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Overview of current and alternative slaughter practices

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The conventional cattle slaughtering process includes some critical stages where a dissemination of Specified Risk Material (SRM: brain, spinal cord) within or onto the carcass and within the slaughterhouse environment can occur. These processes are captive bolt stunning, removal of the head and first of all carcass splitting (sawing the spine lengthways). Captive bolt (CB) stunning results in massive brain tissue damage with bleeding, and in some cases brain tissue also emerges from the CB hole. As the heart is still functioning, there is a risk of brain tissue particles being transferred *via* the blood flow to heart and lungs or even in the whole carcass. This contamination risk is actually assessed to be low, but a continuing leakage of Central Nervous System (CNS) material from the captive bolt aperture in the further slaughter process may lead to direct and indirect contamination of carcass, meat and equipment. Therefore alternative stunning methods like electrical stunning or concussion stunning are discussed. A further critical point is the treatment of the head. When the head is removed, the spinal cord is cut with a knife. There is a danger of cross contamination due to spinal protein that may adhere to the knife and because of liquid cerebralis, which leaks from the foramen occipitale magnum. Further head cleaning with hand-held hoses following skinning also includes the danger of cross contamination from cleaning water or aerosol. Therefore measures regarding the safe handling of head and harvesting of head meat are proposed. The most critical point in terms of contamination of the meat surface with SRM is the currently common practise of sawing the spine vertically in the middle with hand-guided belt-type saws. A mixture of sawing residues and rinsing water ("sawing sludge") collects in the housing of the saw, and if it contains infectious material this leads to contamination of the subsequent carcasses. The most promising methods available at present for minimising this risk appear to be in manual cattle slaughtering boning the entire (not split) carcass, either still warm or refrigerated and in industrial beef cattle slaughtering extraction of the spinal cord by vacuum from the whole carcass followed by conventional sawing or completely sawing out the spine including spinal ganglia.
Keywords. Cattle slaughtering, Specified Risk Material, captive bolt stunning, carcass splitting.

1. INTRODUCTION

The process of slaughtering and cutting of beef carcasses involves some critical stages when tissues included in so-called specified risk material (SRM), particularly brain and spinal cord, are released. In the case of a BSE positive animal, these tissues may be contaminated with the BSE agent, so that the infectious material may be spread over instruments and tools onto the carcass and within the slaughterhouse environment

The conventional slaughtering practice (**Figures 1a, 1b**) nowadays includes primarily the following critical processes:
– captive bolt stunning
– removal of head from carcass and head handling
– carcass splitting by sawing the vertebral column lengthways.

The process stages which follow, including head dressing and sending it over the offal conveyor, taking of brain sample for BSE-test, removal of spinal cord after carcass splitting, washing the spinal processes of the halves as well as deboning of carcass in the area of back and neck musculature can also lead to further distribution of SRM and cross contamination.

In the following, the critical processes are to be analysed and evaluated and alternative technologies discussed. Because no information on the effect of repeated and very low doses of BSE agent on human health is available, the aim must be a strategy of minimizing the risk for the consumer throughout the whole slaughtering process.

2. STUNNING

During the usual practice of stunning by means of captive bolt pistol, a metal bold is fired through the head bone into the brain. This causes massive brain tissue damage with bleeding, also brain tissue may emerge of the captive bolt (CB) aperture. Since the heart function is still active, there is the risk of a transfer of brain tissue particles via the blood flow. This could lead to contamination of blood, blood vessels, heart and lung with prions. During post stunning processing a further release of brain tissue

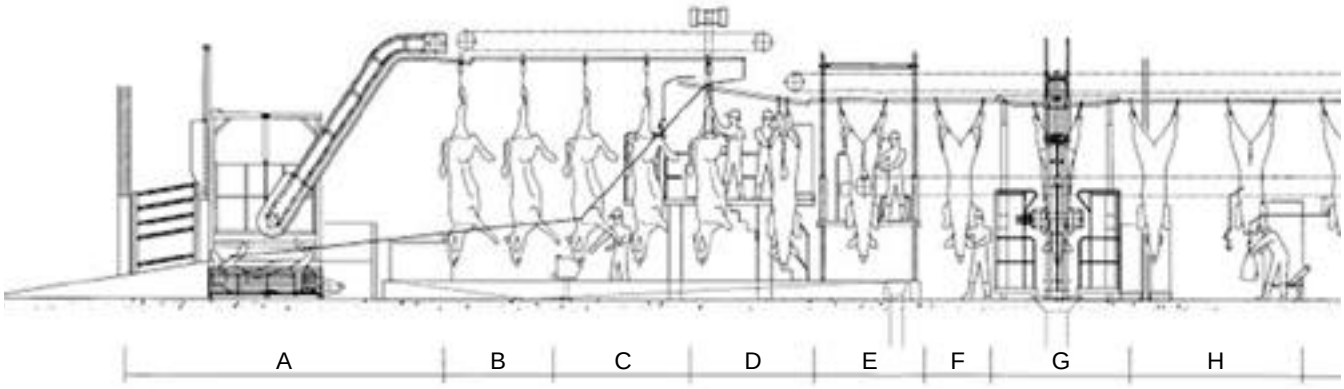

Figure 1a. Cattle line (capacity up to 40 heads/hour; Vogtwerke, Schlüchtern, D).
A: Stunning, shackling hind leg and lifting animal with bleeding elevator; B: Sticking, bleeding in a hanging position; C: Removing fore-feet and horns; D: Pre-dehiding of legs, insert hook in sinew and lifting on dressing line; E: Remove udder, open aitch bone and pre-dehide abdominal side; F: Pre-dehide fore-legs; G: Automatic dehiding from up to down; H: Removing head.

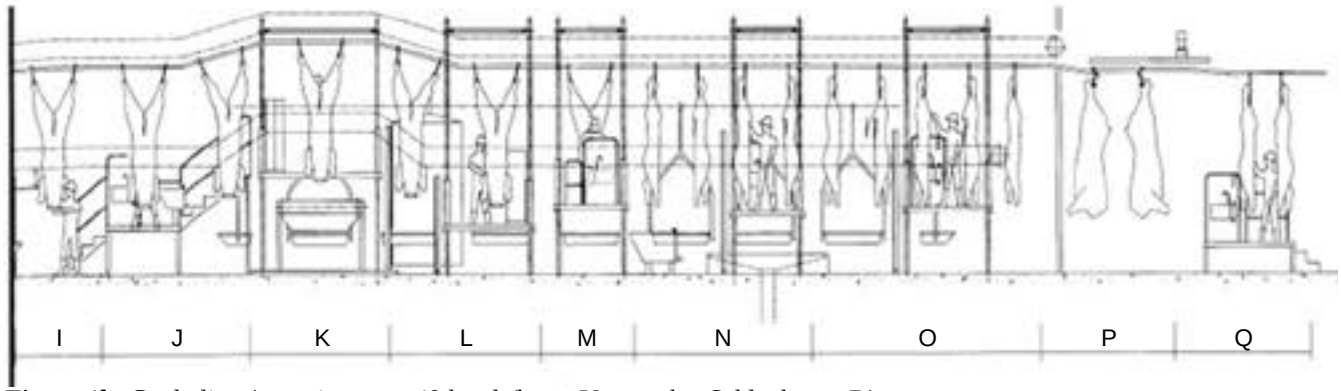

Figure 1b. Cattle line (capacity up to 40 heads/hour; Vogtwerke, Schlüchtern, D).
I: Rodding; J: Sawing breastbone; K: Opening abdominal side, remove vesicle and genitals, take out paunch and intestines; L: Remove red offals; M: Carcass splitting; N: Meat inspection; O: Trimming; P: Drip-down conveyor; Q: Weighting and classifying.

from the CB aperture with dissemination of prions onto the floor and other areas may happen.

Anil *et al.* (1999) reported that no particles of brain tissue were found in the jugular veins after application of captive bolt stunning. Horlacher *et al.* (2001) found low contamination frequency in the lungs. Central Nervous System (CNS) tissue was found in 0.63% of the lungs after application of captive bolt stunner. The CNS tissue quantities found by means of immuno-chemical and immuno-histochemical methods were, however, so small that the human exposure risk after consumption of a contaminated lung was estimated as small.

Prendergast *et al.* (2003) detected CNS proteins on the captive bolt pistol, the landing platform for the stunned animal and in the material emerging from the CB aperture. Due to (also) captive bolt stunning, a superficial contamination of the skinned cattle head with brain tissue frequently occurs (Moje *et al.*, 2002). In 95 of 100 examined heads CNS protein was found in the area around the CB aperture (**Table 1**).

The alternatives to captive bolt stunning are still limited. According to German regulation for animal protection at slaughtering (TierSchlV, 1997) only the electrical stunning in a procedure version which leads to cardiac arrest, is taken into consideration as generally accepted method (**Table 2**). Council Directive 93/119/EC (1993) suggests, as an alternative method, concussion stunning. Semi-automatic electrical stunners, used in New Zealand or Australia for large-scale slaughtering, are not acceptable for most of the European abattoirs from the economical point of view. The alternative might be a newly designed stunning box (**Figure 2**). This laterally tiltable, multifunctional cattle stunning pen possesses integrated head-, neck- and brisket electrodes and allows sticking of the animals immediately after the end of current flow while they are still in the box in an upright position (Troeger, 2002). Brisket- and abdomen-support-bars can be pneumatically extended from the right side and prevent the animal from

Table 1. Detection* of Cerebral nervous system protein (GFAP**) on heads after manual dehiding (Moje *etal*., 2002).

Location of swap sample	Number of cattle	"CNS" positive sample (%)
Captive bolt aperture area	100	95
Foramen occipitale	100	72
Masseter muscle	100	26

* Commercial ELISA(RIDASCREEN Risk Material 10/5 Test, r-biopharm, Darmstadt, D).
** GFAP = Glial Fibrillary Acidic Protein.

Table 2. Electrical stunning: parameters according to German TierSchlV for cattle older than 6 month.

	Stunning	Cardiac arrest
Minimum current (ampere) within 1 sec	2,5	n.d.
Minimum current flow time (sec)	4	8

collapsing after it has been stunned (**Figure 3**). After bleeding, the pen is turned to the side to shakle the hind leg and elevate the animal. The person, who is fastening the chain, is safe from any reflex movements of the limbs. A first study of meat and carcass quality parameters indicates no incidence of broken bones and a positive tendency concerning meat colour (lighter) and tenderness (Schurr, 2003). The electrical parameters of the system are shown in **table 3**.

The concussion stunning apparatus administers a blow to the skull, which causes a heavy brain concussion. These instruments are modified captive bolt pistols where the sharp pin is replaced by a convex metal disk (4–5 cm diameter) to produce a blow on the forehead of the cattle (**Figure 4**). The operator must ensure that the cranial cavity should not be opened, not to cause the problem of CNS dissemination. Actual investigations (Hoffman, 2003) on 1248 animals indicate a too high rate of miss stunning (12%) and in nearly half of the cases both the outside and the internal lamellae of the frontal bone are fractured. Since in almost 50% of cases dura mater is damaged with frequent haematoma in the brain, localized on the frontal side and on the opposite side of the brainstem, this stunning method cannot exclude dissemination of CNS tissue and therefore is no efficient alternative for captive bolt stunning.

3. REMOVAL OF HEAD, HEAD HANDLING

In the process of removing the head, the spinal cord is cut by knife and cerebrospinal fluid may leak. If the same knife is used for cutting other parts of the carcass there is a risk of cross contamination. Also, the knives used for cutting the spinal cord must not be treated together with knives/instruments for other processes in the same sterilising dish with hot water (82°C), because this "hot water sterilization" does not inactivate the prions. Head removal should be done in such a way that one knife (e.g. with green handle) from separate sterilisation dish is used to cut the neck musculature up to the atlas and afterwards another knife (e.g. with red handle) from an extra sterilisation dish (with hypochloride solution) is used to cut only the spinal cord. In case of smaller number of slaughter cattle the use of single-use knives is worth to consider.

Table 3. Electrical stunning: parameters under practical conditions using the BANSS stunning box (**Figure 2**).

	Stunning	Cardiac arrest
Current (ampere)	1,5–2,5	1,5–2,0
Current flow time (sec)	2–4	12–14

During subsequent skinning of the head a contamination of the head surface is nearly unavoidable if the work is done on a table. Therefore systems with automatic dehiding over the head are recommended.

Cleaning of head with hand-held hoses, after hide removal, takes place in cleaning booths, which are sometimes not screened off from the slaughter line. There is the risk of a cross contamination from spray water or aerosols. The cleaning liquid that flows off on the floor (with traces of risk material) can be distributed in a wide area. The cleaned head is afterwards hung up into the organ conveyor and transported through the hall of abattoir to the place of meat inspection. The liquid that is dripping off can also contaminate the floor. Taking a brain sample for BSE analysis is performed with a suitable instrument through occipital cavity or by means of water or air pressure method, by producing (*via* the captive bolt aperture) pressure in the cranial cavity, causing caudal parts of brain to come out from the occipital cavity to be taken as sample. This may contaminate the surrounding surface of the head by brain tissue or cerebrospinal fluid (contaminated with brain particles). This has been proved by examination of 100 cattle heads (Moje *et al.*, 2002). In 72% of the cases presence of glial fibrillary acidic protein (as marker protein for CNS) was proved on the musculature surface from both sides of occipital cavity (occipital muscles), as well as in 26% of the cheeks (**Table 1**).

If head meat shall be harvested, slaughterhouses and cutting plants must have a quality assurance

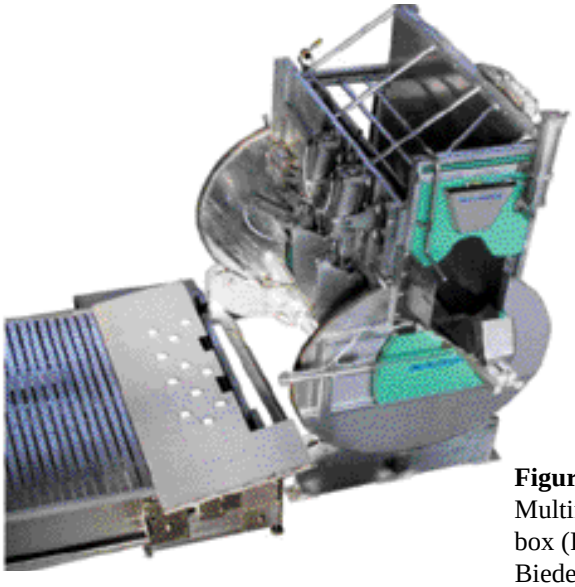

Figure 2. Multifunctional stunning box (Fa. BANSS; Biedenkopf, D).

Figure 3. Multifunctional stunning box (looking in the direction of the animal) with muzzle electrode (middle in the front), green head fixing slide (in down-position, with integrated neck electrodes), brisket- (with heart electrode) and abdomen-support-bars (Fa. BANSS; Biedenkopf, D).

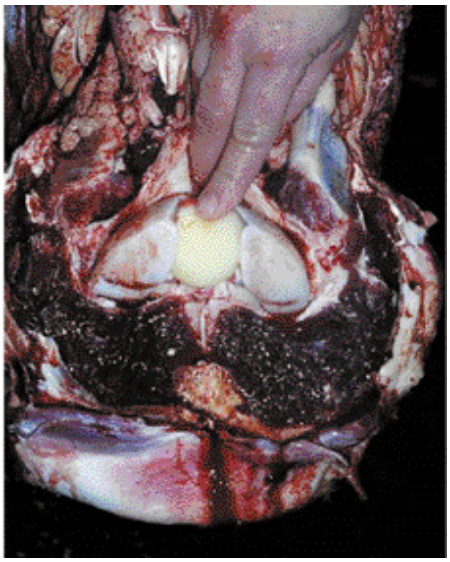

Figure 5. Sealing of foramen occipitale magnum with a stopper.

Figure 4. Pneumatically operated concussion stunner (Fa. Schmid & Wezel, Maulbronn, D).

Figure 7. Pneumatically operated round knife, with rotating blade and hose for vacuum sucking (Fa. EFA; Maulbronn, D).

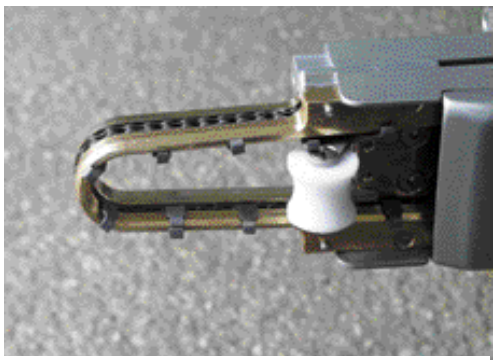

Figure 8. U-shaped chain saw for removal of the whole vertebral column (Fa. BVS Kreis GmbH, Klein-Winternheim, D).

conception to avoid or minimize contamination with brain tissue (Regulation (EC) 1139/2003).

In order to minimize the contamination risk after the captive bolt stunning for the superficial head musculature the following measures are suitable to be applied:
– removing the horns without opening the skull;
– machine skinning of head;
– after removal of the head, this one is immediately transported to a (separated) cleaning cabinet, suspension (muzzle upward) without contact with walls;
– cleaning only inside (nose, nasal cavity) with underpressure;
– when removing tongue and tonsiles use separate knives ("green", "red");
– sampling for BSE test: if the water or air pressure method is applied, then it should be done only on the hanging head in the cleaning cabinet; for sample taking instrument (spoons etc.) an effective desinfection system (e.g. sterilisation dishes with hypochloride solution) must be available;
– sealing the captive bolt aperture and the foramen occipitale magnum by suitable stoppers (**Figure 5**);
– storage and transport of heads never hanging one above the other (at hooks); transport should be avoided if possible (head-boning in the slaughterhouse is preferred).

Further measures for minimizing the risk during head boning:
– meat should not be cut from the parts with potentially high contamination risk (forehead, area around the occipital cavity = so called neck meat);
– meat should be harvested only from cheeks.

4. CARCASS SPLITTING (BY SAWING)

The most critical process stage, regarding the contamination of meat with SRM, is at present the conventional practice of sawing the vertebral column through the midline using automatic circular saws or hand-guided belt saws. The spinal cord is usually cut, on occasions along its length, spreading cord tissue along the whole cut surface of the split carcass (Schwaegele *et al.*, 2002). This particularly affects the internal neck musculature. When testing the internal surface of neck muscles of 107 half carcasses for CNS protein (GFAP) 82% of carcasses were found GFAP positive, 70% had a high contamination rate (**Figure 6**). When using belt saws, a mixture of sawing residues and rinsing water ("sawing sludge") collects in the housing and may lead to spreading of risk material on the next (uninfected) carcasses. To avoid or decrease this contamination risk, several new slaughtering and splitting techniques are conceivable:
– suction of the spinal cord prior to carcass splitting;

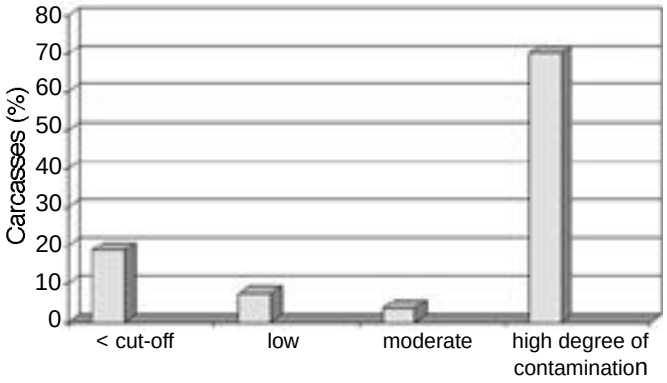

Figure 6. Detection of spinal cord protein [commercial ELISA (RIDASCREEN Risk Material 10/5 Test, r-biopharm, Darmstadt, D)] (GFAP) on neck muscles after conventional carcass splitting (n = 107). Cut off = <0,2 % standard; low = <0,3 % standard; moderate = <0,4 % standard; high = >0,4 % standard.

– removal of the complete vertebral column or paramedian sawing;
– deboning without carcass splitting.

5. SUCTION OF THE SPINAL CORD PRIOR TO CARCASS SPLITTING

Devices for sucking the spinal cord on the non split carcass (e.g. Fa. BVS Kreis GmbH, Klein-Winternheim, D) are used in several larger slaughterhouses. By means of a PVC hose and under vacuum, the spinal cord is completely sucked off, by gradual manual pulling the tip of the hose into the vertebral channel upwards (Troeger, 2001). The pachymeninges (dura mater) and spinal ganglia remain in the spinal channel resp. vertebral bones. The dura mater can be removed after splitting the carcasses manually or with a special round knife with rotating blade and a hose for vacuum sucking (**Figure 7**). The efficiency of this suction method is not satisfying yet; a complete spinal cord removal is made more difficult first of all because of the occurrence of occasional breaks in vertebral column or dislocation of vertebrae.

6. REMOVAL OF THE WHOLE VERTEBRAL COLUMN OR PARAMEDIAL SAWING

Removal of vertebral column as a whole should be possible with special saws. The development of round or oval saws, however, did not progress yet so far that applicable tools are available (Troeger, 2003). A new development is a u-shaped chain saw (**Figure 8**). One possible way of the vertebral column removal, mainly applicable in manual operation, is the so called wedge method (Troeger *et al.*, 2002). The spinal column is cut out with a chopper from the hanging carcass ventrally (from the inside) wedge-shaped on the left

and on the right of the vertebrae at the level of dorsal end of the ribs. The dorsal and occipital musculature from both sides of vertebral column are previously removed. The presence of CNS tissue (in this case spinal ganglia) could not be proven on the sites of carcasses section after this process (**Table 4**). Another possibility of splitting cattle carcasses without opening the spinal channel is the so called lateral method. This is one version of the "wedge method", whereby, in contrast to this method, it is characterized by one off-centre paramedian cut, so that one half remains without vertebral column and the second half with the vertebral column (Troeger *et al.*, 2002).

7. DEBONING WITHOUT SPLITTING

Deboning of the whole carcass which is not split into halves is in principle possible in a hot and cooled condition (Troeger, 2001). For example, the following procedures must be performed in sequence: 1) cut off the shoulders, 2) sawing ribs (from the inside); cutting forequarter flanks, 3) sawing ribs; cutting brisket from neck, 4) removing filets, 5) removing force rib, 6) removing striploin, 7) removing hip, 8) sawing ilium and 9) removal of the whole vertebral column, if necessary with head. This splitting technique avoids the risk of meat contamination with CNS tissue (**Table 5**).

Table 4. Cutting after removal of the whole vertebral column: examination of split carcasses, protecting gloves and cutting tables for CNS protein* (GFAP**) (Troeger *et al*., 2002).

	Number of swab sample	Results	
		Negative	Positive
Split carcasses	60	60	0
Protecting gloves	3	3	0
Cutting tables	12	12	0

* Commercial ELISA(RIDASCREEN Risk Material 10/5 Test, r-biopharm, Darmstadt, D).
** GFAP = Glial Fibrillary Acidic Protein.

Table 5. Cutting without carcass splitting: examination of vertebral columns, working gloves and cutting tables for CNS protein* (GFAP**) (Troeger *et al*., 2002).

	Number of swab sample	Results	
		Negative	Positive
Split carcasses	60	60	0
Protecting gloves	16	16	0
Cutting tables	36	36	0

* Commercial ELISA(RIDASCREEN Risk Material 10/5 Test, r-biopharm, Darmstadt, D).
** GFAP = Glial Fibrillary Acidic Protein.

8. RISK ELIMINATION/MINIMISATION STRATEGIES

Further avoiding dissemination of BSE risk material (brain, spinal cord) to carcass and meat at slaughtering is nowadays mainly possible in small-scale abattoirs, as well as in the small slaughtering plants for manual slaughtering. Due to small number of slaughter animals the presence of skilled labour is economically justified, and the process cycles can be arranged more flexible. The following measures, which practically exclude a contamination risk, may be considered:
1. Electrical stunning;
2. Cutting without opening the vertebral channel;
3. Head remaining on the carcass.

If the conventional slaughtering processes are retained (captive bolt stunning, longitudinal sawing with opening of the vertebral channel) the following measures can be used to minimise the risk of spreading CNS tissue on the carcass:
1. Suction of the spinal cord from the whole carcass (by means of PVC hose and underpressure), changing hose for every batch;
2. Machine skinning of head; closing of captive bolt aperture and foramen occipitale magnum.

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