Delineation of an Acquisition Window within the Respiratory Cycle of Laboratory Animals

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Introduction

Interest from pharmaceutical and genomic industries is expanding the field of laboratory animals imaging because responses to novel drugs and phenotypic aberrations in transgenic or knockout animals can non-invasively be detected and monitored, in vivo, by Magnetic Resonance (MR) and Computed Tomography (CT) (1,2).

Since respiratory-associated motion degrades spatial resolution of the thoracoabdominal organs and the respiratory rate of laboratory animals is significantly higher than in humans, gating techniques have needed to be employed to minimize respiratory-induced artifacts (3). Optimization of laboratory animal imaging protocols requires an knowledge of the pattern of respiratory motion of laboratory animals. This is difficult since no single, well-defined physiologic parameter within their respiratory cycle, analogous to the QRS complex in the cardiac cycle, has been identified. The goal of this study was to characterize laboratory animal respiration and quantitate movement of thoracoabdominal organs for potential application to new gating techniques in MR and CT.

Methods

The laboratory species studied included female Hartley guinea pigs (GPs), Sprague-Dawley rats and CD-1 mice. Anesthesia for imaging procedures was induced by an intraperitoneal injection of a ketamine-xylazine mixture. Once anesthetized, animals were placed on a respiratory gating device, consisting of a balloon stretched over a bowed piece of Plexiglas fitted to the thoraco-abdominal area of each species and a tube connecting the balloon to a pressure transducer. The increase in pressure caused by inhalation was converted by the transducer into a proportional electrical voltage.

Instantaneous organ motion was detected in the coronal and sagittal planes using digital cine x-ray images, acquired with a Siemens Multistar digital radiography system. Each set of images consisted of 16 msec. exposures acquired over a four-second (sec) period (rate = 30 frames/sec at 40 kVp & 54 mA).

Baseline images were selected through visual examination and were defined as the image collected at the midpoint of the phase (middle frame of all frames) in which no organ movement was detected. The baseline image was then subtracted from all other images. To ensure all diaphragmatic motion was quantitated, an image acquired at peak inspiration (max. diaphragmatic displacement) was used to draw an elliptical region-of-interest (ROI) around the entire diaphragmatic area. The variance within this ROI was recorded for all subtracted images. This value represented a measure of organ movement as a function of time that was sensitive to sub-pixel organ displacements.

Results

Under this anesthesia protocol, the respiration pattern was rhythmic and regular, allowing easy visualization of diaphragmatic movement. Analysis of the variance in the subtracted images revealed that the respiratory cycles consisted of four phases.

Figure 1 is a plot of the ROI variances for specified image numbers demonstrating acquisition window potentially (3-fold longer) at the end of expiration, demarcated by brackets within in GP (A), rat (B), and mouse (C) respiratory cycle.

Two phases of rapid movement of the lungs, diaphragm, and upper abdominal organs were associated with inspiration and expiration. It is at peak inspiration that data is acquired by the conventional gating methods. Therefore, data is being collected at maximum diaphragmatic distention and based on our results this is represented by a relatively small time period, ranging from 100 - 360 msec (GPs), 100 - 165 msec (rats) and 33 - 66 msec (mice). Our study demonstrated the availability of a longer period during which no diaphragmatic movement is detectable at the end of expiration. The length of this period was 700 - 1000 msec for GPs , 231 - 400 msec for rats and 100 - 166 msec for mice. The pixel intensity variance in this window was negligible GP mean pixel intensity = 29.7 arbitrary units (SEM = 0.45), rat mean = 28.9 (SEM = 0.41) and mouse mean = 13.14 (SEM = 0.16), in comparison to peak inspiration means (arbitrary units) of 613.35 (SEM = 2.41), 335.64 (SEM = 3.3) and 54.7 (SEM = 1.01), respectively.

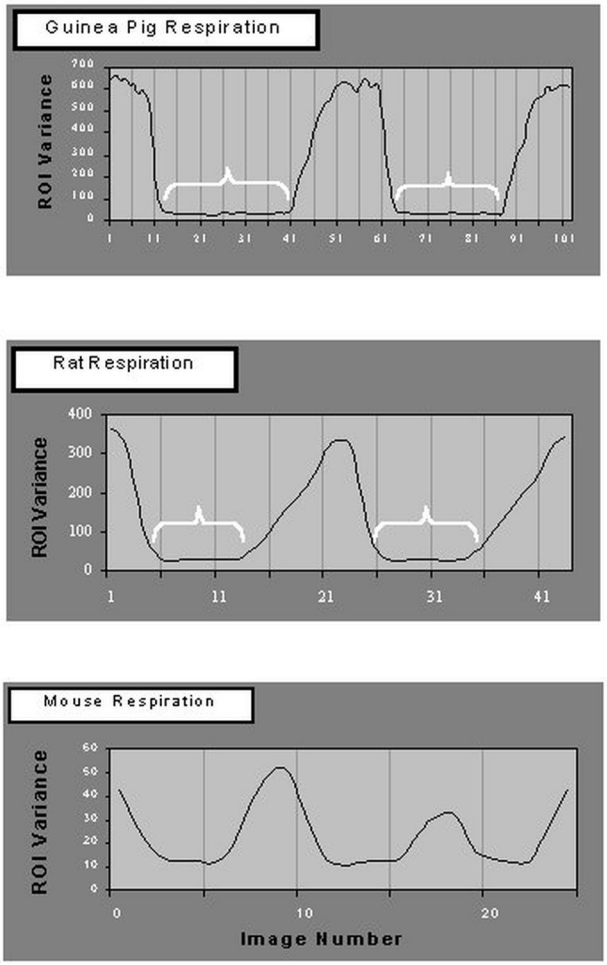

Figure 1:Plot of ROI variance for specified image numbers demonstrating potential acquisition windows (brackets)

Discussion

This study characterized an acquisition window at the end of expiration in which organ movement is undetectable. Acquisition of data after the expiratory phase of the respiratory cycle produces a 3-fold lengthening in the data acquisition window of laboratory animals. As a result, more data may be collected per respiratory cycle, which will significantly reduce scan times while maintaining image quality. For all imaging modalities, this potentially represents a significant improvement over methods currently used to gate respiration in laboratory animals.

References

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