assessment is only feasible for animals near the sidewalls of the truck. However, if welfare consequences are identified for animals which are visible, it is plausible that other animals in the truck are also affected. However, if no welfare consequences are identified for the visible animals, this does 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, injuries), and at the same time, it may expose sheep and goats to new hazards leading to additional welfare consequences (e.g. heat stress).
4) At unloading and during handling and moving of sheep and goats, the three welfare consequences that animals might experience are pain, fear and impeded movement. They can be assessed using ABMs: injuries, lameness, vocalisations, escape attempts, reluctance to move and turning back, slipping and falling.
5) Unloading severely injured sheep and goats 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 sheep and goats might experience are social stress, pain and fear, thermal stress, prolonged hunger and thirst, fatigue, restriction of movement and resting problems. These can be assessed using ABMs: aggressive behaviour, injuries, vocalisation, grinding of teeth, curling lips, panting, shivering, increased water intake, exhaustion, tachypnoea.
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 sheep and goats might experience pain, fear and impeded movement. These can be assessed using ABMs: slipping, falling, escape attempts, vocalisation, injuries, reluctance to move and turning back.
9) The use of painful handling methods for moving the animals (lifting or pulling by wool, skin fold or horns) is considered a serious welfare concern by the Panel.
10) Suckling lambs and goat kids can be prone to cold stress when compared with adult animals and need additional protection in lairage.
11) Suckling lambs and goat kids are more susceptible to prolonged thirst and hunger.

4.3. Conclusions specific to Phase 2 – stunning

1) Consciousness is a prerequisite for sheep and goats to experience pain, fear and distress. Therefore, animals that are not stunned or ineffectively stunned or that 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 through specific ABMs, which can be used at all key stages.
2) Electrical and mechanical stunning methods (excluding firearms) require restraint of the body which imposes additional pain and fear. These welfare consequences will persist during the restraining period until successful stunning.
3) Ineffective electrical stunning is mostly due to wrong placement of the electrodes, poor electrical contact, too short exposure time or inappropriate electrical parameters.
4) In the light of available scientific evidence at present, a minimum of 1.0 A is required to guarantee effective electrical stunning of all sheep and goats, including lambs and goat kids.
5) Head-only electrical stunning results in short duration of unconsciousness and therefore prompt and accurate bleeding is required to prevent recovery of consciousness leading to poor welfare outcome.
6) 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.

7) Ineffective captive bolt stunning is mostly due to wrong shooting position and shooting direction and inappropriate bolt parameters, i.e. velocity, exit length (depth of penetration into the skull) and diameter.
8) Adult sheep and goats have anatomical structures in the skull that will reduce the impact of non-penetrative captive bolt stunning, reducing the efficacy of this stunning method.
9) The shooting position for the effective stunning in polled sheep is the highest point on the head aiming straight down.
10) The shooting position for the effective stunning in horned sheep and goats is behind the ridge between the horns (behind the bony mass), and aimed towards the base of the tongue.
11) Exposure to CO_2 at high concentrations (higher than 90% by volume) is considered a serious welfare concern by the Panel, because it is aversive and causes pain, fear and respiratory distress.
12) Scientific evidence is lacking regarding the impact on animal welfare of the use of inert gases and CO_2 with inert gases, which are potentially less aversive.
13) The effectiveness of percussive blow to the head for killing of neonatal sheep and goats (up to 5 Kg live weight) is very variable, as it entirely depends on the operator skills, and can be very low

4.4. Conclusions specific to Phase 3 – bleeding

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.
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.

5. Recommendation

5.1. General recommendations

1) Design, construction and maintenance of the premises and handling facilities should be based on understanding how sheep and goats 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 sheep and goats 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 sheep and goats should be assessed through ABMs at each phase of slaughtering to prevent and correct hazards and mitigate negative welfare consequences.
4) When the use of ABMs is not feasible and the hazard is present, the sheep and goats should be assumed to experience the related welfare consequences and treated consequently.
5) The ranking of the hazards according to the severity, magnitude and frequency of the welfare consequences for sheep and goats at slaughtering should be performed in a future scientific opinion in order to prioritise preventive and corrective measures and improve the procedure at slaughter.
6) The standard operating procedure (SOP) – as requested by EC Reg 1099/2009 – 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 premises,
   b) training and rotation of the staff,
   c) appropriate settings and use of the equipment.
9) When a hazard is identified, it should be corrected without any delay.

10) Additionally, measures to prevent and mitigate the welfare consequences should be put in place.
11) Practices leading to serious welfare concerns should be avoided, redesigned or replaced by other practices leading to better welfare outcomes.
12) Sheep and goats can be handled and moved using lead animals of the same species. Dogs should not be used during the three phases of the slaughter process.

5.2. Recommendations specific to Phase 1 – Pre-stunning

1) Assessment of the welfare state of sheep and goats at the time of arrival should be performed as an important first step in fulfilling animal protection at slaughterhouse.
2) At arrival, sheep and goats should be unloaded without delay 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, preventive measures should be put in place to avoid thermal stress and hazards inducing thermal stress (too high effective temperature, too low effective temperature) should be prevented (e.g. by providing ventilation).
4) Sheep and goats 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 without delay to prevent further suffering of the animal.
5) At the time of arrival, the animals should be examined to identify poor welfare outcomes and to take corrective or mitigation measures to deal with poor welfare outcomes, including emergency slaughter.
6) The design, construction and maintenance of the unloading facility, and the aptitude and attitude of the staff should prevent animals from slipping and falling.
7) The unloading platforms should have solid sides to prevent animals from jumping or escaping.
8) Sheep and goats should be slaughtered after unloading without any delay. Keeping animals in lairage should be avoided or kept to a minimum.
9) In lairage, animals should have access to water and protection from adverse weather conditions. Lactating females should be milked to release the udder pressure. If milking is necessary, the milking interval should not exceed 12 h. Mixing of unfamiliar goats, particularly of horned animals, should be avoided.
10) In lairage adequate space should be offered to sheep and goats 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 sheep and goats and k is a constant value that depends on the sheep and goats posture. A minimum k value of 0.027 is recommended, which should be increased according to the climatic conditions and density and length of wool.
11) If the effective temperature is above the thermoneutral zone, ventilation should be increased to cool down the animals and this can only be achieved through effective air movement.
12) Painful handling, such as lifting and dragging by horns or wool, hitting with a stick, etc. should be avoided. Instead, passive stimuli such as flags and paddles should be used.
13) Suckling lambs and goat kids should be slaughtered without lairage. If slaughter is delayed, they need to be fed with suitable milk replacement at regular intervals.

5.3. Recommendations specific to phase 2- Stunning

1) Appropriate restraining of the animals (i.e. animals should be held firmly and presented to the operator) is required to achieve effective stunning.
2) Restraining methods or practices which cause severe pain and fear should not be used.
3) ABMs should always be used to assess pain and fear associated with restraint.
4) Animals should not be restrained if the operator is not ready to stun them without delay.
5) Animals should not be stunned if the operator is not ready to bleed them without delay.
6) Animals should not recover from stunning since it will expose them to hazards linked with bleeding, causing severe welfare consequences, such as pain, fear and distress.

7) Head-to-body electrical stunning eliminate the chance of recovery of consciousness compare to head-only electrical stunning and is therefore recommended.
8) For electrical stunning of sheep and goats, it is recommended to use a minimum current of 1.0 A, delivered using 150–400 V, for at least 2 s.
9) 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 ABMs.
10) Animals ineffectively stunned or recovering consciousness should be stunned without delay with a backup method.
11) The use of non-penetrative captive bolt guns for stunning sheep and goats should be restricted to animals of less than 10 kg live weight.
12) For polled sheep, the muzzle of the penetrative captive bolt stunner should be placed on the highest point of the head, and on the mid-line, aiming straight down.
13) For sheep and goat with horns, the muzzle of the penetrative captive bolt stunner should be placed on the mid-line, behind the ridge between the horns (behind the bony mass) and aimed towards the base of the tongue.
14) Percussive blow to the head of neonatal sheep and goats should not be used.
15) More research is recommended on the use of inert gases and/or CO_2 with inert gases for stunning of sheep and goats.

5.4. Recommendations specific to Phase 3 – Bleeding

1) Unconsciousness should be confirmed in animals before neck cutting.
2) Recovery of consciousness following reversible stunning methods should be avoided by: (i) prompt and accurate bleeding of animals, (ii) severing completely the brachio-cephalic trunk or both carotid arteries, (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 recognise signs of consciousness and to apply a back-up stunning method without delay.
5) Slaughter without stunning should not be practiced, as during slaughter without stunning all animals have to endure the welfare consequences resulting from remaining conscious during neck cutting and bleeding and therefore experience severe pain, fear and distress.

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Abbreviations

ABMs	Animal-based measures
AC	Alternating current
DOA	Dead on arrival
LS	literature search
LCT	lower critical temperature
UCT	upper critical temperature
MLAEPs	middle latency auditory evoked potentials
OIE	World Organisation for Animal Health
SOP	standard operating procedure
TNZ	Thermal neutral zone
ToR	Term of Reference
WG	working group

Appendix A – Literature search outcomes for small ruminants

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 small ruminants' 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 small ruminants 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 'small ruminants'. 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: 17 July 2020 (Restriction to English)

Web of science search string	
Years 2004–2019	
	Category
Search terms	**Field searched**
TS=small ruminants OR TS=small ruminant OR TS=sheep OR TS=goats OR TS=goat OR TS=lambs OR TS=lamb OR TS=kids OR TS=kid OR TS=muttons OR TS=mutton OR TS=rams OR TS=ram OR TS=billy-goats OR TS=billy-goat OR TS="Ovis aries" OR TS="Capra aegagrus hircus"	Topic
AND	
TS=slaughter* OR TS=kill* OR TS=stun*	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
AND	
TS=Welf* OR TS="animal welfare"	Topic
Results: 221	
Results after screening: 90	

Refinement of literature search results

The search yielded a total of 221 (2004–2020) 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 90 relevant records. Discrepancies were discussed between the WG members until a final subset of 46 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 small ruminants' resulting from the Literature Search

ID	Reference
1	Abyaneh et al. (2020)
2	Alcalde et al. (2017)
3	Barbour et al. (2005)
4	Berg et al. (2012)
5	Coleman et al. (2012)
6	Collins et al. (2018)
7	Cozar et al. (2016)
8	De la Fuente et al. (2012)
9	Deiss et al. (2009)
10	EFSA (2006)
11	EFSA AHAW Panel (2013a)
12	EFSA AHAW Panel (2013b)
13	EFSA AHAW Panel (2014)
14	EFSA AHAW Panel (2017)
15	Eriksen et al. (2013)
16	Fernandez et al. (2018)
17	Gibson et al. (2012)
18	Grandin (2020)
19	Gregory et al. (2009)
20	Greenwood et al. (2010)
21	Grist et al. (2018a)
22	Grist et al. (2018b)
23	Hemsworth and Jongman (2017)
24	Hemsworth et al. (2011)
26	Ivanov (2020)
27	da Leme et al. (2012)
28	Liste et al. (2011)
29	Liu et al. (2012)
30	Llonch et al. (2015)
31	Mason et al. (2018)
32	Miranda-de la Lama et al. (2014)
33	Nakyinsige et al. (2013)
34	Orford et al. (2016)
35	Rodríguez et al. (2012)
36	Rodríguez et al. (2016)
37	Sabow et al. (2016)
38	Sabow et al. (2018)
39	Sanchez-Barrera et al. (2014)
40	Sutherland et al. (2016)
41	Teke et al. (2014)
42	Teke et al. (2018)
43	Terlouw et al. (2008)
44	Verhoeven et al. (2015)
45	Velarde et al. (2014)
46	Weeks (2008)