MicroCT imaging of rodent lungs using the Quantum GX3 system.

Overview

- MicroCT and other X-ray-based imaging methods are best-suited to study lung anatomy and disease.
- Gated (synchronous) microCT imaging improves image quality and quantitation by correcting for breathing artifacts.
- The retrospective lung gating feature of Revvity's Quantum™ GX3 microCT preclinical imaging system enables anatomical and functional analysis of both healthy and diseased lungs in live animals across multiple species.

Introduction

Micro-computed tomography (microCT) has emerged as a powerful, non-invasive imaging tool for a broad range of preclinical research applications. In the context of pulmonary diseases, microCT imaging is particularly well-suited to longitudinally assess lung morphologic and/or functional respiratory changes during disease progression or treatment response. This is due to the inherent density differences between lung tissue comprised mostly of air and surrounding tissues, which results in superior image contrast for pulmonary research applications.

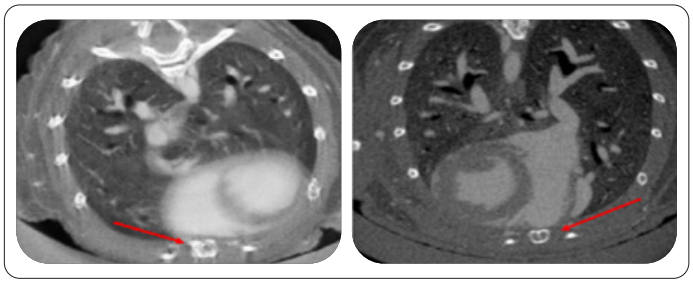
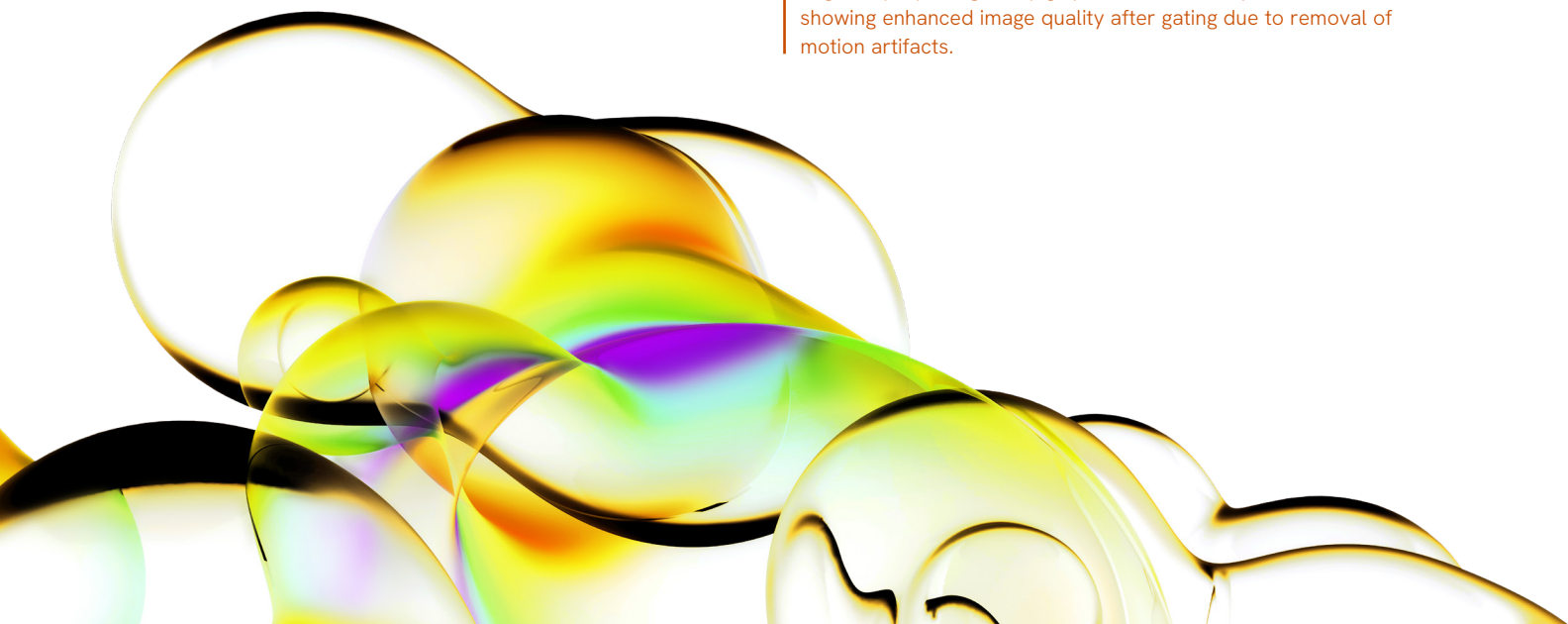


Figure 1: Image-based, retrospective gating of a mouse lung: ungated (left) and gated (right). The red arrows point to the sternum, showing enhanced image quality after gating due to removal of motion artifacts.



Revvity's Quantum GX3 microCT imaging system enables researchers to visualize and measure lung anatomical and functional changes across various species, including mice, rats, and ferrets. However, accurate lung microCT reconstructions often require techniques to reduce motion artifacts due to respiratory motion. The Quantum GX3 system uses image-based, two-phase retrospective respiratory gating to filter out motion artifacts during lung imaging (Figure 1).

This is achieved by drawing a region of interest (ROI) over the diaphragm to obtain a respiratory trace in the raw projections (Figure 2). Following data acquisition, proprietary software algorithms automatically reprocess the data, using only projections captured during peak inspiration and expiration of the respiratory cycle in the final lung reconstruction (Figure 3). This workflow provides optimal data from lung imaging studies where motion artifacts can compromise image quality and quantitative accuracy.

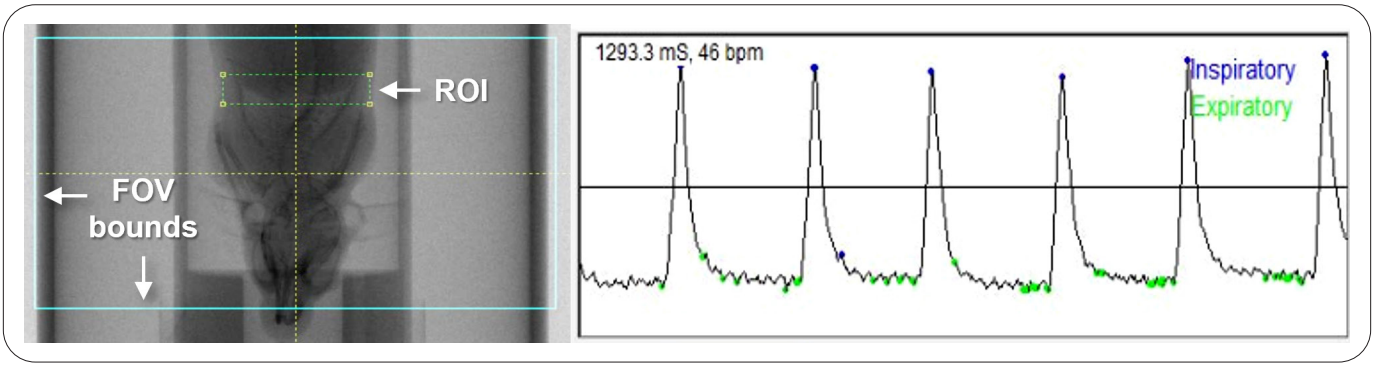


Figure 2: Lung gating ROI placement. A gating ROI (narrow green box) is positioned around the moving diaphragm (left) to obtain a respiratory trace (right) for gated lung scans. The larger teal box indicates the field of view (FOV).

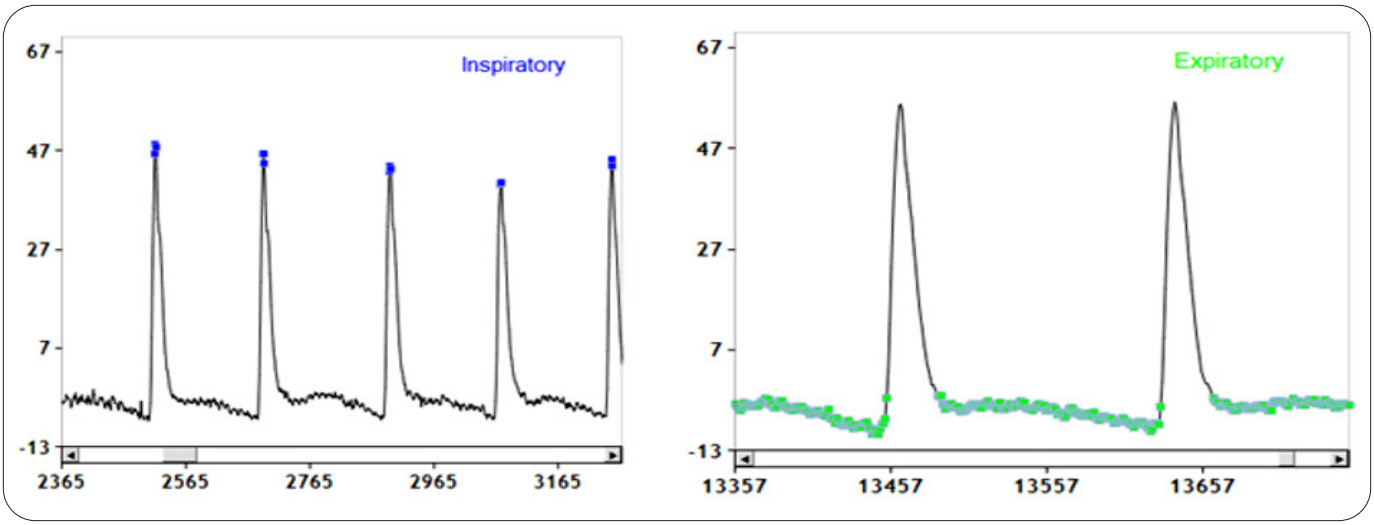


Figure 3: Automatic reconstruction of lung-gated images. Final gated lung reconstructions use projections captured at end inspiration (left) and end expiration (right) phases of the breathing cycle to reduce motion artifacts, which improves image quality and quantitative accuracy.

Animal models and imaging methods

Lung gated scans were performed on a Quantum GX3 microCT scanner using a healthy CD-1 male mouse. Briefly, an anesthetized mouse was placed supine on the mouse imaging bed (Figure 4). The arms were taped up and away from the chest to ensure animal breathing was not perturbed. Further, taping the arms keeps them out of the x-ray path to prevent signal attenuation.

A gating ROI was positioned around the moving diaphragm to obtain a breathing trace. ROI placement was verified at 0° and 90° to ensure the moving diaphragm remained within the ROI and the mouse stayed centered in the FOV during full rotation. Once a stable breathing trace was established, the mouse underwent a gated scan (4 mins, 100 kV [200 µA], FOV 36 mm, 0.5 mm Al filter). Final lung images were automatically reconstructed using projections captured at end inspiration and end expiration phases of the breathing cycle to minimize motion artifacts.

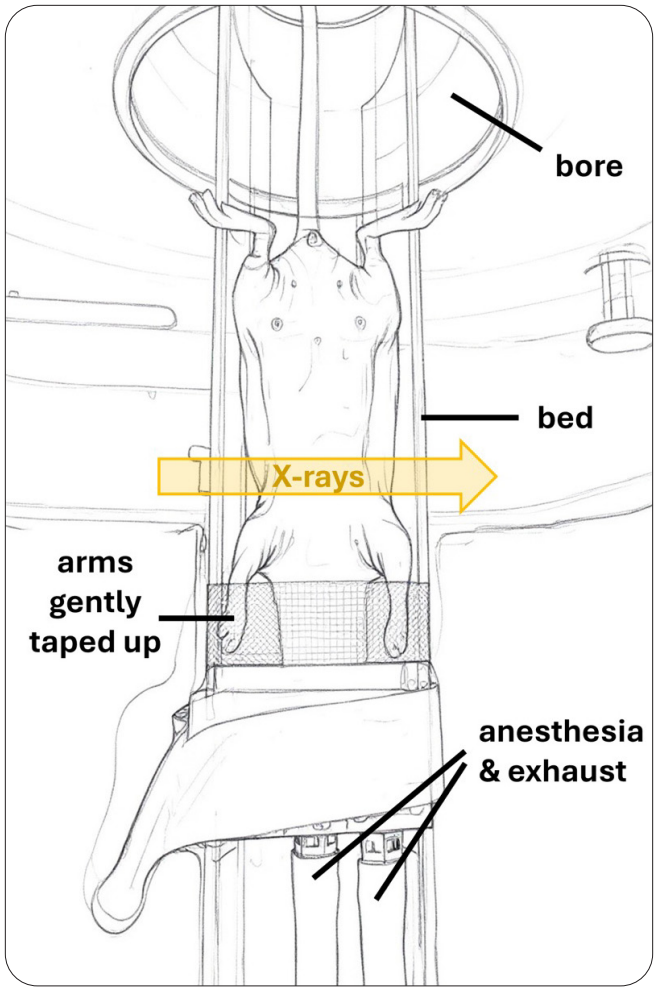


Figure 4: Animal positioning for lung gated scans. Animals should be placed supine on the mouse bed with arms taped up and away from the chest to ensure animal breathing is not perturbed and to ensure arm bones are out of the x-ray path and do not attenuate signal.

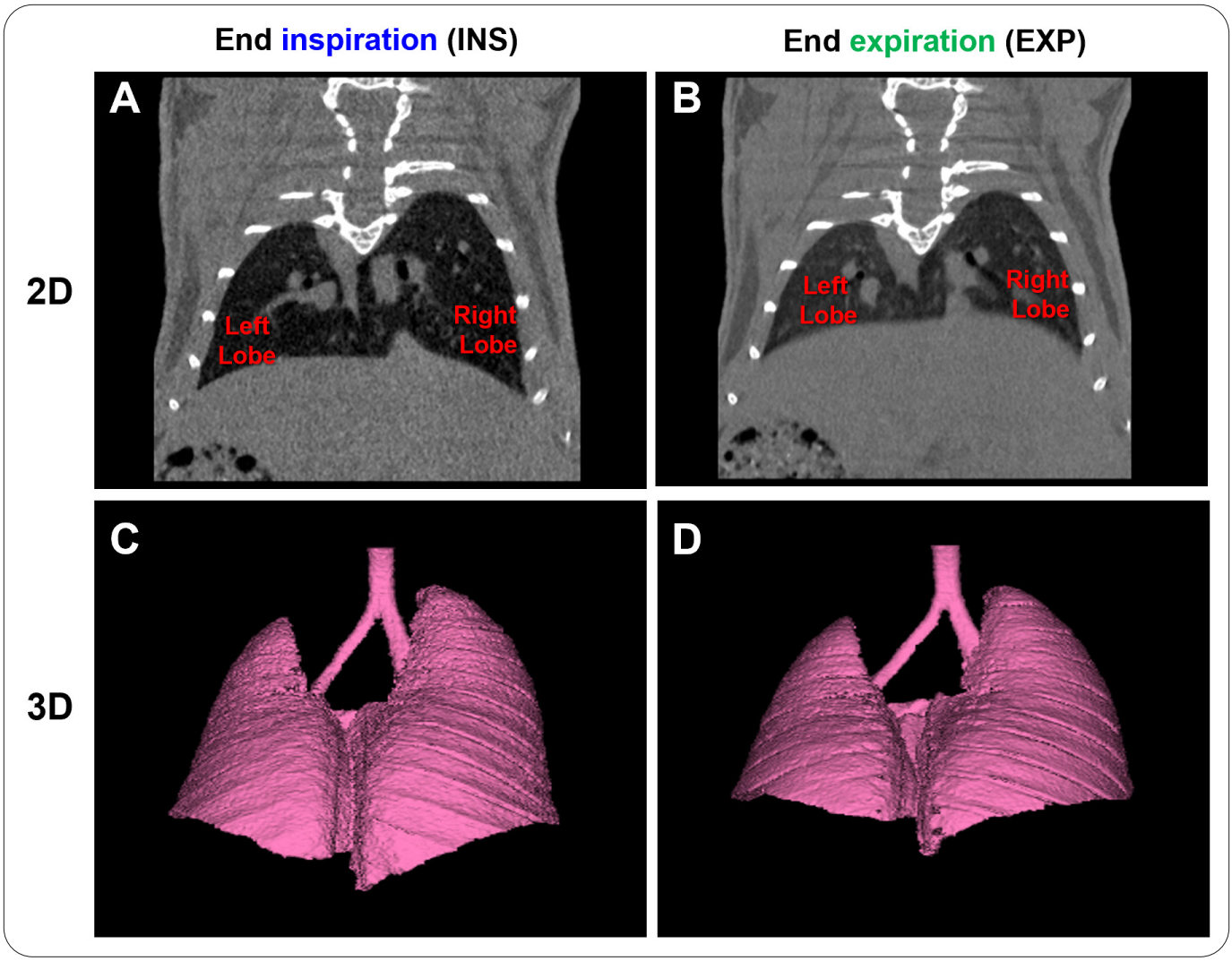


Figure 5: Sample images of mouse lungs shown in 2D coronal (A,B) and 3D volume rendered views (C,D).

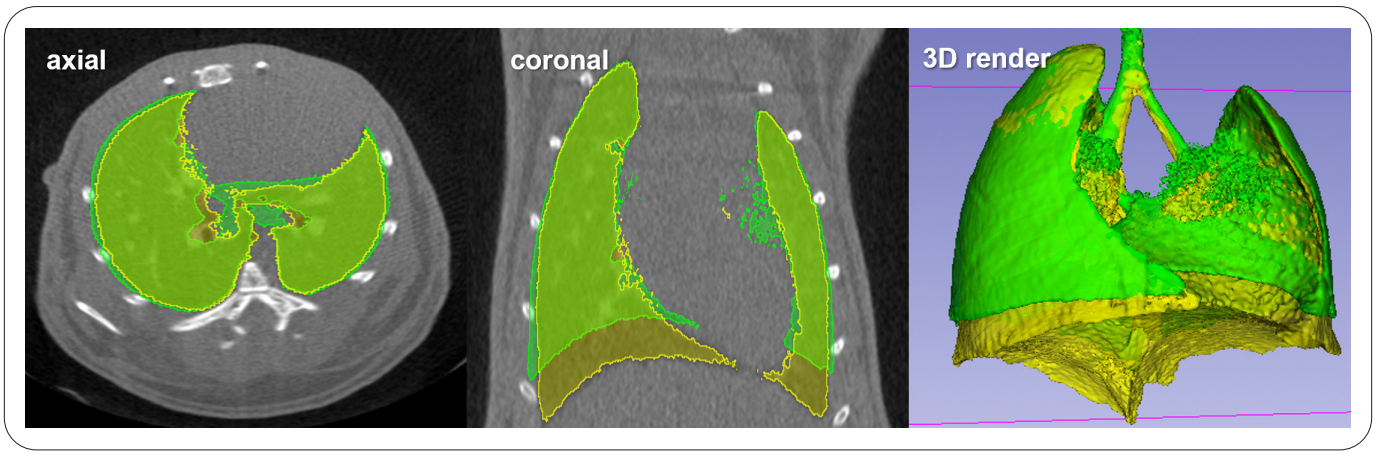


Figure 6: 2D and 3D image overlay of lung inspiration (yellow) and expiration (green) phases.

Quantification of microCT lung data

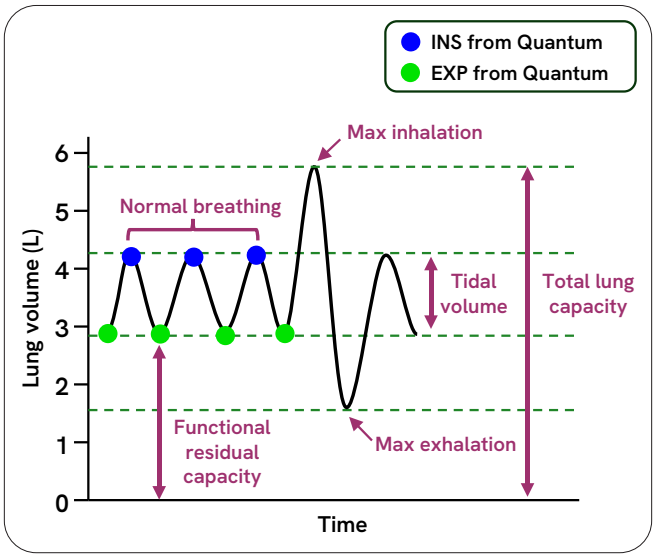


Figure 7: Lung volumes. The y-axis shows volume approximations for humans.

Respiratory-gated microCT imaging enables quantitative evaluation of lung morphology and function at both end-inspiration (INS) and end-expiration (EXP) in healthy and diseased rodents. Commonly assessed parameters include mean lung density (measured in Hounsfield Units, HU), total lung and airway volumes (mL), and airway diameter. In addition, tidal volume, the volume of air inhaled and exhaled during a normal passive breath, and functional residual capacity (FRC), the volume of air remaining in the lungs at the end of passive expiration, can be calculated from three-dimensional INS and EXP microCT datasets (Figure 7).

Importantly, changes in lung volumes can serve as indicators of pulmonary disease progression or regression. In lung cancer, for example, affected lungs typically exhibit both density alterations and volumetric changes compared with healthy lungs, as diseased tissue replaces normal parenchyma. Similarly, conditions such as fibrosis and inflammation lead to measurable changes in lung volume and tissue density. Alterations in FRC are also associated with specific pulmonary disorders. An increase in FRC generally suggests obstructive lung diseases, including emphysema, asthma, chronic bronchitis, and constrictive bronchiolitis. In contrast, a decrease in FRC is commonly observed in restrictive lung diseases such as pulmonary fibrosis and pneumonia, as well as in destructive bronchiolitis.

Summary

MicroCT imaging has become a versatile preclinical tool for non-invasive assessment of health and disease in small animal models. The lung tissue's natural density contrast makes microCT particularly well-suited for pulmonary applications such as COPD, fibrosis, and cancer. Revvity's Quantum GX3 microCT system was evaluated for preclinical lung imaging using a retrospective gating technique that captures projections at end-inspiration and end-expiration to minimize motion artifacts and improve image quality. Retrospective gating on the Quantum GX3 system requires only a 4-minute scan, eliminates the need for external sensors, and automatically reconstructs end-inspiration and end-expiration volumes in approximately one minute. Results confirm that the Quantum GX3 system produces high-resolution 2D and 3D lung reconstructions capable of quantitatively assessing morphologic and functional changes in both healthy and diseased rodent models.