Quantum GX3: a low-dose solution for microCT imaging.

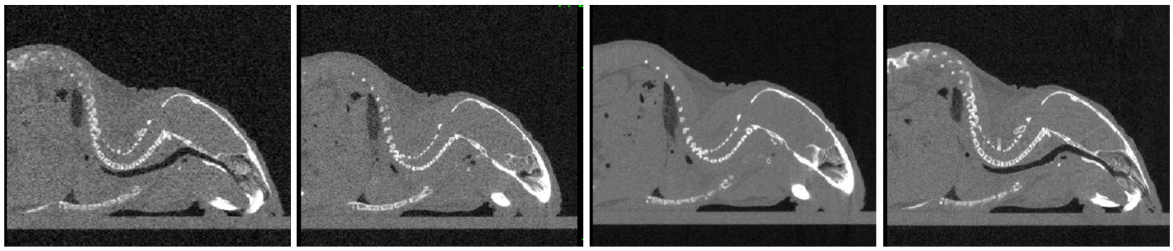
Overview

- MicroCT is a powerful imaging tool providing key insights into disease progression
- However, with repeat imaging, the cumulative radiation dose can begin to induce unintended biological changes
- Radiation dose can be minimized by:
  - Reducing scan times
  - Using larger fields of view
  - Choosing systems like the Quantum™ GX3, with ideal hardware features, such as flat panel detectors with large surface areas

Introduction

Micro-computed tomography (microCT) is a powerful imaging tool for evaluating a range of preclinical disease models and organ systems. Due to their high tissue penetration, X-ray-based imaging systems enable visualization of deep biological structures in both small and large animals. Longitudinal imaging further allows monitoring of the disease state and related biology over time as different treatments are tested.

For *in vivo* imaging, however, one major consideration is the cumulative ionizing radiation dose. At sufficiently high doses, animals may experience immunomodulation or other adverse effects.[1-13] Conversely, reducing scan times to minimize dose can compromise image quality and quantitative accuracy (Figure 1). While cumulative radiation doses used for imaging (< 2 Gy) are generally far lower than those used for therapy (~10-40 Gy), it is still important to keep exposure as low as reasonably achievable ("ALARA") and to understand at what doses radiation begins to induce unintended biological changes. Here, we discuss ways to reduce radiation dose and some of the hardware benefits to the Quantum GX3 microCT instrument.



Scan time:	3.9 s	18 s	2 min	4 min
Dose:	3.6 mGy	13 mGy	79 mGy	166 mGy

Figure 1: The effect of microCT scan time on dose and image quality. Images show sagittal cross-sections of mouse head and upper torso. Scan parameters: 72 mm FOV, 100 kV, 120 µA, Cu-Al filter. Images were obtained on the Quantum GX3 microCT instrument.

Measuring dose from a CT scanner

For live animal imaging, the primary metric of interest is *absorbed* dose—a measure of the X-ray energy absorbed per unit mass of tissue. However, this can be difficult to determine for every tissue type *in vivo*. For practical reasons, most microCT instruments report dose either using Monte Carlo calculations or direct measurements from ionization chambers.[14]

Radiation-induced biological changes

For radiation therapy, the goal is to induce a biological change through the delivery of a high radiation dose. However, for microCT imaging, the objective is to observe the natural biology without introducing radiation-induced changes from the imaging equipment itself. Researchers studying X-ray–induced biological changes in mice rely on a combination of molecular, cellular, and whole-animal readouts that capture both early and late responses to radiation. Reported effects include DNA double-strand breaks, oxidative stress, inflammation, apoptosis, vascular damage, and fibrosis, to name a few (Figure 2).[15] Different animal strains can vary in their response to radiation; therefore, it is essential to understand the intricacies of your model before initiating imaging experiments (Figure 2).

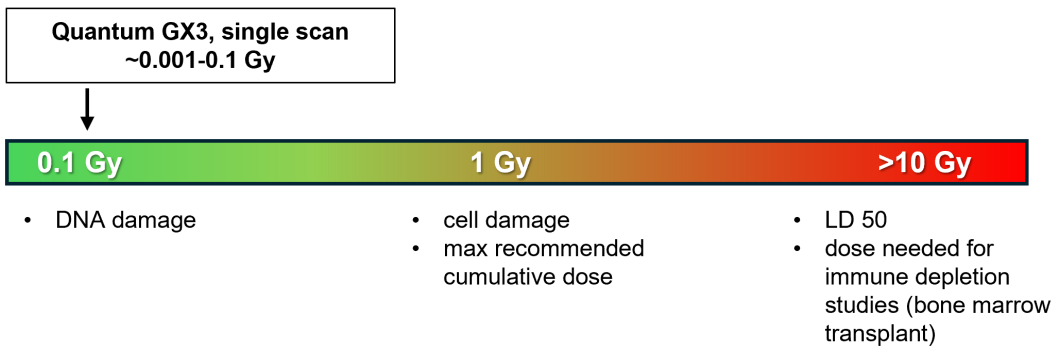


Figure 2: Biological changes based on radiation dose.

Ways to reduce dose

To reduce cumulative radiation dose in live animals, both experimental design parameters and instrument hardware features must be considered. In particular, a flat-panel detector with a large surface area will increase photon capture efficiency by allowing more photons to be captured in a shorter period of time (Figure 3). Compared to smaller chip-based detectors, large flat panels can achieve comparable image results in less time, reducing the overall dose delivered to the animals.

- Adjust experiment parameters:
  - Shorter scan times
  - Fewer imaging timepoints
  - Larger field of view (increase the distance between the animal and the X-ray source)
  - Choose the resolution necessary to detect differences between healthy and diseased states. Lower resolution requires shorter scan times and results in lower radiation dose. Higher resolution provides greater detail but is not always needed to detect relevant biological differences.
- Choose optimal hardware:
  - Large bore size
  - Flat-panel detector with a large surface area to maximize the number of X-ray photons recorded in a given unit of time.

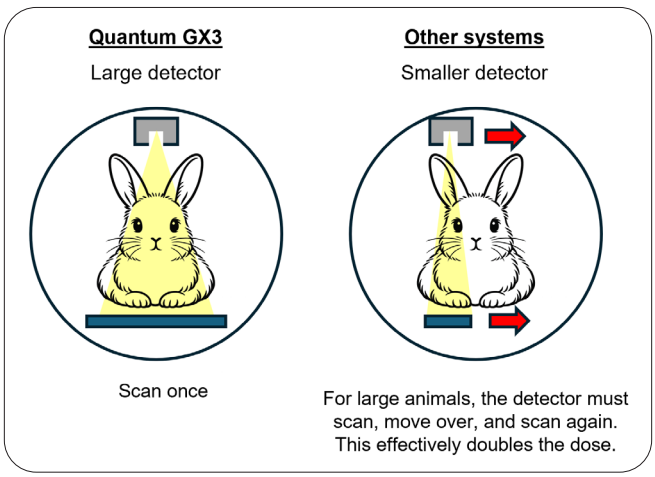


Figure 3: How flat-panel detectors allow for lower dose imaging.

Conclusion

MicroCT is a powerful, non-invasive imaging tool that provides important insights into disease progression, therapeutic efficacy, and underlying biological mechanisms in both healthy and diseased animal models over time. Careful monitoring of cumulative radiation dose in live animals is critical to ensure animal safety and to avoid compromising data through instrument-induced biological changes. When selecting and configuring a new imaging instrument, both imaging parameters and hardware features should be considered to achieve high-quality images while maintaining low radiation doses.

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