Appendix 46

Preliminary study of the use of thermal imaging to assess surface temperatures during foot-and-mouth disease virus infection in cattle, sheep and pigs

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Abstract:

Introduction: Fever and the production of blisters on the feet and tongues are prominent clinical features of acute infection of ruminants and pigs with foot-and-mouth disease virus (FMDV). Inflamation and the resultant production of heat and generalized fever may be detectable by thermal imaging and a preliminary study was conducted to evaluate this.

Materials and Methods: Cattle, sheep and pigs were infected with FMDV (O/SKR/2000) and then monitored for clinical signs and temperature for 4 days. Thermal imaging with a recording camera, Thermoview model Ti30, 8-13um wavelength (Raytek) was used to monitor the surface temperatures of the feet of all in-contact animals once a day from 0 – 4 days after inoculation of donor animals. The average foot surface temperature (ASFT) and the hottest part of the foot or hottest foot surface temperature (HFST) were compared to rectal measurements of core body temperature.

Results: Pigs consistently showed the largest increases in HFST after infection. Ruminants were less likely to present with hot feet that could be directly attributable to FMDV infection and hot feet were sometimes observed at day 0.

Discussion: The camera and the associated software for image analysis were simple to use. Areas of inflammation accompanied by heat showed clearly on the images. Although the progression of disease could be followed to some extent, the practical value of thermal imaging for the diagnosis of FMD seems limited in ruminants because of the variable temperatures detected prior to infection. In pigs, there appeared to be a better correlation between progression of disease and hot extremities, although more measurements are needed, especially from uninfected animals. In the field, the camera might be used to help single out animals for examination and sampling.

Introduction:

Foot-and-mouth disease (FMD) is characterized by the appearance of vesicles or blisters on the feet and the mouth of affected animals to varying extents but especially in pigs, cattle and with lesser symptoms in sheep. Livestock affected by FMD pose a great risk to other non-infected animals and the disease is capable of transboundary transmission that can cause devastating economic consequences as was suffered by the UK in 2001. Early clinical detection of infected animals during monitoring in peacetime and in the face of an outbreak would benefit control efforts.

Lesions and/or the effects of inflammation that may be readily detectable during acute infection with FMDV are most likely to be on the feet, either on the coronary band, interdigital cleft and mouth, sometimes as blister(s) on the lips, muzzles or snouts of sheep, cattle or pigs. The first signs of inflammation may be a rise in the surface temperature of the inflamed area. Therefore, remote thermal imaging of feet and heads of FMD infected animals may provide a non invasive method of assessing infection.

Clinical applications of thermal imaging have been explored previously by several researchers for example, to detect fever in children (Ng *et al.,* 2005) and raised body or ear temperatures in pigs either due to infection (Loughmiller *et al.,* 2001) or as an indicator of stress (Warriss *et al.,* 2006). The sensitivity of detection of fever in children was high (89%) but the specificity was low (75%) and therefore the negative predictive value was high but the positive predictive value was 34%. In infection, the mean body surface temperature correlated well with the core body temperature of pigs as did ear surface temperatures. Skin surface temperatures taken by infrared sensing were as reliable as those taken with in-contact thermisters (Burnham *et al.*, 2006). In cattle, thermal imaging has been used to detect ear implant abscesses (Spire *et al.,* 1999) and sole haemorrhages by measuring hoof temperatures (Nikkhah *et al.,* 2005). In this report, we describe the use of infrared imaging in a preliminary study to detect temperature rises mainly in the feet of cattle, sheep and pigs in response to infections with foot and mouth disease virus.

Materials and Methods:

This study took advantage of animal experiments being conducted primarily for other research purposes. Three cattle, 3 sheep and 3 pigs were kept separately in biosecure animal accommodation and in contact with an equal number of donor animals of the same species that were inoculated with FMD type O from South Korea (O/SKR/2000) either intradermally into the dorsal surface of the tongue, coronary band or heel pad, respectively. All animals were monitored for clinical signs and temperature for 4 days after inoculation. Thermal imaging with a recording camera, Thermoview model Ti30, 8-13µm wavelength (Raytek) was used to monitor the surface temperatures of the feet of all in-contact animals once a day from day 0 – 4 after inoculation of donor animals. Images of feet including the digital clefts and coronary bands of animals were taken without handling or excessively disturbing the animals. The average foot surface temperature of all four feet (AFST) and the hottest part of any foot or hottest foot surface temperature (HFST) were considered in the analyses in comparison to body temperatures taken conventionally with a thermometer.

Results:

All animals inoculated with FMDV type O/SKR/2000 developed signs of clinical disease within 1-2 days post inoculation (dpi). Vesicular lesions developed on the tongue at 3 dpi and on coronary band (skin) at 3 dpi.

The average rise in body temperature of inoculated animals is compared with that of ASFT and the HFST in Figure 1. Generally, sheep were the first to show increases in body temperatures but this was not reflected in the AFST or HFST data. However, peaks in body and foot temperatures in sheep were at 2 dpi compared with 3 dpi for cattle and pigs. Figure 2 shows increased temperature of sheep feet at 2 dpi.

Pigs consistently showed the largest increases in ASFT and HFST after infection (Figure 3). The rise to peak foot temperatures was rapid and all feet showed signs of inflammation as indicated by the closeness of the AFST and HFST curves in Figure 1.

Ruminants were less likely to present with hot feet that could be directly attributable to FMDV infection. Often there was only one consistently hot foot (Figure 4). In cattle this was more difficult to photograph, especially early in infection, because the interdigital cleft surfaces needed to be assessed (Figure 5). Hot feet nearing the average for infected feet on 3 dpi (about 30 °C) were sometimes observed at day 0 in cattle and sheep, possibly where one foot may have been warmed under the resting animal.

Discussion:

The use of a thermal imaging camera to detect surface temperature variations in infected animals is described here in preliminary experiments to evaluate this technology for remote sensing on infection. The camera and the associated software for image analysis were simple to use and required a minimal amount of training. Areas of heat were clearly evident in the images and corresponded to known areas of inflammation that occur in FMD infected ruminants and pigs namely feet, especially the coronary band and interdigital clefts and the hocks, respectively. The progression of disease could be followed best in pigs' feet that had the greatest thermal variations. Here, there appeared to be a better correlation between progression of disease and hot extremities. This was less obvious in ruminants because many sheep had hot feet before inoculation and progressive increases in daily temperatures were difficult to see in individual sheep simply from the images. As a group and after analysis these variations were more evident and temperatures of the group could me monitored more easily. In cattle, increasing heat in could be monitored daily once the affected foot was located.

The practical value of thermal imaging for the diagnosis of FMD seems limited in ruminants because of the variable temperatures detected prior to infection. In pigs, it may be more useful and in all cases more measurements are needed, especially from uninfected animals. In the field, the camera might be used to help single out animals for examination and sampling but some practical complications may arise from environmental factors such as varying holding conditions and mud and debris on feet.

Conclusions:

- The thermal imaging instrument enables surface temperatures to be recorded and analysed very easily;
- Hot spots are readily visualised;
- Variability between surface temperatures of extremities within and between normal animals makes simple interpretation against a threshold difficult (low specificity);
- Useful trends can be seen over time;
- In the field, the technique could help identify animals (especially pigs) for further examination.

Acknowledgments:

This work was supported by the Department for Environment, Food and Rural Affairs (DEFRA), UK.

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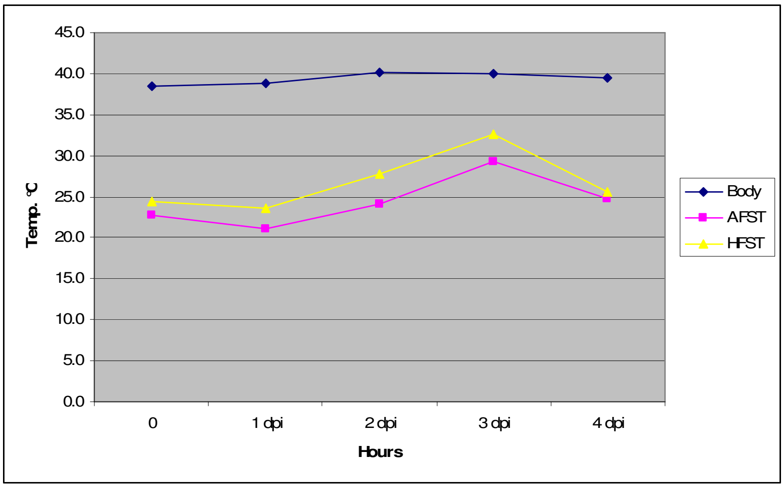
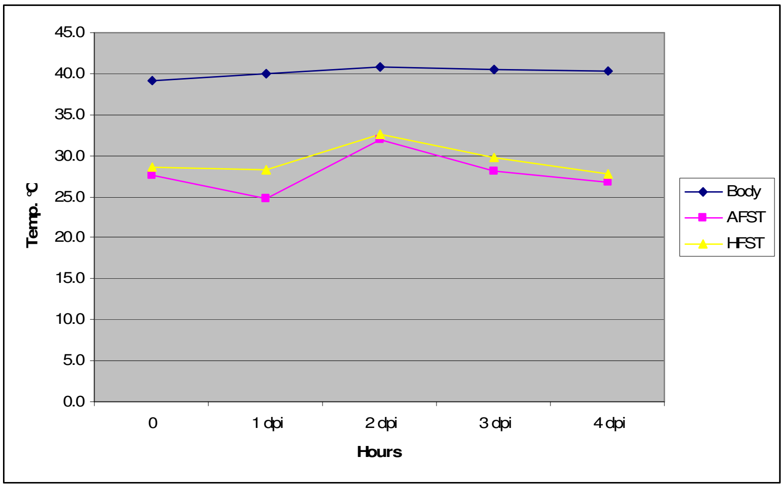
Figure 1 Average foot surface temperatures (AFST) and Hottest Foot temperatures (HFST) of animals inoculated with FMD O/SKR/2000 compared with body temperatures.

Cattle



Sheep



Pigs

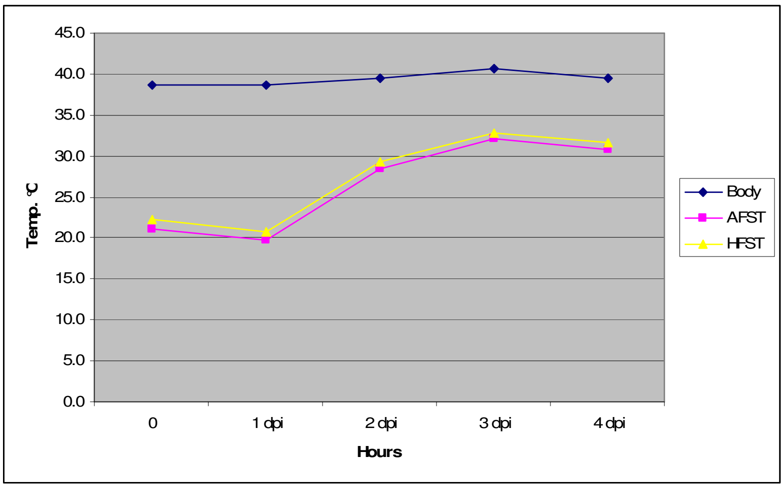


Figure 2. Sheep 2 dpi

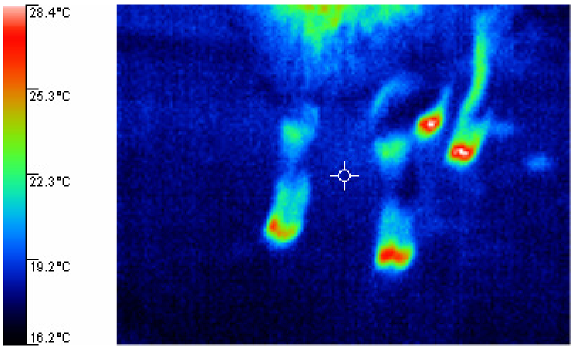


Figure 3. Pig 3 dpi

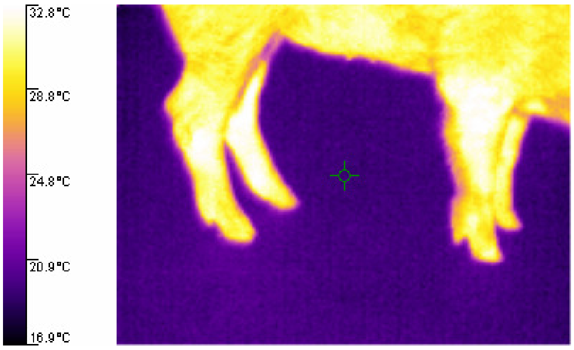


Figure 4. Cattle 0 dpi showing increased temperature of one foot

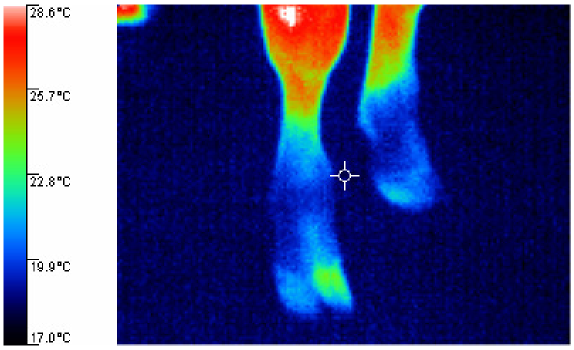


Figure 5. Cattle 3 dpi showing increased temperature of the coronary band and interdigital cleft