Chemistry of Contrast Media

Basic Considerations about Suitable Modalities and Probes

Physical Limits: Sensitivity, Specificity and Quantitation

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Learning Objectives:

- Quantification limitations in µCT and nuclear imaging
- Limiting factors impacting the spatial resolution in small animal imaging
- Factors how the imaging probe specificity can impact quantification

Imaging modalities significantly differ in their ability to display anatomy and to quantify the accumulation of probes. MRI and CT for example, provide an excellent tissue contrast but have low sensitivity for contrast agents. Furthermore, quantification is more complex with MRI compared with CT. Nuclear medicine techniques and optical imaging are highly sensitive to probes but do not provide much anatomical information. In addition, while PET and SPECT data can considerably easy be quantified, quantification of optical data is challenging. Ultrasound displays a good tissue contrast and is sensitive to probes however visualization of deep lesions can be difficult and demand for experienced observers. Furthermore, the reproducibility is lower as compared with other tomographic technologies besides a general overview on the strengths and limitations of imaging technologies. This educational session will focus on data quantification with µCT and nuclear medicine technologies. PET, SPECT: Nuclear imaging methods rely on the detection of radioactive decay emitted by radiolabeled bio logical probes. This approach provides data yielding reproducibility in the range of 95% and detection sensitivity in the pica-molar range. However, as the spatial resolution of PET and SPECT is limited to around 1 mm, the reconstructed image data suffer from partial volume effects (PVE) and restrictions to resolve tiny lesions. The PVE results in an underestimation of the activity concentration in the target volume of interest. This educational talk will review the different effects of PET and SPECT limiting the accurate tracer quantification and image resolution. It will further provide an overview about the importance of specific radiolabeled probes with high specific activity levels. µCT: The voxel intensity of µCT data sets is proportional to the absorption of the voxel with respect to the x-ray wave length, which in turn depends linearly on the elemental composition of the tissue. However, when dealing with µCT systems one should know that many µCT systems are not calibrated and display CT numbers not Houncefield units (HU). Furthermore, background noise levels are much higher in µCT than clinical systems and can reach values of 30 HU and more. This has to be considered when performing dynamic contrast enhanced CT-scans. Injecting contrast agent (CA) doses that are equivalent to those used in clinics may thus not be sufficient to generate a sufficient change in contrast. Blood pools CA allows longer scan times and CA injection can be made outside the CT-system. Taking the change in contrast intensity before and after CA injection in tumor tissue and dividing it by the contrast change in a feeding vessel relative blood volume in tumors can be quantified accurately. If the applied x-ray dose is a critical factor the pre-scan can be discarded when using dual energy scans. Single source CT-scanners allow quantitative decomposition of tissue into two components, e.g. into soft tissue and calcium. When a third component is present (e.g. CA), iodine and calcium-based enhancements may be hard to distinguish. Dual energy µCT systems acquire two data sets at two different wavelengths, potentially allowing quantitative decomposition of three components. This can, for example, be used to distinguish calcified atherosclerotic plaques from iodine enhanced blood vessels.