SECTION 7

Preslaughter handling, stunning and slaughter methods

Hygiene of animals presented for slaughter

- Animals presented for slaughter should be sufficiently clean so that they do not compromise hygienic slaughter and dressing.
- The conditions of holding of animals presented for slaughter should minimize cross-contamination with food-borne pathogens and facilitate efficient slaughter and dressing.
- Slaughter animals should be subjected to ante-mortem inspection, with the competent authority determining the procedures and tests to be used, how examination is to be implemented, and the necessary training, knowledge, skills and ability of personnel involved.
- Ante-mortem inspection should be science- and risk-based as appropriate to the circumstances, and should take into account all relevant information from the level of primary production.
- Relevant information from primary production where available and results of ante-mortem inspection should be utilized in process control.
- Relevant information from ante-mortem inspection should be analysed and returned to the primary producer as appropriate.

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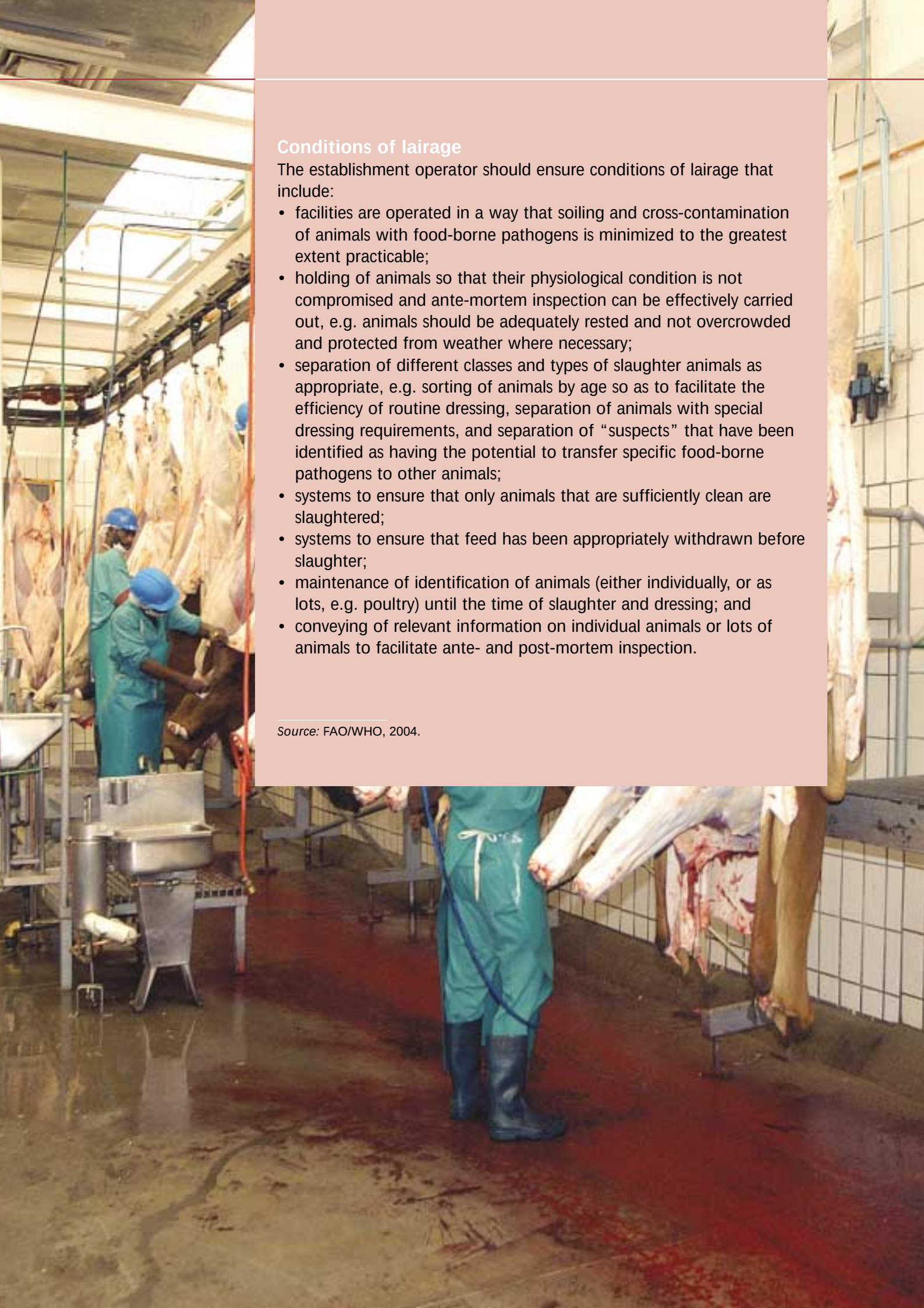

Conditions of lairage

The establishment operator should ensure conditions of lairage that include:

- facilities are operated in a way that soiling and cross-contamination of animals with food-borne pathogens is minimized to the greatest extent practicable;
- holding of animals so that their physiological condition is not compromised and ante-mortem inspection can be effectively carried out, e.g. animals should be adequately rested and not overcrowded and protected from weather where necessary;
- separation of different classes and types of slaughter animals as appropriate, e.g. sorting of animals by age so as to facilitate the efficiency of routine dressing, separation of animals with special dressing requirements, and separation of "suspects" that have been identified as having the potential to transfer specific food-borne pathogens to other animals;
- systems to ensure that only animals that are sufficiently clean are slaughtered;
- systems to ensure that feed has been appropriately withdrawn before slaughter;
- maintenance of identification of animals (either individually, or as lots, e.g. poultry) until the time of slaughter and dressing; and
- conveying of relevant information on individual animals or lots of animals to facilitate ante- and post-mortem inspection.

Source: FAO/WHO, 2004.

INTRODUCTION

When animals are killed for food, it is imperative for ethical reasons that the methods used do not inflict pain. To comply with this requirement, animals should be rendered insensible before slaughter. The period of insensibility must include the time when it is initiated, through the start of the slaughter process to the time taken for the animal to bleed to death. In most instances, except for certain forms of religious slaughter, insensibility is achieved by stunning the animals prior to slaughter.

In each of the methods that are used for stunning and slaughtering animals, there should be means of verification that the processes were adequately carried out. Care should be taken to protect operators during potentially hazardous processes. Furthermore, principles of meat hygiene should be strictly adhered to in order to prevent any contamination of edible parts of the carcass.

The length of time animals spend in the lairage awaiting slaughter varies according to the abattoir's work practices and throughput, but should not exceed 72 hours if in a covered part of the slaughterhouse. In practice, the average time will usually be only a few hours. Following this period, when the animal should be resting, it is moved from the holding pen to the stunning pen or area, a process that should induce minimal stress (to both animal and stock handler).

ANIMAL RESTRAINT TO FACILITATE STUNNING AND/OR SLAUGHTER

Animals have to be transferred from the lairage pens either directly or through a race into an area where stunning and slaughter are carried out (see Section 5). Animals are often transferred from the lairage through a race to the stunning area. The race design should take into account animals' natural instincts and normal behaviour. Race designs incorporating solid, smooth sides and walls, and non-slip flooring work well. Curved races with no dead ends facilitate smooth movement of animals. Adequate lighting in the race also improves animal movement. Goading in the race should be as minimal as possible.

In order to facilitate stunning and to protect the operators, some kind of restraint is necessary. Restraint should allow correct application of stunning equipment and protect animal welfare, as well as protecting operators from potential injury, especially from large animals. This may be achieved in a number of ways.

Manual restraint in an open pen

This is usually done by manually handling the free standing animal in an open area or a pen. The animal may enter the pen either directly from holding areas or through raceways. Electrical or captive bolt stunning in pigs and sheep and religious slaughter (Photo 7.1) can be carried out this way. However, safety and

PHOTO. 7.1
Restraint by shackle before religious slaughter

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PHOTO 7.2
Upright cattle restraint with monorail conveyor
a) Chin lift, b) Monorail, c) Neck restraint

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PHOTO 7.3
Upright cattle restraint with monorail (internal view)
a) Chin lift, b) Monorail, c) Neck restraint

welfare problems may be common, especially when handling cattle.

Restraint in a squeeze/crush pen

This method involves holding the animal by pressure from the sides. Usually one side moves. It is not commonly used.

Cattle stunning pens

Different designs of cattle restraint pens can be used. The objective is to confine the animal in a pen so that stunning and slaughter can be carried out effectively and safely. Animals usually enter the pen after going through a race. The race should have smooth curved sides if they are long, and have sufficient light. Use of prods should be minimal. Pens must have gates to close after entry.

For captive bolt stunning, facilities to present the head for correct stunning at the front are useful. Some cattle pens are specially constructed for captive bolt or electrical stunning and/or religious slaughter. Upright (Photos 7.2 to 7.4) and Facomia pen (Photo 7.5) designs have additional features for extra restraint, such as a belly lift, back push and chin lift. The Facomia pen tilts the animal to approximately 45°. Rotary pens that turn the animal 180º (i.e. upside down) are more stressful and are banned in the United Kingdom.

V-type restrainers

V-type restrainers use the principle of suspending the animals in a funnel-shaped apparatus, which often has a conveyor system and is commonly used for pigs and sheep. It seems to work better for sheep than pigs. Sheep can be electrically stunned, either head only or head-to-back at the end of the conveyor, either manually or automatically (Figure 7.1).

Monorail restrainers

This system holds the animal in a straddle position over a rail. When combined with a conveyor system, animals are moved to the point of stunning with possibly less stress than with V-restraint. This system is successfully used for pigs (Figure 7.2).

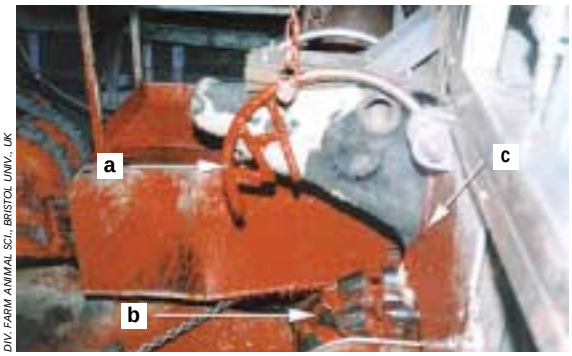

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PHOTO 7.4
Upright cattle restraint: exsanguination by religious method
a) Chin lift, b) Monorail, c) Neck restraint

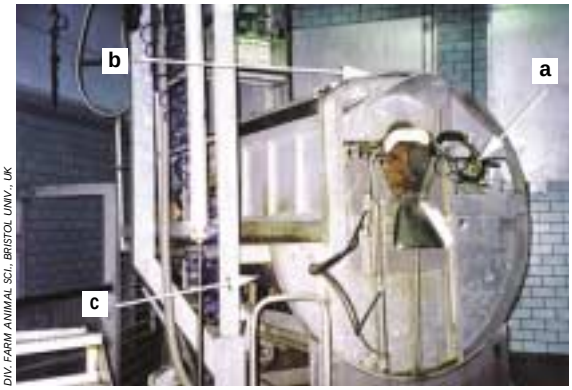

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PHOTO 7.5
Facomia cattle pen
a) Chin lift, b) Rotating pen (45°), c) Belly lift

PRESLAUGHTER STUNNING

Animals must be stunned before slaughter by an appropriate, recognized stunning method that must produce immediate unconsciousness that lasts until death. Animals should be restrained prior to stunning if it improves the effectiveness of the stunning procedure, but they must not be restrained unless they can be stunned and slaughtered without delay. Also, stunning must not be carried out unless the animal can be slaughtered without delay. Operators must be trained and competent to carry out and recognize effective stunning. The assessment of stunning must take place before any other procedure is carried out. Spare stunning or killing equipment must always be available for immediate use.

Electrical stunning

Electrical stunning equipment must be capable of producing an effective stun for the species and size of the animal. Electrodes must be placed so that they span the brain (Figures 7.3 and 7.4) and sufficient voltage (> 200 volts) applied for ≥ 3 seconds to cause immediate unconsciousness. When sufficient current is applied to the brain, an epileptic fit will be produced during which the animal is unconscious.

FIGURE 7.1 **V-type restraint conveyor for sheep**

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FIGURE 7.2 **V-type restraint conveyor for pigs**

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FIGURE 7.3 **GOOD PRACTICE: optimum tong position for head-only electrical stunning of pigs**

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TABLE 7.1 **Recommended minimum currents for head-only stunning of red meat species**

Species	Minimum current to stun (amps)
Pigs	1.3
Sheep and goats	1.0
Lambs/kids	0.6
Calves	1.0
Cattle	1.2

The relationship between Voltage (V), Current (I) and Resistance (R) is given by the formula: V = I x R. Therefore, the resistance between the electrodes will affect the induced current. The electrode/animal interface forms a major part of the overall resistance and, thus, the condition of the electrodes must be regularly inspected and maintained. The recommended minimum current to stun is given in Table 7.1.

Head-only stunning tongs (pigs, sheep, goats and calves) should be fitted with electrodes that contain two parallel rows of teeth that are sharp enough to penetrate the outer layers of skin and to ensure that the electrodes do not slide following initial contact, thus maintaining the continuity of the current application. Electrical stunning equipment must contain an ammeter and voltmeter display.

Electrical stunning equipment should be used and maintained according to the manufacturer's instructions and must not be used to immobilize, restrain or goad an animal. The operator must be trained and competent to carry out the stunning procedure and the electrodes must be placed accurately on the animal's head and for the required duration.

The following are signs of an effective electrical stun:

- Tonic phase (duration 10–12 seconds):
  - animal collapses and becomes rigid;
  - no rhythmic breathing;
  - forelegs extended and hindlegs flexed into the body.
- Clonic phase (duration 20–35 seconds):
  - uncontrolled kicking or paddling movements;
  - eye roll or flicker and salivation.

The clonic phase will be followed by the return of rhythmic breathing and subsequent recovery in an unbled animal. Therefore, effective stunning and slaughter can be characterized by the absence of rhythmic breathing from the initiation of the stun through to the death of the animal (through correct sticking).

Mechanical stunning

The objective of mechanical stunning methods is to induce immediate unconsciousness by the administration of a severe blow to the head of the animal. The unconsciousness produced must last until death. Mechanical stunning devices (nowadays, almost universally captive bolt guns

FIGURE 7.4 **Good practice: optimum tong position for head-only electrical stunning of sheep**

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FIGURE 7.5 **Penetrating CBG with hand trigger**

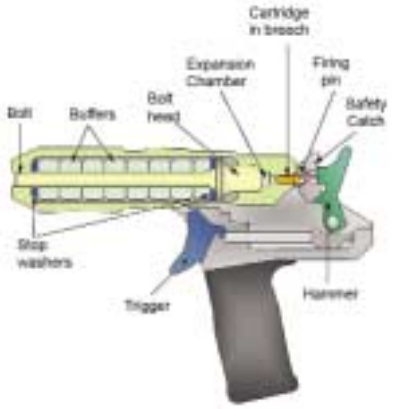

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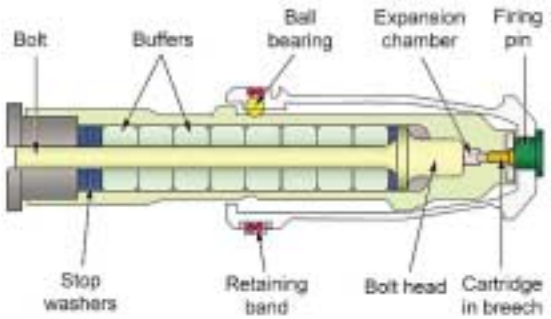
FIGURE 7.6 **Penetrating CBG with contact trigger**



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[CBGs]) can be divided into two broad categories:

- penetrating;
- non-penetrating.

Penetrating CBGs (Figures 7.5 and 7.6) are primarily used for stunning cattle; however, they can also be used for sheep, goats, pigs, deer, horses and rabbits.

There are various non-penetrating devices, ranging from the sledge-hammer or maul to a mushroom-headed CBG (knocker). The knocker (Figure 7.7) is the only non-penetrating device that should be used in practice as, unlike the manual methods, it is designed to apply a controlled blow to the head of the animal. Non-penetrating CBGs should only be used for cattle.

Physical and physiological effects of mechanical stunning

When a penetrating device is used there are two main types of effect. There are the general effects of concussion produced when the bolt impacts with the skull and the physical damage produced when the bolt enters the brain. The impact of the bolt on the skull causes disruption of brain activity resulting in unconsciousness. A common misconception is that the bolt must enter the brain to cause unconsciousness. This is not true and there are devices available that are designed to apply a blow to the head of the animal, inducing concussion, without penetrating the brain. Concussion is normally defined as the reversible loss of consciousness, which is why mechanical stunning should always be followed by a killing method, e.g. exsanguination. However, it must be stressed that concussion is not always a

reversible condition and the loss of consciousness may often be long-lasting or even permanent.

The two key elements of mechanical stunning that are required for the effective induction of concussion are the positioning of the blow (shot position) and the amount of energy transferred to the animal's brain (force of impact). Bolt velocity and bolt mass are important because they determine the force of impact of the bolt on the head of the animal and the amount of energy transferred to the brain (kinetic energy). High bolt velocities result in a greater acceleration of the head of the bolt during the percussive blow, which more effectively induces a state of concussion.

Kinetic energy = $1/2\ mv^2$

where m = mass of the bolt, v = bolt velocity

Bolt velocity can be affected by of number of other factors, including:

- gun type and condition;
- choice of cartridge/air pressure.

Shooting positions

A critical factor for successful mechanical stunning is the application of the blow to an area of the head where it will have maximum effect in causing brain dysfunction. In most animals this is the frontal area of the head; however, the ideal position is affected by species, animal age and type of device used (whether penetrating or non-penetrating).

- Cattle: For penetrating devices, the ideal shooting position is the intersection of two imaginary lines drawn between the eyes and the centre of the base of the opposite horn bud (Figure 7.8). A non-penetrating device should be positioned approximately 20 mm above the position used for the penetrating instrument.
- Sheep: For horned animals the captive bolt device should be positioned on the midline, behind the ridge between the horns and aimed towards the base of the tongue (poll position). When animals are shot in the poll position they must be bled within 15 seconds. For polled sheep, the device should be placed on the highest point of the head and aimed vertically (Figure 7.9).
- Goats: The correct position for stunning goats (both horned and polled) is the same as for horned sheep. The captive bolt device should be positioned on the midline, behind the

FIGURE 7.7 **Non-penetrating CBG with hand trigger (knocker)**

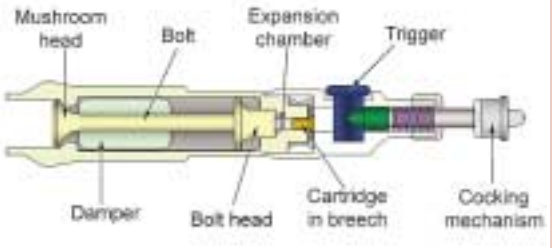

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FIGURE 7.8 **Captive bolt stunning of cattle – gun aimed at right angles to head**

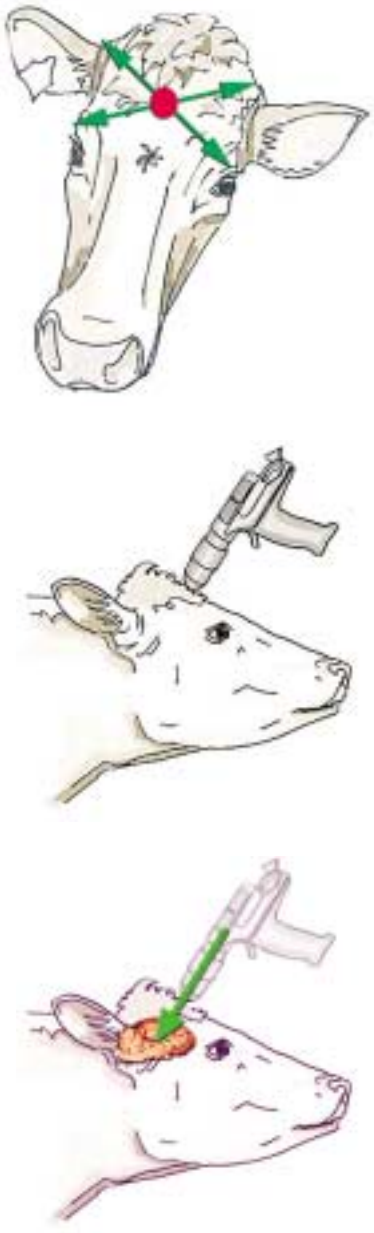

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FIGURE 7.9 **Captive bolt stunning of sheep**

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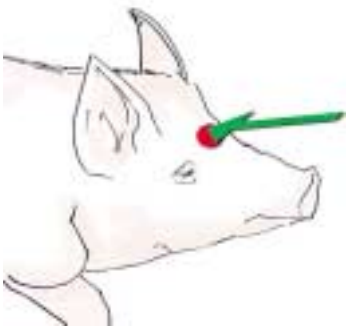
FIGURE 7.10 **Optimum shooting position for pigs**



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ridge between the horns and aimed towards the base of the tongue (poll position).

- Pigs: The device should be placed on the midline, 20 mm above eye level and aimed towards the tail of the animal (Figure 7.10). The position should be 50 mm above eye level for older sows and boars and adjusted slightly off the midline to avoid a bony ridge. Note that CBG stunning can cause severe convulsions in pigs.

Design and operation of captive bolt devices

Captive bolt devices are activated either by trigger or by impact with the animal's head. Non-penetrative devices are always trigger-fired. The choice of device is usually based on species of animal, handling/restraint system, availability, personal preference and experience. The bolt in a captive bolt or concussion device is propelled forward by compressed air or the expansion of an explosive charge held in a blank cartridge. Cartridge strength is expressed in terms of grain size, where 1 grain is the equivalent of 0.0648 g of propellant. It is essential that the cartridges used are appropriate for the type of device and the animal being stunned (Table 7.2).

With captive bolt devices used in the correct shooting position, the bolt penetrates the cortex and midbrain areas (Figures 7.8 and 7.9) where the physical damage can prevent recovery. Following penetration (about 7.5 cm), the bolt is returned back into the barrel by the action of the recuperating sleeves (buffers).

The following are signs of an effective mechanical stun:

- the animal collapses immediately;
- the eyes are fixed;
- no corneal reflex;
- no rhythmic breathing.

TABLE 7.2 **Cartridge sizes based on manufacturer's recommendations**

Animal size & species	Device type	Calibre	Cartridge grain
Very large *(heavy bulls)*	Penetrating Penetrating Non-penetrating	.22 .25 .25	4.0–4.5 4.0 6.0
Large *(large cattle, horses)*	Penetrating Non-penetrating	.22 .25	3.0–4.0 5.0
Medium *(other cattle, pigs, goats)*	Penetrating Non-penetrating	.22 .25	2.5 4.0
Small *(sheep, calves, young lambs and goats)*	Penetrating	.22	1.25

The following are signs of an ineffective mechanical stun:

- the animal does not collapse immediately and may attempt to raise its head and stand up;
- the eyes are rolled down;
- positive corneal reflex;
- rhythmic breathing is present.

In the event of an animal being ineffectively stunned or showing signs of recovery, there should be procedures in place to deal with it effectively and protect its welfare. Cattle that are ineffectively stunned or showing signs of recovery should be restunned using a shooting position that is 10 mm above the ideal and 5 mm either to the left or right of the midline. Animals must never be reshot through the first shooting hole.

Slaughter methods following captive bolt stunning

Bleeding either by neck-cutting or by a thoracic stick should be carried out as soon as possible to prevent the risk of recovery. After the use of a penetrating captive bolt device, the animal should be stuck as soon as possible (ideally within 60 seconds). If a non-penetrating device is used, it is even more critical to ensure that sticking is performed as soon as possible.

Additional requirements for mechanical stunning

- Manufacturer's recommendations/instructions must be observed at all times.
- Animals must be appropriately restrained.
- Stunning devices must be well maintained and suitable for species.
- Stunning devices need to be cleaned at the end of production and worn out components must be replaced by parts supplied by the manufacturer. The lumen of the barrel must be brushed out to remove carbon deposits. The undercut (wider area where the bolt head fits) should also be cleaned with a special device called a reaming tool.
- Stunning devices also need to be serviced every two years by the manufacturer.
- A spare stunning device must be available for use in the case of failure or emergency.
- There must be documented procedures for action to be taken in the event of ineffective stunning or an animal showing signs of recovery.
- The animal must be assessed for signs of an effective stun prior to shackling and hoisting and during bleeding.

KILLING

Modified atmosphere stunning/killing

The gas or gas mixtures used to induce unconsciousness must not cause aversion and the duration of exposure must be long enough to cause the death of the animal. This must be verified before any other process is carried out.

The concentration of the gas or gas mixtures used must be continuously monitored and audible and visual warnings given should the gas fall below the correct concentration. The equipment used must be constructed so as to avoid injury to any animal.

How to recognize effective gas killing:

- When the animal leaves the gas chamber it should be off its feet, generally relaxed and must not display rhythmic breathing.
- The animal must not respond to a painful stimulation, e.g. a pinprick to the nose.

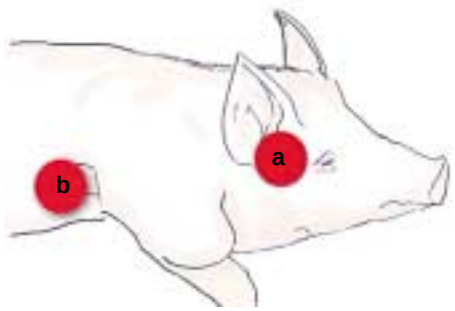
Electrically induced stunning/killing

The application of sufficient current at low frequency (50/60 Hz) to cardiac muscle will result in ventricular fibrillation with subsequent cardiac arrest. Electrical stunning systems can be applied to animals so that the electrodes span both the brain and the heart (Figure 7.11). With sheep, head-to-back systems must apply ≥1.0 amps using electrodes that are applied in front of the brain (in line with the eyes) and in the middle of the animal's back (Figure 7.12). One problem with head-to-back stunning of sheep is pelt-burn caused by the rear electrode. With pigs, automatic systems are designed to apply a "split stun" system with an initial head-only application (220 volts) and a simultaneous head-to-chest application (120 volts) that commences after the initiation of the head-only stun.

The electrical stun/killing of adult cattle must be carried out in a stunning pen designed for that purpose (Figures 7.13 and 7.14).

Voltages in excess of 260 volts should be applied via electrodes that are capable of delivering ≥1.2 amps to the head and ≥1.6 amps to the heart. There can be some variation in the physical activity seen following cardiac arrest stunning in cattle; for example, the return of

FIGURE 7.11 **GOOD PRACTICE: head-to-back stunning**



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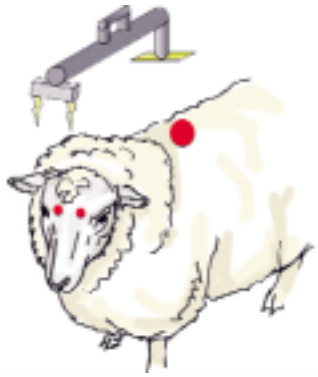
Note: head stunning (a) followed by chest electrode (b).

FIGURE 7.12 **GOOD PRACTICE: optimum electrode position for head-to-back electrical stunning of sheep**



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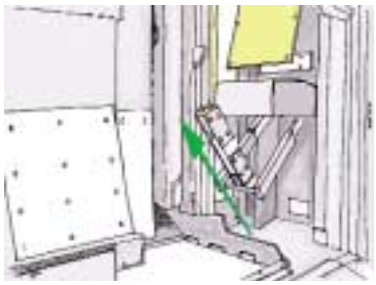
Note: the rear electrode is used to stop the heart.

FIGURE 7.13 **GOOD PRACTICE: side view of an electrical stunning pen for cattle with electrodes in the on position**



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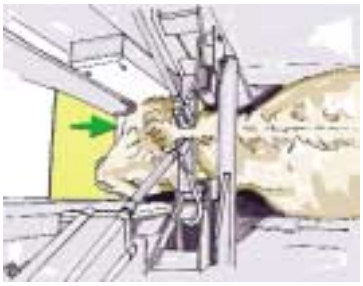
Note: the arrow shows the direction of the brisket (heart) electrode. Stunning electrodes are in yellow.

FIGURE 7.14 **GOOD PRACTICE: top view of an electrical stunning pen**



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Note: stunning electrodes are in yellow.

rhythmic breathing has been witnessed in animals that are dying from a cardiac arrest.

Signs of effective electrically induced stunning/killing:

- Tonic phase (usually foreshortened):
  - animal collapses and becomes rigid;
  - no rhythmic breathing;
  - forelegs extended and hindlegs flexed into the body.
- Clonic phase (usually foreshortened):
  - little physical activity.

SLAUGHTER

Sticking must only be carried out on animals that are stunned. The knife that is used must be clean and sharp and of sufficient length for the species and size of the animal. Both carotid arteries, or the vessels from which they arise (close to the heart), should be severed.

Following sticking, the animal must be allowed to bleed to death before any further dressing procedure or any electrical stimulation is carried out. The minimum times are 25 seconds after sticking pigs, sheep and goats; and 60 seconds for cattle and deer.

Sticking methods:

- **Thoracic stick:** (a) Make a cut in the jugular crease at the base of the animal's neck. (b) With the knife-point at the base of the breastbone and pointed towards the chest, insert the knife to sever the major blood vessels coming from the heart (Figures 7.15 and 7.18).

FIGURE 7.15 **Chest sticking in cattle**

a) Long initial skin cut

b) Sticking point under the sternum

c) Knife inserted into chest in upward direction

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Note: GOOD PRACTICE: for a good bleed out, the popular method is chest sticking, which involves cutting the skin longitudinally from the neck down to the chest following the midline and then cutting into the chest near the heart.

FIGURE 7.16 **Neck sticking in cattle**

a) Position of knife insertion and neck cut in cattle

b) All vessels are severed

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Note: transverse neck sticking can also be used, which must include severance of both carotid arteries and jugular veins.

- **Neck stick:** (c) Insert a knife, close to the head, cut through the neck (with the back of the knife against the spine), cut forward severing all the soft tissues between the spine and the front of the neck. Reverse the blade and cut back against the spine. This action will sever both carotid arteries and both jugular veins (Figures 7.16 and 7.17)

These methods can be used for different animals as follows:

- cattle and calves: (a) + (b);
- pigs: (b);
- sheep and goats: (b) or (c).

Unconventional local/traditional slaughter methods

In some countries unconventional, local slaughter techniques exist. Some of these need consideration:

- immersion of pigs in a basket in water to drown and kill;
- unilateral sticking of pigs in standing position or slaughter on the floor without stunning;
- punctilla of cattle, which involves severance of the spinal cord in the neck without stunning.

The above practices severely compromise animal welfare and must be avoided.

Control of processes

To ensure that the welfare of animals is maintained during slaughter, and that the process operates at maximum effectiveness, a quality management programme should be implemented and maintained. A HACCP-type system is strongly recommended. By making

regular measurements at critical control points (CCPs), various critical operations that are carried out by workers handling and slaughtering livestock can be monitored to ensure that they are done correctly, leading to steady improvements in welfare and operational quality. An objective scoring system with five major CCPs of animal handling and slaughter is suggested in Table 7.3. Monitoring and evaluation of the CCPs should be done on a regular basis.

RELIGIOUS SLAUGHTER

Jewish method of slaughter (*shechita*)

Jews consume beef, lamb and poultry, but not pork. These meats must be slaughtered and prepared in accordance with the rabbinical laws. Slaughter is carried out by an approved slaughterman of the Jewish faith, called a *shocet*. The slaughter process, which precludes any type of stunning, is preceded by positioning the animal, though this is not subject to regulation by the religious authorities.

A single, transverse cut severing all tissues and blood vessels is made across the neck using a very sharp, special knife (*chalaf*). The knife has to be examined for its sharpness between each cut. It is usually 16 inches (40.64 cm) long for cattle. Once an animal is dead, an incision is made through the abdominal wall and a Jewish inspector feels at arm's length into the thorax to check for pleural adhesions or any other signs of abnormality. If any abnormality is found, the entire carcass is rejected for Jewish consumption on the grounds that the animal was not healthy at the time of slaughter.

In some practices the meat is "porged" to remove veins and other forbidden tissues.

FIGURE 7.17 **Neck sticking in sheep**

a) Position of knife insertion and neck cut in sheep

b) Insertion of knife before severance of vessels

c) Exsanguination after neck cut

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FIGURE 7.18 **Chest sticking in pigs**

a) Position of knife insertion and chest cut in pigs

b) All vessels are severed

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TABLE 7.3 **Suggested CCPs for animal handling and slaughter**

CCP	Description of CCP	Method of scoring	Rating of scores
Stunning efficacy	The percentage of animals rendered insensible at the first attempt.	• Captive bolt stunning: a minimum of 20 animals, or 20% in large plants, should be scored per day.	• Excellent: 99–100% instantly rendered insensible with one shot • Acceptable: 95–98% • Not acceptable: 90–94% • Serious problems: less than 90%
		• Electrical stunning: score all pigs, sheep or ostriches or a minimum of 100 in a large plant.	• Excellent: 99.5–100% • Acceptable: 99–99.4% • Not acceptable: 95–98% • Serious problems: less than 95% **NB** If one-shot efficacy falls below 95%, immediate action must be taken to improve the percentage.
Insensibility after stunning	The percentage of animals that remain insensible before and after bleeding.	• Score a minimum of 20 animals or 20% in a large plant. • Evaluate after hoisting for animals that are hoisted after stunning. • Wait 15–30 seconds before evaluating animals that are left on the ground after stunning.	• Excellent: less than 0.1% in cattle; less than 0.05% in pigs • Acceptable: less than 0.2% in cattle; less than 0.1% in pigs **NB** Any animal that shows signs of sensibility must be restunned immediately.
Vocalization	The percentage of cattle that bellow or moo, or pigs that squeal during adverse events, such as a missed stun, excessive electric prod use, excessive pressure from restraint devices, slipping or falling, etc. **NB** Vocalizing score is not used for sheep because they rarely do so.	Each animal is scored for vocalization during handling and stunning, not while in the holding pens. • In crowd pen, lead-up race, stun box or restraint device, score each animal as "Yes" for vocalizer and "No" for non-vocalizer.	Cattle: • Excellent: ≤0.05% = "Yes" • Acceptable: ≤3% = "Yes" • Not acceptable: 4–10% = "Yes" • Serious problem: >10% = "Yes" Pigs: • Excellent: 0% = "Yes" • Acceptable: ≤1% = "Yes" • Not acceptable: ≥2% = "Yes" • Serious problem: ≥10% = "Yes"
Slipping and falling	The percentage of animals that slip and fall during handling or stunning. Selected stations should be chosen for monitoring.	Slipping and falling in the stunning area (includes restrainer entrances, races, holding pens and unloading ramps). • Score a minimum of 20 animals or 10% in large plants. • Score "Yes" for slipping and "No" for no slipping.	• Excellent: no slipping or falling • Acceptable: <3% slipping • Not acceptable: 1% falling down (body touches floor) • Serious problem: 5% falling down or 15% slipping
Electric prodding efficacy	Percentage of animals requiring prodding with an electric goad.	If the prod causes the animal to vocalize, the current is too strong. • Score a minimum of 20 animals or 10% in large plants. • Score "Yes" if animal vocalizes and "No" if it does not.	Total % of cattle prodded: • Excellent: ≤5% = "Yes" • Acceptable: ≤10% = "Yes" • Not acceptable: ≤20% = "Yes" • Serious problem: ≥ 50% = "Yes" Total % of pigs prodded: • Excellent: ≤10% = "Yes" • Acceptable: ≤15% = "Yes" • Not acceptable: ≤25% = "Yes" • Serious problem: ≥ 50% = "Yes"

Special consideration must be given to minimizing welfare problems during *shechita*. Preslaughter handling must have the same criteria used before application of stunning methods. It would be advisable to use a restraint apparatus, preferably an upright stunning pen or one that incorporates a monorail conveyor for Jewish slaughter (Photos 7.2 to 7.4). If necessary, a V-type restraint pen or a Facomia pen (Photo 7.5) that slightly tilts the animal (around 45º) can also be used. However, rotating pens that invert the animal 180º and cause undue stress must be avoided. Restraint of animals must be quick, of short duration, and slaughter carried out immediately without delay.

Exsanguination must be carried out rapidly and all blood vessels in the neck cut. The neck needs to be in an extended position during the cut. Ballooning on the cut surfaces of the carotid arteries must be avoided.

Exsanguinated blood must flow rapidly and copiously so that brain death is quick. Physical restrictions in the neck area impeding blood flow must be avoided (e.g. metal parts of the restraint device).

At least 20 seconds must be allowed for exsanguination before any other procedures. In some practices, Jewish authorities allow captive bolt stunning after the neck cut. Where possible, this should be encouraged to protect animal welfare.

Muslim method of slaughter (*halal* slaughter)

This method is now commonly referred to as *halal* slaughter. As for Jews, pig meat is forbidden. There seems to be more variation in the way slaughter is practised than in the Jewish system. These variations are possibly due to different interpretations of the Koran and the Hadis (the sayings of the prophet Mohammed).

The act of slaughter (*Al-Dhabh*) is allowed in the name of God; therefore pronouncing the name of Allah is the usual practice. Animals are restrained but there are no specific religious regulations as to how this should be done. Following restraint, slaughter is achieved by severing both carotid arteries and jugular veins using a sharp knife. The usual type of incision is severance of the vessels in the retrograde fashion following an initial stab incision in the neck, as described above under "Slaughter". A sharp slaughter knife is sufficient. The most significant variation in *halal* slaughter is that preslaughter stunning may be an acceptable practice. It is now more common to see stunning being used for *halal* slaughter in western countries. Furthermore, all *halal* meat produced in New Zealand for export to Asia and the Near East comes from animals killed after electrical stunning. However, the stunning method must not kill the animal before exsanguination. Therefore, head-only electrical stunning (so that the current does not reach and stop the heart) or captive bolt stunning may be used if acceptable.

Animal welfare concerns in religious slaughter

Religious slaughter has been a controversial issue for decades because of concerns about animal welfare. These can be summarized as follows:

- stressful preslaughter handling:
  - rotating pens, tying of legs and blindfolding of animals;
- possibility of pain during neck cut and afterwards:
  - neck cuts on conscious animals, wound edges rubbing together, ballooning on carotid arteries;
- variations in the time to loss of unconsciousness after exsanguination:
  - ineffective cuts and ballooning that impede blood loss and compromise welfare.

The following recommendations are made for religious slaughter:

- slaughtermen must be trained and experienced so that animal handling and slaughter are carried out efficiently and effectively;
- tying legs of animals and blindfolding should be avoided;
- the knife must be sharp and the neck cut made swiftly to sever all blood vessels;
- ballooning on cut ends of the carotid arteries should be prevented; if this occurs, it should be investigated and measures taken to prevent it;
- blood loss must be rapid so that consciousness is lost as soon as possible;
- sufficient time must be allowed for exsanguinations;
- a stunning method such as electrical or captive bolt stunning before *halal* slaughter

and immediately after *shechita* should be encouraged;
- operative safety is of particular concern – religious slaughter of only manually shackled animals can be dangerous and accidents may be reduced if a restraint apparatus is used. Sharp knifes can also inflict cuts due to unexpected movement of animals.

Blood loss during religious slaughter

This is an important issue that is often raised when comparing religious slaughter with no stunning with stunning and slaughter. It has frequently been argued that stunning may impede blood loss. Recent research by Bristol University has shown that blood loss is not impeded after stunning compared to slaughter without stunning in sheep (Figure 7.19). Similar results have been found in cattle. This should help allay fears about adverse effects of stunning on blood loss.

STUNNING, SLAUGHTER AND PUBLIC HEALTH CONCERNS/PROTECTION

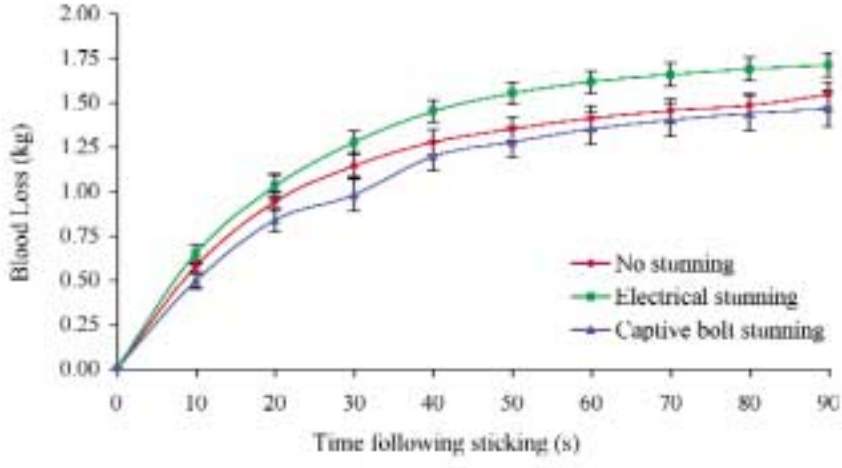
Contamination of carcasses by stunning methods

Since the bovine spongiform encephalopathy (BSE) outbreak, stunning and slaughter procedures have been questioned and considered for the potential risk of contaminating edible parts of the carcass with central nervous system (CNS) material. Research has shown that captive bolt stunning can cause brain tissue to become dislodged and disseminated into the blood circulation in cattle and sheep (Box 7.1). Since, in a BSE-infected animal, brain and spinal cord tissue contain the highest number of infective units, carcasses may be contaminated with the BSE agent. In addition, there is a possibility of contaminating the brain with pathogenic bacteria through the use of captive bolt stunning (Box 7.2). Consequently, there are now concerns and discussions about the use and future of CBGs and alternative stunning methods are being considered. One alternative is the use of electrical stunning. However, this method is expensive, and incorrect use may result in welfare problems. Nevertheless, an automated system of electrical stunning is successfully used in New Zealand.

Contamination of beef carcasses by spinal cord material during splitting

Since 1989, legislation in the United Kingdom has required the removal of the spinal cord from beef carcasses after splitting. A similar requirement was introduced by the European Commission on 1 October 2000, calling for the removal of CNS material from sheep carcasses over 12 months of age and all cattle carcasses in all European Union states. However, in the majority of abattoirs, carcasses are split using a band saw. This often cuts the spinal cord in half

FIGURE 7.19 **Comparison of the effects of different slaughter methods on blood loss in sheep**



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BOX 7.1 **Implications of captive bolt stunning for public health and animal welfare**

The use of captive bolt guns (CBGs) may damage intra-cranial blood vessels and dislodge brain tissue. The heart continues pumping for several minutes following the use of a CBG, during which time any central nervous system (CNS) material that enters the jugular venous blood could be disseminated throughout the body. This possibility and the concern have been investigated in studies conducted in cattle and sheep. Blood samples from Foley catheters, introduced into both jugular veins and inflated after stunning the animals with one of several CBG, were taken for analysis. The stunning methods tested were: pneumatically-activated penetrating CBG (no pithing required due to air injection into spinal canal); cartridge-operated conventional penetrating CBG, known as Cow followed by pithing; non-penetrating cartridge-operated (therefore no pithing) CBG, known as Cash Knocker; electrical stunning (only in sheep).

These projects used immunocytochemistry on sections of buffy-coat cytoblocks for S-100b protein, and capture enzyme-linked immunosorbent assay (ELISA) for syntaxin 1-B to look for CNS tissue in blood. Neither of these CNS proteins is normally found in the blood (Anil *et al.*, 1999, 2001; Anil and Harbour, 2001; Love *et al.*, 2000).

Multiple fragments of brain tissue were detected in the jugular venous blood of cattle slaughtered after use of a pneumatically operated penetrating CBG and after the use of a conventional cartridge-operated CBG followed by pithing. CNS tissue was also detected in the jugular venous blood of sheep that had been stunned with a conventional penetrating CBG or in those stunned with a pneumatically activated penetrating CBG. Electrical stunning did not result in any detectable neural tissue in blood. The emboli are detectable in jugular venous blood within 30 seconds of stunning and will already have passed into and, possibly, through the lungs before exsanguination is carried out. It is noteworthy that the showers of embolic brain tissue include many fragments of small size CNS tissue, which, in principle, are capable of passing through the pulmonary capillary bed. Further studies are planned to detect emboli in arterial blood and visceral organs.

These results confirm that there is a risk of embolic dissemination of brain tissue with the use of the pneumatically operated air injection gun and, in addition, show that neuroembolism can also occur with use of a conventional penetrating CBG followed by pithing in cattle. Penetrative captive bolt devices, if applied correctly, can provide an effective stunning method that needs to be followed by a procedure that results in the death of the animal (Daly, Gregory and Wotton, 1987), for example exsanguination or pithing. Pithing, a common practice in 70 percent of abattoirs in the United Kingdom (Meat Hygiene Service, 1997), has been used by the industry to protect operative safety by greatly reducing the reflex kicking that takes place following captive bolt stunning. It is also commonly claimed that pithing has welfare benefits as it prevents recovery in effectively stunned animals. As a result of the BSE contamination fears, pithing is now banned in the whole of the European Union. However, this new ban has implications for abattoir operators handling carcasses as well as for animal welfare.

When penetrating captive bolt stunning is used, the bolt trajectory causes considerable damage. We have, in a preliminary investigation, examined brains of several cattle stunned with a penetrating captive bolt. We estimate that an average of 10 g of brain tissue (out of a total of 450 g) can be dislodged (unpublished results). On the basis of these criteria, we have calculated that between 50 mg and 500 mg of brain tissue should be sufficient for transmission of infection by the oral route. Therefore, 10 g of dislodged brain tissue may represent between 20 and 20 000 units of infectivity (Anil and Harbour, 2001).

In regard to sheep, although there are no naturally occurring cases, the possible infection of sheep with BSE is a cause for concern. Therefore, the use of electrical stunning seems to be the safer option at present (Anil *et al.*, 2001).

Source: Anil and Austin, 2003.

BOX 7.2 **Contamination by micro-organisms during captive bolt stunning**

To determine whether penetrating captive bolt stunning of animals can result in internal and/or external microbial contamination of meat, slaughter sheep were inoculated with marker organisms (*E. coli* K12 or *Ps. fluorescens*) into the brain through the stun wound immediately after stunning by a cartridge-operated, penetrative captive bolt gun (CBG). The marker organisms were detected in blood, liver, lungs, spleen, lymph nodes, in deep muscle and on carcasses. When the gun that had been used to stun a brain-inoculated animal was used to stun consecutive, intact sheep, the marker organisms were found in blood of 30 percent and on the carcass surface of 40 percent consecutively stunned animals. Overall, the results from this study indicate that penetrative stunning of food animals can carry risks of internal and/or external microbial contamination of edible tissues and organs. Similar results have been obtained using the same markers in cattle (Daly *et al.*, personal communication).

These recent developments summarized above could undoubtedly have implications for public health measures and animal welfare at slaughter. It is clear that there is a risk of contamination of carcasses with CNS tissue if a pneumatically operated CBG or a cartridge-operated CBG followed by pithing is used. The ban on pithing should reduce the risk considerably. However, it is also possible that penetrating CBGs alone could cause problems. The results of recent research on the spread of central nervous tissue resulting from the use of different stunning devices are currently under discussion by the European Commission (EC) and the United States Food and Drug Administration (FDA). This is likely to lead to prohibition of the use of pneumatically operated guns and penetrating CBGs in cattle and sheep. Therefore, there is need to consider the options left and improvements to be made.

First, non-penetrating guns offer a good alternative. However, the potential problems associated with this type of gun should be resolved, such as the infrequent recovery before exsanguination. Second, the removal of pithing is causing operative safety problems in some plants, especially, where space is limited. An alternative solution to this problem is required. Third, electrical stunning should be considered for stunning cattle. This system is used in three plants in the United Kingdom. However, the high cost and some doubts about animal welfare associated with sometimes ineffective use of this method need looking into.

Source: Anil and Austin, 2003.

along much of its length. Obviously this may lead to potential dissemination of CNS material over the carcass and surrounding area, resulting in possible contamination with the BSE infective agent.

Studies conducted by Helps *et al.* (2002) have shown the presence of CNS material on carcasses after splitting with a conventional band saw. This contamination was still present after the carcass had been washed or steam vacuum-cleaned. However, significantly less CNS contamination was observed on carcasses following the removal of the spinal column by an experimental oval saw, which cuts out the whole spinal column and dorsal root ganglia from the carcass prior to splitting. With further engineering development, this new technique should be capable of removing spinal cord with minimal risk of contamination. Hot boning is another alternative method that is being investigated to reduce contamination of the carcass with CNS material.

Summary

- Animals should be stunned before slaughter in order to render them unconscious, and hence insensible to pain during slaughter.
- All stunning methods should:
  - render the animal unconscious immediately and the state of unconsciousness should last until death;
  - be verifiable in their effectiveness;
  - be implemented by trained and competent operatives;
  - be safe for the operatives;
  - be implemented in such a way that they do cause contamination of the meat with any hazards.
- Stunning methods that are currently employed include:
  - electrical stunning, which may be applied to the head only or to the head and body; the latter causes cardiac arrest, and hence kills the animals;
  - modified atmosphere stunning, which involves the use of high concentration of gases such as carbon dioxide, nitrogen or argon; the method may also be employed as a killing method;
  - captive bolt stunning; the method may be either concussive only or concussive and penetrative – the animal does not usually recover in the latter case. For each species:
    - the correct gun calibre and cartridge strength should be used;
    - the appropriate shooting position should be used;
    - guns should be maintained in good working condition and stored safely when not in use.
- Animals should be exsanguinated as soon as possible after stunning, especially if the stunning methods allow the animals to recover.
- Sticking should be done with a clean knife that does not cause contamination of the meat.
- Thoracic sticking is recommended over neck sticking.
- Religious slaughter that does not include stunning should be carried out efficiently and effectively, with consideration for the animal's and operative's welfare, as well as meat safety.
- In the light of the threat of transmissible spongiform encephalopathies (TSEs), there are ongoing investigations for ways of averting possible contamination of the carcasses with CNS material during stunning, slaughter and carcass cutting.

Bibliography

Anil, M.H. & Austin, A. 2003. *Bovine spongiform encephalopathy: a review of some factors that influence meat safety* (available at http://www.fao.org/DOCREP/ARTICLE/AGRIPPA/590_en.htm).

Anil, M.H. & Harbour, D.A. 2001. Current stunning and slaughter methods in cattle and sheep: potential for carcass contamination with central nervous tissue and microorganisms. *Fleichwirtschaft*, 81(11): 123–124.

Anil, M.H., Love, S., Helps, C.R. & Harbour, D.A. 2002. Potential for carcass contamination with brain tissue following stunning and slaughter in cattle and sheep, *Food Control*, 13(6–7): 431–436.

Anil, M.H., Love, S., Helps, C.R., McKinstry, J.L., Brown, S.N., Philips, A., Williams, S., Shand, A., Bakirel, T. & Harbour, D.A. 2001. Jugular venous emboli of brain tissue induced in sheep by use of captive bolt guns. *Vet. Rec.*, 148(20): 619–620.

Anil, M.H., Love, S., Williams, S., Shand, A., McKinstry, J.L., Helps, C.R., Waterman-Pearson, A., Seghatchian, J. & Harbour, D.A. 1999. Potential contamination of beef carcasses with brain tissue at slaughter. *Vet. Rec.*, 145(16): 460–462.

Daly, C., Gregory, N.G. and Wotton, S.B. 1987. Captive bolt stunning of cattle: effects on brain function and role of bolt velocity. *Br. Vet. J.,* 143: 574–580.

FAO/WHO. 2004. Draft code of hygienic practice for meat. In *Report of the 10th Session of the Codex Committee on Meat Hygiene*. Alinorm 04/27/16. Rome (available at ftp://ftp.fao.org/codex/Alinorm04/AL04_16e.pdf).

Helps, C.R., Hindell, P., Hillman, T.J., Fisher, A.V., Anil, H., Knight, A.C., Whyte, R.T., O'Niell, D.H., Knowles, T.G. & Harbour, D.A. 2002. Contamination of beef carcasses by spinal cord tissue during splitting. *Food Control,* 13(6–7): 417–423.

Love, S., Helps, C.R., Williams, S., Shand, A., McKinstry, J.L., Brown, S.N., Harbour, D.A. & Anil, M.H. 2000. Methods for detection of haematogenous dissemination of brain tissue after stunning of cattle with captive bolt guns. *J. Neuro. Meth.*, 99: 53–58.

Meat Hygiene Service. 1997. *Animal abattoir welfare survey*. London, Ministry of Agriculture, Fisheries and Food.