Physiological insights into *Shechita*

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The Government recently announced that it intends to reject a recommendation by the Farm Animal Welfare Council that all animals should be stunned before slaughter (see *VR*, April 10, p 446). In this Viewpoint article, Dr Stuart Rosen discusses physiological aspects of *Shechita*, the Jewish method of religious animal slaughter. He outlines the religious context and describes the act of *Shechita*. He discusses the scientific literature on the behavioural responses to *Shechita* as well as neurophysiological studies relevant to the assessment of pain, and concludes that *Shechita* is a painless and humane method of animal slaughter.

THE purpose of this paper is to review the Jewish religious method of animal slaughter, *Shechita*, from a physiological point of view. Much of the data presented on scientific aspects of *Shechita* has been known for decades, although a number of new perspectives are included. To illustrate the principles, and make the process more comprehensible, a number of analogous human clinical scenarios are also considered. The author's principal research involvement in the topic of pain has been through the exploration of the neurophysiology of angina pectoris as a model of visceral pain (see, for example, Rosen and others 1994, 1996, 2002).

As a preamble, it should be stated that the reason for the Jewish observance of *Shechita* is that it is a basic commandment, conveyed via the Oral Law and dating back to the time of Moses. *Shechita* is a fundamental religious practice and constitutes the only method of animal slaughter permissible according to the traditional body of Jewish law, the *Halacha*. *Shechita* is, in fact, part of a broad range of legislation in the *Halacha* that promotes kindness to animals. Examples of this include: the injunction that animals are to rest on the Sabbath (Exodus XX 10); the interdiction against ploughing with an ox and an ass together (their natural powers being unequal) (Deuteronomy XXII 10); the injunction to send away a mother bird before removing eggs from a nest (Deuteronomy XXII 6); the prohibition against muzzling an ox at the threshing floor (Deuteronomy XXV 4); animals to be with their mother for (at least) the first seven days of their lives (Leviticus XXII 27); no slaughter of a mother animal and its offspring on the same day (Leviticus XXII 28); the need to reload an overloaded animal (Exodus XXIII 5, Deuteronomy XXII 4); and the obligation to feed one's animals before feeding oneself (Deuteronomy XI 15). It should be noted that Jewish people regard themselves as culpable within their religious law if their actions cause animals to suffer. Thus, consistent with the halachic legislation on other aspects of animal welfare, *Shechita* is embraced as a painless and rapid method of slaughter.

Because it is the only religiously permissible method of animal slaughter for Jews, moves to undermine the Jewish people's ability to perform *Shechita* have implications with regard to rights to religious expression. Historically, attacks on *Shechita* have not been based on prima facie scientific objections to its effects. For example, *Shechita* was banned in Germany in 1933, despite having been widely endorsed throughout the scientific community in 1932. This and other legislative aspects of *Shechita* were discussed extensively by Munk and others (1976).

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ACT OF SHECHITA

Shechita is the act of slaughtering an animal by a perfectly clean incision through the structures at the front of the neck – the trachea, oesophagus, carotid arteries and jugular veins.

Before *Shechita*, the animal has to be fit and healthy and capable of independent life. This last point, in addition to the fact that the act of *Shechita* must be the effective cause of the animal's death, underlies the unacceptability of stunning before *Shechita*, according to the *Halacha*.

Shechita is performed using a *Chalaf* (*Shechita* knife) (Fig 1). This is honed to an exquisite sharpness, comparable to that of a surgical knife, and it is repeatedly checked between each animal to avoid any imperfections. The name of the knife, *Chalaf*, is derived from the Hebrew verb 'to change', since it effects a change in the state of the animal from being forbidden as food while alive to being permitted for consumption after *Shechita*.

There are a number of key halachic considerations in this act: *Shehiya* – there should be no interruption of the incision; *Derasa* – there should be no pressing of the blade against the neck (this would exclude the use of a guillotine); *Halada* – the blade should not be covered by the hide of cattle, wool of sheep or feathers of birds (and therefore the blade has to be of adequate length); *Hagrama* – the incision has to be at the appropriate site on the neck, in effect that which permits the severance of the neck structures as quickly and as neatly as possible; and *Ikkur* – there must be no tearing of tissues.

Each of the five halachic considerations has important and positive practical implications. Grandin (1994) specifically highlighted the importance of using an instrument of exquisite sharpness and adequate length, swiftly applied and with avoidance of the wound closing over knife. Together, these factors are a major contribution to the efficacy of *Shechita* as a method of combined stun and slaughter.

Subsequent to the act of *Shechita*, certain other procedures are mandatory, such as the covering of the blood of poultry or game with earth or ash (*Kissuy HaDam*), the removal of forbidden fat (*Heleb*) from the mesenteric, pararenal and other areas, and the removal, via the koshering process, of the residual blood in the meat. (Koshering involves the soaking of the meat for prescribed periods of time and the application of substantial amounts of coarse salt to draw out the blood. Roasting with an open flame can also be employed; this is obligatory in the case of liver. This is discussed in detail by Grunfeld [1972].)

Restraint of larger animals

To maintain optimal positioning, larger animals (mostly bovids) are led into a restraining pen in which the animal is held while *Shechita* is performed. Grandin (1994) has described in detail designs and operational procedures for this device.

It is important to note that the restraint is not a 'crush'. Significant features of the upright pen, recommended by the Farm Animal Welfare Council in 1985, are a belly-plate designed to lift and support the animal at slaughter and a chin lift and poll stop. These features were made law in 1992. An advantage in the use of a chin lift is the prevention of re-occlusion of the carotid arteries. This is important in allowing a very rapid loss of cerebral function.

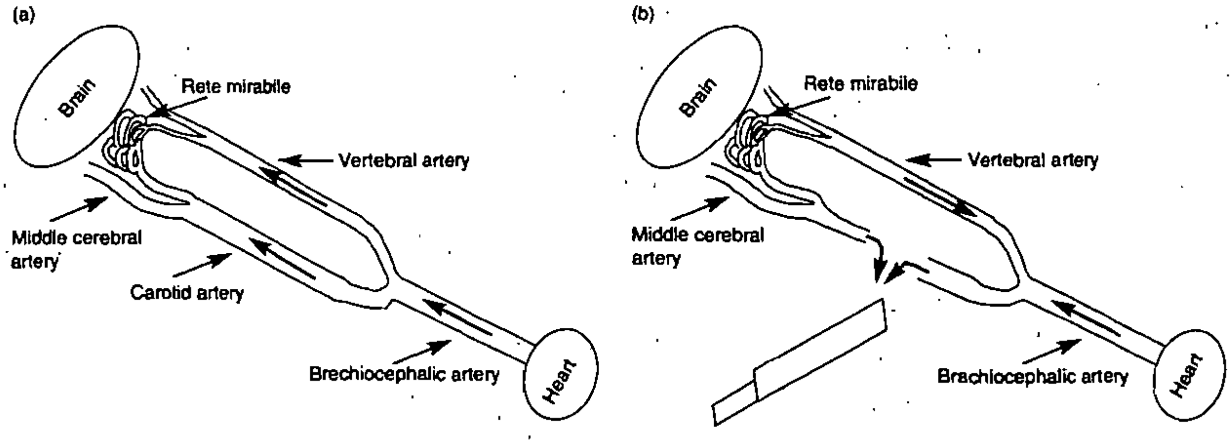

FIG 2: Effect of the *Shechita* incision on blood flow through the main arteries to the brain. (a) Before the incision and (b) after the incision. Note that blood flow is in the direction of least resistance

of the stain could be shown in the liver and kidneys, little, if any, could be seen within the brain, and certainly too little to be compatible with the support of brain function.

In contrast, Blackman and others (1986) looked at possible differences in blood supply to the cerebral cortex between sheep and calves during slaughter. They reported that methylene blue was demonstrable in the brain of calves more than 100 seconds after bilateral carotid severance. However, the slaughter was not performed through *Shechita*.

One reason that some of the data cited appear to be in conflict may be that the actual circumstances of the studies are not strictly comparable (*Shechita* v a non-*Shechita* cut). There have also been confusing (and misguided) attempts in the past to compare *Shechita* to experiments in which the carotid arteries were clamped (Levinger 1961). After carotid clamping, drowsiness and swaying are observed and the animals pass urine and faeces. With continuation of the clamping, a recovery of equilibrium is achieved after about one-and-a-half minutes. In this case, the maintenance of brain function is presumably by means of blood flowing through the vertebral arteries.

More recently, Shaw and others (1990) reported on the role of the vertebral arteries in maintaining spontaneous electrocortical activity after electrical stunning and slaughter in calves. When the blood supply to the brain was severely reduced by the carotid arteries being clamped to mimic a clot (rather than severed), then even when all available blood was effectively forced through the brain via alternate pathways, cortical function could not be maintained or be re-established. The time to isoelectric electrocorticogram (ECoG) in these calves was not different from that in calves which had undergone carotid severance after earlier surgical ligation of the vertebral arteries.

In contrast, after the *Shechita* incision in cattle, there exists a low-resistance route through which blood in the vertebral arteries exits. As noted above, this does not apply to sheep, in which the vertebral arteries terminate before reaching the brain.

Cardiac activity

The heart continues to beat for a few minutes after the *Shechita* incision. For the first minute, the force of contraction is maintained as venous blood from the periphery of the body continues to flow back to the heart despite the arterial blood being lost through the severed carotids. Within approximately one minute, lack of venous return leads to a reduction in cardiac preload. Cardiac contractility is diminished because of this, as well as the reduction in oxygen reaching the myocardium. In contrast with the cardiac arrest immediately provoked in head-back electrical stunning, the fact that, after *Shechita*, the heart can continue to beat for a few minutes means that this method of slaughter contributes very positively to exsanguination. This has positive health and hygiene implications.

In summary, the collapse in the arterial blood pressure that follows on from the severance of the carotid arteries at *Shechita* causes a dramatic fall in cerebral perfusion. The cerebral cortex is particularly sensitive to this (see, for example, Noell and Chinn 1950). Consciousness is lost rapidly (within approximately two seconds) and irreversibly.

EXPERIMENTAL DATA ON THE EFFECTS OF SHECHITA ON CEREBROSPINAL FLUID PRESSURE

Cerebrospinal fluid pressure

The brain is a soft and hollow organ and its usual shape and structure are, to an extent, maintained by the pressure of cerebrospinal fluid (CSF) within the cerebral ventricles (De Lange 1977, Walton 1993). The shape of the brain is also maintained by the gradient between the relatively high pressure of the arterial blood flowing into it and the lower pressure in the veins draining it. The venous pressure, in turn, also has an influence in maintaining the correct pressure in the CSF (Cohen and others 1970).

Sudden changes in these pressures can have a devastating effect on brain function (Levinger 1970). A good human model of this is the patient with hydrocephalus (Hong and Pickard 1996), for example, due to obstruction of the flow of CSF from the cerebral ventricles to the outer surface of the brain. The only effective treatment is implantation of a shunt – usually between the brain ventricles and one of the great veins or the right atrium. The shunt contains a valve to prevent reflux of blood to the brain. There are numerous documented cases of shunt obstruction, which produces an increase in brain pressure, headache and then diminished consciousness (Kestle and others 2000). Less commonly, there are descriptions of leaks of the shunt valve, causing brain irritability followed by collapse and unconsciousness. Other causes of reduction in CSF pressure are also recognised (Khurana 1996).

Pressures within the brain ventricles

Levinger (1976) has shown by direct measurement that after *Shechita* the CSF pressure within the brain ventricles falls even more rapidly than the blood pressure within the internal maxillary artery. This is because of the collapse in jugular venous pressure, without replacement by arterial blood. The maintenance of brain structure is impaired as a kind of 'implosion' of the brain occurs.

PRACTITIONER OF SHECHITA – THE SHOCHET

The act of *Shechita* is performed by a *Shochet*. The *Shochet* studies intensively for many years and must have a thorough knowledge of animal anatomy, pathology and the laws of *Shechita*. The *Shochet* must be licensed by both a local authority and by the Rabbinical Commission for the Licensing of *Shochetim*. The commission is a statutory body established by Parliament and now governed by Schedule 12 of the Welfare of Animals (Slaughter or Killing) Regulations 1995. Every *Shochet* is examined annually by this commission and must apply for renewal of his licence every 12 months. Such rigorous training, supervision and continuous professional assessment is much more arduous than the lot of the general slaughterman. The latter is licensed to practise for life, provided he or she does not contravene any animal welfare regulations.

PHYSIOLOGY OF SHECHITA

Brain anatomy and physiology

Though it comprises only about 2 per cent of the body's weight, the brain receives 20 per cent of cardiac output (Poole-Wilson 1989). It is sensitive in its requirements for oxygen and is generously supplied, mostly via the carotid arteries. A lesser supply may come via the vertebral arteries. The anastomosis between the two internal carotid arteries as well as with the vertebral arteries forms a 'ring road' at the base of the brain. In cows this is the rete mirabile; in sheep, by way of contrast, the vertebral arteries are rudimentary, petering out before they reach the brain (Levinger 1995a). In man, this arrangement is the Circle of Willis.

The effect of having an arterial 'ring road' at the base of the brain is that if there is a stenosis or occlusion of one of the cerebral arteries, the brain region supplied by that vessel can still obtain adequate perfusion via one of the other vessels. However, this is not the case if the carotid arteries are opened, in which case blood flow follows the route of lowest resistance.

Autoregulation

Blood flow through the brain is kept at a steady level, despite quite wide variations in the prevailing blood pressure, through autoregulation (Haddy and Scott 1977). In the microcirculation of the brain, vessels dilate or constrict to keep tissue perfusion constant. However, there are limits to this corrective mechanism and (at least in man) autoregulation fails if blood pressure falls by more than 50 per cent (Kleinerman and others 1958, Njemanze 1992).

Cerebral blood flow and consciousness

In clinical cardiological practice, a rare but (fortunately!) usually reversible complication of routine diagnostic coronary angiography is the provocation of ventricular tachycardia or ventricular fibrillation. When this happens, the collapse in cardiac output immediately leads to a failure of brain perfusion and the patient rapidly loses consciousness (Rossen and others 1943). The whole process can, in these circumstances, be timed very precisely by following the electrocardiogram (ECG). It takes less than five seconds for a patient lying on his or her back to lose consciousness during a cardiac arrest. An even quicker loss of consciousness would be expected in a standing individual because of the need for a greater driving pressure to propel blood up to the brain.

Not surprisingly, this is exactly what one finds when performing head-up tilt-table testing for the investigation of patients with syncope (Grubb and others 1992). After an appropriate (approximately 50 per cent) fall in cardiac output, loss of consciousness follows in less than five seconds.

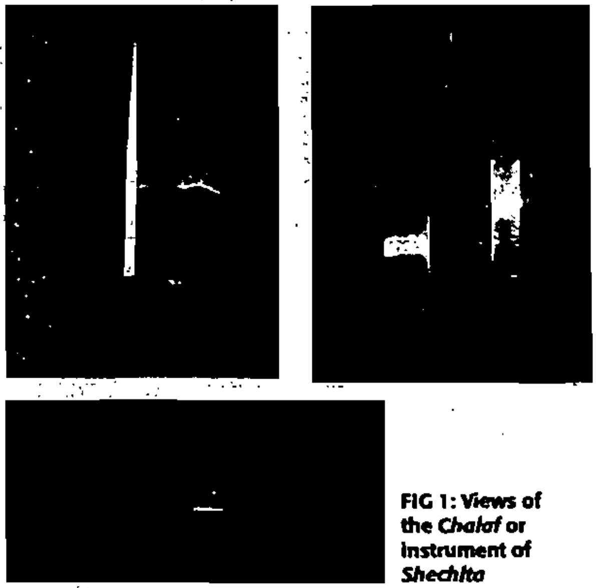

FIG 1: Views of the *Chalaf* or instrument of *Shechita*

Another medical model germane to this discussion is the acute management of severe hypertension. It is of the greatest importance not to bring the blood pressure down too precipitously, otherwise patients are at a high risk of stroke because of underperfusion of the brain (Diringer 1993).

The cerebral regions most likely to be affected in all of these examples of precipitous loss of brain perfusion are the cortical areas (Noell and Chinn 1950).

IMMEDIATE PHYSIOLOGICAL EFFECTS OF THE SHECHITA INCISION – EXPERIMENTAL DATA

Cerebral perfusion

After the *Shechita* incision, blood loss is extremely rapid. In Dukes's classical studies (Dukes 1958), 33 per cent of the animal's entire blood volume was lost in approximately 30 seconds and 50 per cent within one minute. The decrease in blood flow to the brain has been measured by means of a manometer placed in the internal maxillary artery, and the fall in blood pressure in the brain has been shown to be greater than the fall anywhere else in the arterial tree (Spörri 1965). As a consequence, flow through this artery was zero after *Shechita*. These rapid and important falls in blood pressure were associated with loss of consciousness within a few seconds.

Since the carotid arteries are severed at *Shechita*, blood flows out of them at a great rate. This applies not only to the blood that passes from the aorta, up the brachiocephalic trunk to the carotid arteries, but also to the blood that runs through the brachiocephalic trunk to the vertebral arteries. In the case of carotid severance (as in *Shechita*) blood flowing through the vertebral arteries follows the route of lowest resistance, which is, in fact, back to the distal stump of the carotid (Fig 2). The importance of restraint for post-*Shechita* bleed out might also explain the variable period to loss of function reported in an experiment in cattle by Blackmore (1984). In this study, there was a manual cut of exteriorised neck vessels, but 'after incision of the neck, all restraint was immediately released'. This could produce re-occlusion of the vessels, which should not occur in *Shechita*.

With regard to experimental studies looking at the relative contribution of the cerebral vessels to overall perfusion of the bovine brain, Levinger (1976) examined changes in regional brain blood flow after *Shechita*, using a dye dilution method. Dye was injected through a catheter directly into the right and left ventricular chambers immediately before *Shechita*. Although, with microscopic investigation, appreciable amounts

BEHAVIOURAL RESPONSES TO THE SHECHITA INCISION

Direct observation of an animal's responses before, during and after *Shechita* are both fascinating and important, especially since, in the assessment of potentially painful experiences by animals, pseudoaffective responses are the major indication of how stressful or painful such experiences are.

The free animal before *Shechita*

In accordance with the *Halacha*, *Shechita* is performed on one animal at a time. Cattle and sheep are sentient creatures; however, there is no sign that the animals are frightened of impending death since they continue to ruminate normally.

Handling before *Shechita*

There is no direct evidence of behavioural signs of stress in anticipation of *Shechita*. The restrained animal is calm and still before the act of *Shechita*, probably due to calm and purposive handling. A further pointer to the efficacy of restraint in this fashion is the fact that it has been adopted by a number of non-*Shechita* slaughtermen.

Immediate response to the *Shechita* incision

Grandin (1994) reported that before *Shechita*, at the moment of the incision, and immediately after *Shechita* there was no flinching and no reflex defence response suggestive of any sensation of pain. Bager and others (1992) also observed a lack of flinching. It can be deduced, therefore, that the incision itself is not painful. The animals studied by Grandin were in a restraining pen, but not constrained to the extent that such movements would have been impeded. The lack of a response to the *Shechita* incision is in contrast to the observable effects of inflicting such painful stimuli as ear tagging or, possibly, captive bolt stunning. Reports such as that of Grandin are of particular importance, being studies of cattle, the species about which greatest concern has been expressed in relation to pain perception.

Laboured respiration

After about 30 seconds, a strained and noisy form of slow breathing supervenes, related to muscular spasms of the diaphragm or unusual signals to the respiratory muscles from the hypoxic brain. Unsurprisingly, this does not improve tissue oxygenation, and this form of breathing has also been observed after severance of the head.

It has been asserted, without any supporting data, that the very fact of breathing through the severed trachea must per se be very distressing. We know from the many human tracheostomy cases that this is untrue; in addition, in an animal that has undergone *Shechita*, consciousness will have been lost long before it could be aware that it is breathing through a severed trachea.

Muscular spasms

Also after about 30 seconds, strong muscular spasms frequently cause the limbs to thrash violently (Levinger 1995b). These movements are in no respect at all a conscious reaction to pain; they are reflexes due to hypoxia of the spinal cord causing abnormal efferent signals to the muscles and can be abolished by electrical depolarisation of the spinal cord (Gilbert and others 1984). This phase can last for up to four minutes.

THE ISSUE OF PAIN

The nature of pain

The crucial animal welfare question in relation to methods of animal slaughter is whether the methods cause pain. It is not straightforward to answer this question, for a number of reasons. The first is that pain itself is not easy to define (Wall 1989), beyond it being an unpleasant sensation or awareness in response to a physical or mental stimulus. Secondly, it is an intrinsically subjective experience. Any notion that one might have of pain in another person or animal is dependent on one's imagining how one would feel in that situation and projecting the same on to the other person or animal. Thirdly, in the absence of an articulate expression of feelings, which is clearly impossible in the case of animals, one can only infer the presence of pain by observation of behavioural responses (for example, withdrawal from the stimulus, efforts to escape from the stimulus, cries or other vocalisations, etc) or through clear neurophysiological data, if such are available.

Neurophysiological basis

The hope that scientific methods could overcome these limitations, for example, through physiological measurements of an animal's responses, remains to be realised, not least because the issue is extremely complex and the data are difficult to interpret. More obvious parameters such as increases in heart rate or blood pressure due to activation of the body's sympathetic ('fight/flight') system are non-specific. This is also the case for neurohumoral markers such as plasma cortisol, or β-endorphin.

A few key points are generally accepted; for example, a functioning, conscious brain is necessary for the perception of pain. Studies have been performed using positron emission tomography, which can measure regional cerebral blood flow as an index of neuronal activation, to investigate brain activation in live, awake humans. These studies have shown that, within the brain, the cerebral cortex is essential for the perception of pain, whether the origin of the pain is the skin surface (Jones and others 1991), the oesophagus (Aziz and others 1997) or the heart (Rosen and others 1994).

In addition, the painful stimulus from the periphery has to be adequate to activate the pain pathways. Considering the situation with *Shechita*, the starting point is, indeed, an animal which is conscious up to the moment of the act of *Shechita*, but the drastic and rapid fall in cerebral blood flow immediately after the *Shechita* incision inactivates the cerebral cortex by depriving it of its blood supply, leading to a rapid loss of consciousness. Also, the exquisite sharpness of the *Chalaf*, coupled with the smoothness of the incision, mean that, as for a surgical incision, there is minimal stimulation of the incised edges, typically below a level adequate to activate the pain pathways. The latter is analogous to the frequent experience of surgeons who have cut themselves in the course of an operation and only noticed it well after the event. It will also be recalled that proper attention to the halachic requirements during *Shechita* also contributes to the lack of stimulation of the incised edges.

A medical event relevant to this discussion is the experience of stroke. Regardless of the mechanism of stroke (whether thromboembolic or haemorrhagic), they are painless, as attested to by patients who retain or regain the power of speech after a stroke.

Data from electrophysiological studies

Brain electrical activity has been assessed classically from the surface of the scalp – the electroencephalogram (EEG) (Goetze and others 1959, Modarres 2000), and, more invasively, by means of recording electrodes on the brain surface – the ECoG. A number of waves are recognised on the EEG. The dominant wave during wakefulness is the α wave, an almost sinusoidal discharge with a frequency around 10 Hz and amplitude between 0 and 100 mV. The α rhythm is inhibited by visual input and concentration with effort. As wakefulness is lost, for example, during anaesthesia, the α waves give way to β and γ waves. A β rhythm was noted between three and seven seconds after the *Shechita* incision. This represented a shift from low amplitude, high frequency waves to high amplitude, low frequency. An isoelectric state (flat trace) supervened in 15 to 30 seconds in sheep and goats (Nangeroni and Kennet 1963). In the cattle studied by Nangeroni and Kennet (1963), there was a shift in wave form to high amplitude, low frequency, with loss of consciousness in approximately three seconds. An isoelectric trace was displayed in less than 25 seconds. There were, however, disparate responses to carotid clamping in one of the calves, suggesting an abnormal anatomical variant in the cerebral blood supply in this animal.

Schulze and others (1978) studied 25 sheep and 15 calves and saw no effect of the *Shechita* incision on the raw EEG trace. The time to an isoelectric state was less than 13 seconds in the sheep and less than 23 seconds in the calves.

In more recent times, the use of raw EEG data, especially the measurement of time to an isoelectric state, has come in for much criticism for several reasons. First, the anaesthetised patient does not have a flat EEG and yet is (hopefully!) not sensible to pain. Most dramatically, EEG activity can even be demonstrated in severed heads (Swaab and Boer 1972, Mayevsky and Chance 1976). Since these decapitated animals are clearly dead, it can be deduced that the mere presence of an EEG trace certainly does not equal consciousness.

It is noteworthy that after captive bolt stunning the relevant changes in EEG frequency might also take at least 25 seconds in cattle (Fricker and Riek 1981). Thus, if insensibility were to be defined on this basis, it would not be achieved instantly by captive bolt stunning (Daly and others 1988). On this basis, the requirement stated by a number of the critics of *Shechita*, that the stunning method of choice is the one that is first to produce an entirely flat EEG, is irrelevant.

Daly and others (1988) assessed brain function in adult cattle after conventional captive bolt stunning compared to *Shechita*. The measurement of brain function was, in terms of visual and somatosensory evoked potentials, unlike the simpler reports of raw EEG data described above. These authors reported that, compared with captive bolt stunning, the act of *Shechita* led to greater variability in the time to loss of evoked responses, between 20 and 126 seconds (mean 77 seconds for somatosensory and 55 seconds for visually evoked responses), with spontaneous activity lost between 19 and 113 seconds (mean 75 seconds).

These data have been the focus of much attention, because, within welfare considerations, the length of time during which an animal *could* potentially experience pain has (rightly or wrongly) been regarded as a surrogate of the relative risk of distress associated with the particular technique of slaughter. In this context, it is important to note the caveats of the authors themselves: 'The evoked responses do not represent a conscious awareness of the stimulus but are produced by neural activity at a rudimentary level which precedes conscious awareness. This is best demonstrated by the fact that evoked responses can be recorded in anaesthetised animals.' In addition, as noted by Levinger (1995c), when Kallweit and colleagues compared the time from bleeding until the isoelectric line in both methods of slaughter, the length of time was greater after carotid severance without prestunning. However, if it is borne in mind that the length of time during which an animal could potentially experience pain is from the beginning of the shot with the captive bolt, not at the bleeding cut after the shot, then the time from *Shechita* to the isoelectric line is actually shorter.

A further refinement in the analysis of EEG data has been the application of techniques of time and frequency domain analysis, which are already well established in the study of heart rate variability in man. Bager and others (1992) described a study of calves in which a fast Fourier transform had been applied to the raw EEG data and possible correlations with metabolic markers of brain failure after slaughter were examined. They assessed ECoG and metabolic markers (PO_2, PCO_2, pH, lactate and glucose levels in brain arterial and venous blood) in groups of calves which were either stunned, recovered for 80 to 100 minutes and then stunned and slaughtered; or stunned and immediately slaughtered; or slaughtered without stunning (although not by *Shechita*, but rather by a 'gash cut' that severed the jugular veins, the common carotid arteries and the vagosympathetic trunks at the level of the trachea). Their findings included several of interest to the present paper, including that the head-only stun employed produced an epileptiform seizure lasting for between 22 and 29 seconds after the stun, which was probably responsible for the biochemical signs of substantially increased cerebral metabolism. They also found that after the unstunned gash cut, animals became insensible very quickly, that is, they showed a quick onset of high amplitude, low frequency waves, unless the carotid arteries re-occluded. The authors commented that 'simply using the amplitude of the ECoG, therefore, is insufficient to determine sensibility. A delayed attainment of an isoelectric ECoG also does not indicate that the animal is sensible.' In addition, no correlations were found between the indices of cerebral metabolism measured and the time to loss of (electrical) cortical function. There were other observations of interest, such as the absence of an increase in haemoglobin in the unstunned calves, which might suggest that changes in sympathetic activity were minimal in those calves. Bager and others (1992) commented that 'Slaughter without stunning, while mostly resulting in rapid irreversible loss of ECoG activity, may sometimes be associated with a period of low frequency activity when a residual blood supply is maintained.' As noted above, when the act of *Shechita* is performed correctly, such a residual blood supply will *not* be operative.

In broader terms, it can be seen that time to insensibility is not actually being measured in any of the above experiments, let alone time to loss of any possible feeling of pain. The measurement that has been made is time to 'brain failure'. Raw EEG and ECoG data can indicate undoubted consciousness and undoubted insensibility, but not the start of insensibility. There is little likelihood that the more sophisticated mathematical derivatives of the raw data would yield much improvement because the techniques are still nonspecific – there would still be no way of knowing whether the change in the parameters being measured would be saying anything about a feeling of pain.

Exploration of the corneal reflex has also been applied to the study of pain perception in animals. In man it is well known that touching the cornea elicits a reflex involving the Vth cranial nerve that brings about a withdrawal from the stimulus or a closing of the eye (Pappworth 1984). The length of time until the disappearance of the corneal reflex has been considered by some to be a marker of the time to loss of consciousness. However, a more detailed consideration of the corneal reflex reveals that it is dependent not on the cerebral cortex, but on lower brain structures, particularly the brainstem. It is therefore quite possible to have an intact corneal reflex for a little while after the loss of the capacity to think or feel.

It follows that some stunning techniques, either through mechanical impact or electrical disturbance, will very likely affect function of subcortical structures and cause the corneal reflex to be lost a little quicker than *Shechita* (Nangeroni and Kennet 1963), in much the same way as an individual whose brain had been blown out would also fail to show rudimentary reflexes. After *Shechita*, the corneal reflex may indeed still be elicited for some 20 seconds, but consciousness will have been lost in less than three seconds.

STUNNING

In the course of discussing the physiological aspects of *Shechita*, reference has inevitably been made to stunning.

Stunning refers to the process of rendering an animal insensible before slaughter. It is often assumed, although with no positive proof having been adduced, that stunning is a kindness to the animal to be slaughtered and some use the phrase 'humane stunning'. There are a number of mechanisms of stunning, as described below.

Mechanical stunning

With this method, a severe blow is delivered to the head of the animal (Daly and others 1987), usually through the use of a captive bolt pistol. When fired, the central metal core of this device emerges a short distance. Despite the small distance, the bolt emerges with considerable speed so that its momentum, and therefore the force of the blow to the head, is very great. The captive bolt method requires accurate placement of the pistol on the animal's head, and a degree of restraint of the animal is necessary to facilitate this. Captive bolt stunning, and, as described below, carbon dioxide stunning, entails massive sympathetic discharge, which might be taken to indicate a very large stress response (Mitchell and others 1988, Hartung and others 2002). As an aside, there have been recent suggestions that the captive bolt method of stunning may be associated with risk of transmission of infection, including prion diseases (Love and others 2000).

Electrical stunning

Electrical stunning causes insensibility in an animal by means of a large electrical discharge across its head. The electrical discharge is likely to achieve its effect by a number of means, the most likely of which is asphyxia due to paralysis of the respiratory muscles (Hillman 2003). Massive sensory stimulation is probable and this might be extremely painful (Sassoon 1956, Hillman 1993), although the paralysis of the motor system would mask important signs of distress.

Another mechanism of action of electrical stunning would appear to be the induction of a prolonged epileptiform seizure (Bager and others 1992). It is noteworthy that electric shock therapy has never had any application in human anaesthesia. On the contrary, in the one situation in which an electrical discharge through the brain is used therapeutically, that is, the treatment of depression by electroconvulsive therapy (ECT) (Gelder and others 1996), full general anaesthesia, including paralysing agents, has to be given first, because of the severe muscle damage and potential for fractures which occurred with the older, so-called unmodified, ECT.

Other methods

Other methods of stunning have been developed. The main one of these is that of narcosis – making animals sleepy to the point of being comatose – by their breathing carbon dioxide-enriched air. Carbon dioxide narcosis is almost exclusively used in poultry slaughtering. As with the other methods of stunning, its introduction was effected with no direct objective evidence of any reduction in distress on the part of the animal. There have, though, been many human physiological experiments on carbon dioxide rebreathing. Such studies have shown that, before subjects get to the sleepy phase of carbon dioxide intoxication, there is an extremely distressing, agitated phase during which the increase in inspired carbon dioxide provokes a severe and frightening air hunger (West 1990). There are data to suggest that turkeys stunned by this method also go through a similarly distressing phase before narcosis (Erhardt and others 1996), and carbon dioxide is undoubtedly irritating to the respiratory tract (Raj and Gregory 1993). Even if other gases, such as argon, are used for stunning, the same essential mechanism applies, namely deprivation of oxygen, and the same agitating air hunger effects would be expected, as in all other cases of asphyxiation.

The relevance to *Shechita* of this brief survey of stunning is as follows. It will be noted that, in the course of the first two types of stunning described, the nervous system is directly damaged, before the final act (sticking) which terminates the life of the animal. This unquestionably makes the animal a *Trefah* (that is, unfit for *Shechita* because of an existing injury or abnormality). Even in the case of any putative method of stunning which did not inflict direct damage to the nervous system, the stunned animal would be unable to be seen to stand up fit and well before its final dispatch, an essential halachic prerequisite.

It has been commented by some in discussions on animal welfare that, while it is accepted that there is no scientific evidence of *Shechita* being painful, prestunning is nevertheless desirable because the animal should be given 'the benefit of the doubt.' There is an assumption (even described by some as a 'tenet of belief') that stunning before slaughter is a kindness to the animal. The argument underpinning this has been said to be 'intuitive'. This, though, is an unreliable measure, to say the least. 'Intuitive' in this context' equals 'unscientific'; it might also equal 'irrational' or, worse still, 'untrue'. For example, intuitively one might imagine that in countries where the death penalty is applied, rendering a human being unconscious before execution by means of a massive blow to the head would be a painful and unacceptable method. The same could be said for electrical stunning or gaseous asphyxiation.

It is likely that one reason for the clamour for stunning in certain quarters is confusion of an aesthetic nature. Characterisation of *Shechita* as 'cutting an animal's throat', with descriptions of blood spurting from the neck or of the late muscular spasms, are unattractive, to say the least. However, to the uninitiated, coronary artery bypass surgery is also visually unappealing! In dealing with an issue as important as the potential suffering of animals, it is unacceptable that superficial aesthetic considerations should be allowed to cloud the argument.

CONCLUSION

In conclusion, after a review of the physiological issues involved and the experimental data, it is submitted that *Shechita* is a painless and effective method by which to stun and dispatch an animal in one rapid act.

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With reference to the paper submitted to the Veterinary Record (1988) 122, 325-329, Cortical function in cattle during slaughter, I would like to clarify the following points.

1. The time periods to loss of evoked cortical activity or loss of spontaneous cortical activity is NOT equivalent to the time taken to loss of sensibility or consciousness. Sensibility is lost prior to failure of evoked activity, and this MAY have occurred very quickly.

2. The results described in this paper do not provide any information about pain sensation. The visual and somatosensory evoked responses used in these experiments are not painful, and their presence cannot be used as evidence of conscious, painful experiences.

The rational for using evoked potentials is based on the premise that the absence of evoked activity permits definitive statements that an animal is insensible, such as, for example, following captive bolt stunning. When the evoked activity is present or sustained, the techniques used do not permit making unequivocal statements about the sensory experience of the animal.

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