Effects of vehicle movements during transport on the stress responses and meat quality of sheep

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Two groups of 26 lambs were transported for 15 hours either on smooth highways or on rougher secondary roads. Nine of the animals in each group were monitored for heart rate and the plasma levels of cortisol, creatine kinase and lactate dehydrogenase, before the journey began, after four, eight and 12 hours and at slaughter. The pH of the meat was measured 45 minutes and 24 hours postmortem and its colour was assessed 24 hours postmortem. The lambs transported on smooth roads had a lower heart rate and lower plasma cortisol concentrations after eight and 12 hours than the lambs transported on rougher roads. Twenty-four hours after slaughter the pH of the meat of the lambs transported on smooth roads was lower than that of the lambs transported on rougher roads.

THE transport of live animals has important implications on both economic and welfare grounds (Grandin 1993). Economic losses during transport are due to mortality, particularly of pigs and poultry, carcase bruising and shrinkage (loss of weight) and reductions in meat quality (Warriss 1996). Dark, firm, dry (DFD) meat occurs regularly in pigs and cattle (Tarrant 1981), and is mostly related to fighting, although animals that are not directly involved in fights but which are threatened may also develop DFD (Tarrant and Grandin 1993). Sheep have been reported to develop DFD meat (Apple and others 1995), but little is known about the factors involved in its development while they are being transported.

The to and fro movements induced in the animals by the movement of the vehicle can cause motion sickness (Nicol and Saville-Weeks 1993). The incidence of DFD meat is related to a lack of glycogen for energy provision before slaughter. The effort needed by the animals to keep their balance while the vehicle moves may be demanding in terms of energy requirements and increase the incidence of DFD meat (Tarrant and Grandin 1993). Furthermore, the vibration and movement of the vehicle are unfamiliar to the animals, and are therefore likely to elicit a stress response (Dantzer and Mormède 1983). The aim of this experiment was to study the effects of the movement and vibrations of the transport vehicle on the stress responses and meat quality of the sheep being transported.

MATERIALS AND METHODS

Fifty-two 10- to 12-week-old lambs (26 males and 26 females) of the Ripollesa breed (a mutton-type sheep) and weighing approximately 20 kg were used. Before being transported the sheep were housed singly in pens 4 m^2 in area. The vehicle used in the experiment is shown in Fig 1. A tri-axial accelerometer linked to a multichannel data-logger (EDR-1; Squirrel Grant) was used to record any movement of the vehicle with an acceleration greater than 7 m/s^2 (Broom and others 1996).

Two journeys were made, one involving driving on smooth highways and one involving driving on rougher secondary roads. Each journey lasted for 15 hours, including three stops of about 30 minutes each. Twenty-six lambs (13 males and 13 females) were used on each journey and the stocking density on the vehicle was about 0·26 m^2/animal. This stocking density is within the range permitted by the European Union directive for the transport of live animals (95/29/EC).

The percentage of the animals standing was recorded every 10 minutes using a videocamera (CCD-VX1-E; Sony) with an intervalometer (to record changes in acceleration). Nine of the animals on each journey were randomly selected for measurements of heart rate, and the plasma concentrations of cortisol, creatine kinase (CK) and lactate dehydrogenase (LDH). Heart rate monitors were strapped on to the bodies of the sheep and their heart rates were later transferred to an electronic reading device (Polar Sport Advantage monitors; Polar).

Blood samples were taken from each of the nine animals immediately before the journey, when the vehicle stopped after four, eight and 12 hours, and also when they were slaughtered. The levels of CK and LDH were analysed spectrophotometrically by standard methods recommended by the International Federation of Clinical Chemistry (Anon 1972, Gruber 1978). Plasma cortisol levels were analysed with a commercial radioimmunoassay (Fenzia kit; Orion Diagnostica).

After the journey the animals were electrically stunned (head-only at 350 V for three seconds) and bled out. After slaughter, the pH of the longissimus dorsi muscle was measured after 45 minutes and 24 hours with a pH meter (Scharlau with xerolyt electrode). The colour of the meat was recorded at the internal face of the rectus abdominis muscle on the carcase, with a colorimeter (CR-200; Minolta) and determined in terms of three parameters: a (redness), b (yellowness) and L (paleness).

Statistical analysis

The percentages of the animals standing, the heart rates and the plasma levels of cortisol, LDH and CK were compared by using the Mann-Whitney U test. The parameters of meat quality were compared by using Student's *t* test. All the analyses used the SPSS – Statistical Package for Social Sciences – program v 8.0.

RESULTS

Differences in driving conditions

There were fewer changes in acceleration of more than 7 m/s^2 every 30 minutes during the journey on smooth highways than during the journey on secondary roads; the mean (sd) numbers were 0·75 (0·13) and 15·1 (3·2) ($P<0.005$).

Effects on numbers of animals standing and heart rate

On average, a smaller proportion of the animals remained standing during the smooth journey than during the rough

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TABLE 1: Effects of driving conditions on the mean (se) heart rates, plasma levels of cortisol, creatine kinase (CK) and lactate dehydrogenase (LDH), and the meat quality of lambs transported for 15 hours on smooth or rough journeys

	Period	Smooth	Rough	P
Heart rate	Stationary	0·95 (0·02)	1·32 (0·09)	<0·01
	Moving	0·91 (0·03)	1·31 (0·07)	<0·01
	Total	0·93 (0·02)	1·31 (0·08)	<0·01
	Blood sample			
Cortisol*	2nd	3·29 (0·71)	2·11 (0·45)	NS
	3rd	0·75 (0·13)	1·79 (0·58)	<0·05
	4th	0·74 (0·17)	1·41 (0·24)	<0·05
	5th	2·05 (0·45)	1·43 (0·31)	NS
CK*	2nd	0·97 (0·17)	1·17 (0·18)	NS
	3rd	0·90 (0·15)	0·90 (0·20)	NS
	4th	2·94 (1·48)	1·39 (0·44)	NS
	5th	3·03 (0·40)	3·87 (0·59)	NS
LDH*	2nd	1·09 (0·08)	1·02 (0·04)	NS
	3rd	1·08 (0·05)	1·17 (0·02)	NS
	4th	1·22 (0·10)	1·22 (0·02)	NS
	5th	1·22 (0·05)	1·28 (0·03)	NS
Colour†	a	14·0 (0·30)	15·3 (0·35)	<0·05
	b	6·16 (0·28)	6·75 (0·38)	NS
	L	50·1 (0·59)	49·6 (0·75)	NS
pH	45 minutes	6·71 (0·03)	6·49 (0·04)	<0·001
	24 hours	6·00 (0·05)	6·33 (0·04)	<0·001

* Values shown are the ratios of the level in the sample to the level in the first sample
† Colour values: a Redness, b Yellowness, L Paleness
NS Not significant

journey; the mean (sd) percentages were 25 (3) and 55 (3) respectively ($P<0·001$).

The animals' mean heart rate was lower during the smooth journey than during the rough journey (Table 1), and the difference was significant not only during the periods in which the vehicle was moving, but also during the rest periods ($P<0·01$).

Effects of blood parameters

There was no significant difference between the mean plasma levels of CK and LDH during the two journeys. The levels of cortisol were significantly higher during the rough journey than during the smooth journey in the third and fourth blood samples ($P<0·05$), but lower in the second and fifth blood samples.

Effects on meat quality

The a (redness) value of the meat colour was lower after the smooth journey ($P<0·05$). The pH of the meat from the sheep transported smoothly was higher 45 minutes after slaughter ($P<0·001$), but lower 24 hours after slaughter ($P<0·001$) than the pH of the meat from the sheep transported more roughly.

DISCUSSION

The results suggest that the rough journey was more stressful to the animals, as indicated by the differences in cortisol levels and heart rate. The levels of cortisol were higher in the third and fourth blood samples, but not in the second and fifth samples. The second blood sample was taken only four hours after the journeys began and it is likely that any difference between the driving conditions was then masked by the effect of novelty, because the animals would not have become habituated to being transported (Broom and others 1996). The fifth blood sample was taken at poststunning terminal bleeding, when the stress of handling and slaughter could have masked any putative difference between the treatments.

The differences in heart rate are likely to be partly explained by the differences in the numbers of animals standing up. However, since the energy cost of standing up is low in sheep (Noblet and others 1993), the differences in heart rate – which is strongly correlated with energy expenditure (Rometsch and others 1997) – are unlikely to be explained completely by differences in physical activity but are also likely to be related to the stress response of the animals, which was probably more pronounced during the rougher journey. This could also explain the differences observed when the vehicles were stationary.

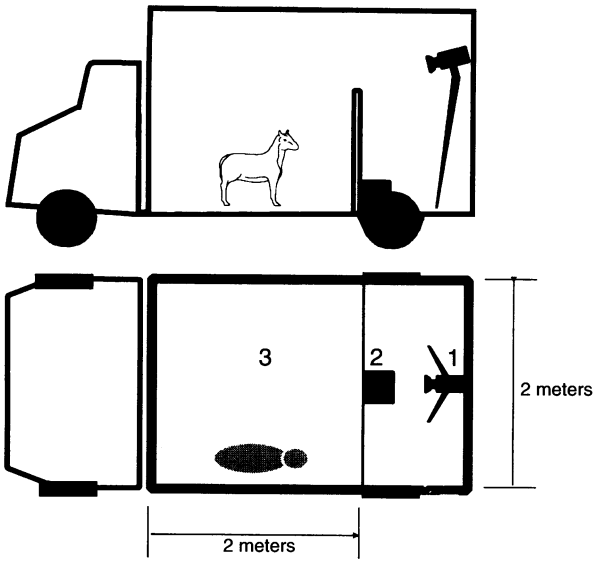

FIG 1: Position of the video camera and accelerometer within the transport vehicle. 1 Video camera, 2 Accelerometer, 3 Animals' area

The increases in heart rate and activity would have involved greater energy expenditure, which would probably have reduced the muscle glycogen stores. Evidence of this reduction is provided by the fact that the pH of the meat measured 24 hours after the rougher journey was indicative of DFD meat. The results therefore show that a rough journey to the slaughterhouse may have a deleterious effect on the meat quality of sheep.

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Magnetic resonance imaging of two normal equine brains and their associated structures

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Magnetic resonance images were obtained from two isolated horses' heads. Ten mm thick, T1-weighted images were taken with a 1·5 Tesla magnet and a body coil, and compared with the corresponding frozen cross-sections of the heads, relevant structures being identified and labelled at each level. The images should provide reference material for clinical magnetic imaging studies of horses' heads.

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AN accurate interpretation of cranial magnetic resonance images requires a thorough knowledge of neuroanatomy. The development of new techniques to improve the spatial and contrast resolution of soft tissues and the continuous acquisition of experience have made this approach indispensable in modern neurological treatment. Magnetic resonance imaging (MRI) has also proved to be very valuable in the study and evaluation of tumours, infections, infarctions, haematoma, demyelinating disease, vascular malformations and calcification of the head in small animals (Grahn and others 1993, Walker and Rogers 1993, Forrest and Thrall 1995, Gordon and Dennis 1995, Thomas and others 1996, Dennis 1998).

Since Lauterburg (1973) published the first clinical magnetic resonance image, the technique has advanced significantly and is now routinely used in human medicine (Bydder 1984, Daniels and others 1987). Owing to its high cost, the limited access to MRI scanners and the lack of radiofrequency coils of suitable design, the technique has been little used for descriptive anatomical research in veterinary medicine (Morgan and others 1993, 1994). Most published reports in small animals deal with cranioencephalic structures (Panciera and others 1987, Kraft and others 1989, Karkkainen and others 1991, Hudson and others 1995) and the musculoskeletal system (Adams and others 1995). Reports of MRI in the horse have been limited to the study of parts of cadavers (Park and others 1987, Denoix and others 1993, Martinelli and others 1994, Holcombe and others 1995, Widmer and others 1999) and of the brain in neonatal foals (Chaffin and others 1997). To the authors' knowledge, there is no published material describing the results of MRI of the adult equine brain. A thorough understanding of neuroanatomy on magnetic resonance images is essential to optimise the diagnosis of brain disease.

This report describes the cross-sectional morphology of the brain of two normal horses in terms of magnetic resonance images and transverse gross sections.

MATERIALS AND METHODS

An eight-year-old mixed-breed horse and a four-year-old thoroughbred were euthanased with an overdose of pentobarbital sodium for medical reasons unrelated to disease of the head. Both heads were cooled and imaged within 24 hours to minimise postmortem changes.

The magnetic resonance images were obtained with a 1·5 Tesla superconducting magnet. Twenty-six T1-weighted transverse images were acquired by using the following parameters: repetition time 600 msec; echo time 20 msec; 45 cm field of view; 192 x 256 matrix; and 5 cm slice thickness with 2·5 cm interslice spacing.

At the conclusion of the imaging, the blood vessels were filled with a latex substance for better definition of the vascular anatomy. The heads were frozen and then sectioned transversely with an electric saw to correspond with the thickness of the magnetic resonance slices. The sections were cleaned and photographed. The magnetic resonance images that most closely matched each gross section were compared with the corresponding gross anatomical sections and with the literature (Hillmann 1975, Schaller 1992, Vázquez Autón and others 1992, Thrall 1994, Asshauer and Sager 1997) to identify the normal anatomy of the brain and associated structures of the head. Some structures present in the anatomical sections could not be seen on the corresponding magnetic resonance images and vice versa.

RESULTS

Clinically relevant structures were identified and labelled in the corresponding magnetic resonance images and gross cross-sections. Seven magnetic resonance images corresponding most closely with the gross cross-sections are presented in a caudal to rostral progression from the level of the occipital condyles to the level of the olfactory bulb. Fig 1