

# Developing the ‘Ouch-o-Meter’ to Teach Safe and Effective Use of Pressure for Palpation

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**Abstract.** Many clinical examinations involve palpation and part of the diagnostic process depends on the application of pressure. Teaching and learning such skills is difficult especially for internal examinations. A modification to a veterinary virtual reality (VR) simulator, the Haptic Cow, was planned to teach safe and effective use of pressure for bovine pregnancy diagnosis. Expert technique was captured when veterinarians performed pregnancy diagnosis in a simulated environment. The information is being used to calibrate a pressure indicator, the ‘Ouch-o-meter’ that together with palpation profiles will provide guidance for students.

**Keywords:** Veterinary, palpation, simulator, pregnancy diagnosis.

## 1 Introduction

Many examinations performed by health professionals involve palpation. Using the hands the clinician is able to detect changes to anatomical structures and gather information that helps in the diagnosis of many different conditions. Palpation is a valuable and inexpensive diagnostic tool available to every clinician but learning and teaching such skills presents a number of challenges.

A series of steps need to be mastered to perform a palpation examination. First, the trainee has to learn to locate landmarks. Then the shape and size of structures are determined and pressure is applied to assess firmness and content. It is important to use enough pressure to gather the required information but in a way that does not cause discomfort or harm to the patient. Teaching the technique can be difficult particularly for internal examinations (e.g. those performed per rectum or per vagina) as the instructor cannot see to direct the trainee’s movements or identify structures. Additionally, clinicians often have difficulty describing their technique in a way that is helpful to the trainee.

Simulators have an increasing role in medical and veterinary education and present a potential solution to some training issues. Trainees can practise repeatedly in a safe, ‘trial and error’ setting without risk to the patient. An example of a simulator developed specifically for a palpation-based skill is the E-Pelvis, a modified partial mannequin, for teaching pelvic examinations [1]. The trainee’s movements inside the model are presented graphically and sensors have been positioned to measure the force applied. There are also a few virtual reality (VR)

haptic simulators for teaching palpation examinations including one for diagnosing prostate cancer [2] and another for teaching osteopathy: The Virtual Haptic Back project [3]. When using the Virtual Haptic Back simulator, the trainee can follow the path of an expert’s examination either being dragged by the haptic device or following a visual trace. Additionally, a guide to the amount of force applied has been introduced with both auditory and visual feedback available, and the guidelines were based on the range of forces used by experts.

A veterinary VR simulator has been developed to teach internal palpation per rectum of the bovine reproductive tract: the Haptic Cow [4], with a PHANToM 1.5 haptic device inside a fibreglass model of the rear-half of a cow (Fig 1). Simulator training has been shown to have a beneficial effect on students’ performance during the real task [4]. However, when using the simulator students often expressed uncertainty about the amount of pressure to apply, particularly when learning to diagnose pregnancy. In early pregnancy, the veterinarian will apply gentle pressure to the uterus to detect foetal fluid and in more advanced pregnancies the foetus is palpated. Verbal descriptions of the techniques and the amount of force used were of limited value to students who continued to learn by trial and error, whether examining a live cow or when using the simulator. Incorrect diagnosis can have serious consequences and rough handling of the uterus could potentially damage the foetus.



**Fig. 1.** A Haptic Cow training session using a PHANToM 1.5 haptic device

Therefore, to improve training we aimed to add new features to the Haptic Cow by providing guidance about the use of safe levels of force and an effective palpation technique. Recent work by Morris *et al.* [5] has demonstrated the potential of simulators for training users in motor skills through visual and haptic cues where the forces used are an important part of the technique. In the current study, recordings were made of experts’ technique, which will be used to develop a pressure indicator or barometer, the ‘Ouch-o-meter’, and to provide palpation profiles, representing the hand movements when in contact with the uterus.

## 2 Methods

An experiment was conducted to gather information about veterinarians' techniques when palpating a cow's uterus to diagnose pregnancy. During the examination, the hand is moved down onto the surface of the uterus and then moved from side to side to compare the size of the two uterine horns. The content of each uterine horn is then assessed by pressing the surface and exerting a downward force. The part of the technique of interest was the amount of pressure applied when assessing the content of the uterus and the pattern of the hand movements. There would be ethical issues and technical challenges associated with capturing the information when examining live cows. Therefore, veterinarians performed the action in a virtual environment using a PHANToM 1.5 haptic device with the middle finger in the thimble gimbal.

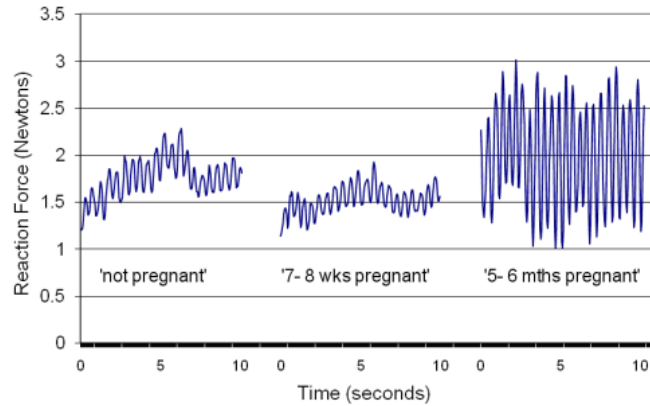
Ten farm animal veterinarians, with 3 to 30 years experience, took part in the experiment. When assessing the content of the uterus the principal direction of palpation is downward and a decision was made to focus on this aspect of the action using recordings in the vertical axis. A simplified simulation, a virtual horizontal platform, was used as the environment in which to capture the data. At any point of contact the platform would represent the dorsal (uppermost) surface of a uterine horn. The veterinarians performed the task unsighted with the PHANToM inside the fibreglass cow (as in Fig 1) and with no visual cues from the computer monitor. They were instructed to move over the virtual platform until comfortable that they could mimic the action used to assess the content of the uterus. The platform stiffness (N/mm) was adjusted to represent 3 different states: not pregnant 'NP' (0.4N/mm); 7-8 weeks pregnant 'P<sub>7-8W</sub>' (0.27N/mm); 5-6 months pregnant 'P<sub>5-6M</sub>' (0.2N/mm). The values were based on settings selected previously by 9 veterinarians when evaluating virtual models used in the Haptic Cow simulator [4]. For each state, a 10 second recording was made at a sample rate of 20Hz. The order of presentation of the 3 pregnancy states was randomised.

The data were analysed to explore 2 aspects of the simulated veterinary examinations. First, the range of peak forces was determined. The PHANToM 1.5 does not contain force sensors so it was not possible to measure the force directly. Therefore, the force was estimated by the reaction force from the virtual platform. Second, information was extracted about the palpation profile, i.e. the hand movements during the examination. For this, the change in the magnitude of the force over time was recorded, and the difference between peaks and troughs in the force used was examined.

## 3 Results

An example recording from one veterinarian is shown in Fig 2. The graph shows the reaction force recorded while the veterinarian palpated simulations representing each state of pregnancy for 10 seconds. The example was typical of all

the veterinarians in two respects. First, the peak (maximum) reaction forces measured were least for the 'P<sub>7-8W</sub>' state, with slightly higher peak reaction forces for 'NP', and the highest peak reaction forces for 'P<sub>5-6M</sub>'. Second, there was a greater difference between peaks and troughs in the forces used for the 'P<sub>5-6M</sub>' state than for the other two states.

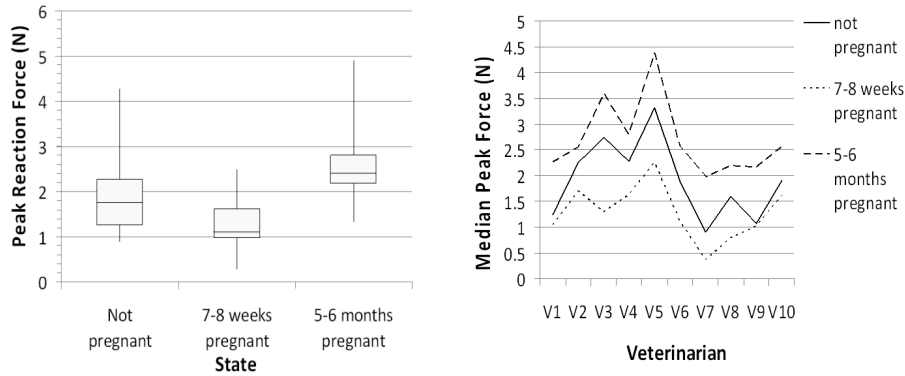


**Fig. 2.** The reaction forces (N) recorded for one veterinarian when palpating simulations for 3 different pregnancy states

Analysis of the change in force over time by all the veterinarians showed a significant difference in the technique used to palpate the 'P<sub>5-6M</sub>' state compared to the other two states. The mean change in force (difference between peaks and troughs in the force trace) for the 'NP' state was 0.57N (std. dev.=0.47N), for the 'P<sub>7-8W</sub>' state was 0.38N (std. dev.=0.34N), and for the 'P<sub>5-6M</sub>' state was 1.37N (std. dev.=0.82N). A GLM ANOVA with *post hoc* Tukey test showed that there was a significant effect of state ( $F=27.7$ ,  $p<0.01$ ) and that the difference in palpation technique was significant between 'P<sub>5-6M</sub>' and 'NP' ( $T=5.7$ ,  $p<0.01$ ), and 'P<sub>5-6M</sub>' and 'P<sub>7-8W</sub>' ( $T=1.4$ ,  $p < 0.01$ ).

The data were also analysed to investigate the range of peak reaction forces used by the 10 veterinarians i.e. all the peaks from all 10 veterinarians' 10 second recordings. The findings are presented graphically as boxplots in Fig 3 (left). The median peak forces were 1.82N, 1.62N and 2.48N for the 'NP', 'P<sub>7-8W</sub>' and 'P<sub>5-6M</sub>' states respectively.

The median peak reaction force was also calculated for each veterinarian and for each state. Fig 3 (right) shows that for each veterinarian the lowest value was for 'P<sub>7-8W</sub>' and the highest was for 'P<sub>5-6M</sub>', indicating that each veterinarian's use of force changed consistently in relation to state. A Kruskal-Wallis test showed that the peak reaction force was significantly affected by the state ( $H=13.96$ ,  $P<0.01$ ). *Post hoc* paired Wilcoxon tests using Bonferroni corrections showed that there was a significant difference between peak force used in all comparisons (all  $P<0.02$ ).



**Fig. 3.** Left shows the values of all the peak reaction forces (in Newtons) from the 10 veterinarians combined (a boxplot for each pregnancy state). Right shows the median peak reaction forces for each of the 10 veterinarians for the 3 different states.

#### 4 Discussion

The aim was to provide extra guidance for students learning bovine pregnancy diagnosis. The recordings from the 10 veterinarians will be used to calibrate a pressure barometer: an ‘Ouch-o-meter’. A decision was made to use the inter-quartile range of the peak forces recorded (Fig 3 left) as a conservative estimate of safe pressure for an inexperienced student. However, a wider range will also be considered as this would be easier for a trainee to target. During training, the student’s application of pressure would be recorded and the colour of the ‘Ouch-o-meter’ would change accordingly. A traffic light analogy is proposed. The bar would be green when the peak force was within the safe range, orange when in the fourth quartile, and red when exceeding the range used by any of the veterinarians. Below the inter-quartile range would be a pale green zone, safe but not necessarily effective. Auditory feedback will also be included with a “Moo!” warning that the force is excessive, corresponding to the red zone.

The recordings of the palpation profile, the change in force over time, will provide additional guidance. The veterinarians used a different technique for the 5-6 months pregnancy with a greater change in force over time than for the other states. For the not pregnant and 7-8 weeks pregnant states the hand movements resulted in relatively small fluctuations in force. Whereas for the 5-6 months pregnant state the hand movements produced much wider variations in force. This represents the wave-like action used by clinicians when feeling for a calf, a technique sometimes referred to as ‘ballottement’. The palpation profiles will be incorporated into the simulator’s guidance system. Several options are being considered to help trainees learn to achieve the expert action. The expert profile could be presented through graphical, auditory or haptic playback and the trainee would try to match his or her palpation profile to that of the veterinarian. Further research will be undertaken to develop guidance options and investigate the learning effects associated with each modality.

The study has certain limitations. Firstly, the recordings were made in a simulated environment, which is an approximation of the real situation. Additionally, a simplified simulation, a platform, was used to capture the downward aspect of the action. This represents the principal component but further recordings should be undertaken to characterise the action on a more realistic simulation i.e. of the whole uterus. Another limitation relates to using the PHANToM, which provides a single point of contact while in the real animal the whole hand is used. However, even with the single point of contact, experts using the middle finger rated the Haptic Cow simulations as realistic or acceptable and simulator training has been shown to be effective [4].

There was quite a wide range in the forces applied between veterinarians. This may represent the natural variation or be a factor of the simulator environment. However, there were also similarities in the measurements and techniques used. All the veterinarians changed the magnitude of force in a consistent way in relation to the state with a different palpation profile for the '5-6 months pregnant' state compared with the other two states. These consistencies suggest that the measurements captured an element of the real task, a 'clinical skill', providing some credibility to the findings. However, the recordings should still be considered as an estimate of the technique in the live animal and ideally a further means of validating the measurements should be found.

In conclusion, the provision of guidance and feedback are important ways of enhancing a trainee's learning process. However, for internal palpation-based examinations, such as bovine pregnancy diagnosis, providing effective instruction is difficult. The current work demonstrated that a simulation could be used to capture certain aspects of expert technique. Using the findings, a guidance system including a pressure indicator, the 'Ouch-o-meter', will be incorporated into simulator training for veterinary students. Whatever the simulation used, an important aspect of future work will be to investigate whether the enhanced training environment results in the desired learning effects.

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