Single & Multiple Mouse Imaging on a Clinical Scanner using Receiver Coil Arrays

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With the availability of commercial high field small animal MRI scanners, one might ask why anyone would want to use a clinical scanner to image a mouse. A clinical scanner is designed for a human, which is on average 4,000 times larger in volume than a mouse. The larger magnet which limits the field strength, the larger gradient coils which results in weaker and slower magnetic field gradients for spatial encoding, and the larger radiofrequency (rf) coils which results in very low filling factors translate to a large reduction in image quality in terms of SNR and spatial, spectral and temporal resolution when compared to a small animal system. Quite often, the answer is the same as the most famous three words in mountaineering: "*Because it's there*." In institutions where small animal systems are unavailable, it provides a convenient alternative. Numerous publications have reported anatomic[1-12], functional[1,2,6,7,8,10,11] , and spectroscopic[11,12] mouse imaging studies in clinical systems. In some cases, such as for translational research on new contrast agents[8,12,13], or for multiple mice imaging[5,6,7,9], clinical scanners may be the better choice. In this lecture, we will cover the steps necessary to optimize the performance of clinical scanners for mouse imaging.

The rf receiver coil is critical to the sensitivity, which in turn affects the resolution of an MRI scanner. Although it's possible to image mice with clinical coils, the smallest commercially available coils (surface coil, wrist coil, head coil array) are usually not small enough. In order to obtain optimal imaging performance, a coil designed for the mouse must be used. The larger magnet offers more options for coil geometries than a small animal system. A solenoidal volume coil that is optimal for imaging the whole mouse body with a single channel can be used[10]. A saddle shaped coil allows for conventional placement of animals in the scanner at slightly lower sensitivity[3]. A smaller volume coil or surface coil[5-6] can also be used to image small extremities or regions in the mouse. Lower resistance wires made with high temperature superconductor (HTS)[4] or nanotubes[14] can also be used to increase coil Q to improve sensitivity. State-of-the art clinical scanners now support multiple channels (32 and higher) that offer unique possibilities not available in most small animal systems. This can be used to improve imaging sensitivity and speed with the use of a multiple element surface array[9] similar to those used on humans. The multiple receiver channels can also be used to image multiple mice at the same time without loss of sensitivity by placing each mouse on separate rf coils and receiver channels.[3,5,6,7,15,16] Multiple mice imaging with multiple array coil on each mouse is also possible.[9,17] When imaging multiple mice, the animal handling system need to be designed to optimize the time it takes to load the animals[3,5,15,16]. Some mouse receiver coils are available commercially from the manufacturer or third party or they can also be constructed in-house will reasonable effort. In both cases, a research agreement with the manufacturer is typically required.

The gradient coil system is critical to the spatial resolution and scanning speed, and it can also affect sensitivity performance that can be gained from methods like Fast Spin Echo (FSE) and Fast Field Echo (FFE) by increasing the minimum refocusing time and repetition time (TR). Thus, the echo time (TE) and TR are longer when scanning a

mouse compared to a human. The performance of Echo Planar Imaging (EPI) and Spectroscopic Imaging (SI) sequences is also degraded by the limited gradient strength and speed. The obvious solution is to insert a commercially available smaller gradient system for mouse imaging. Unfortunately, this requires significant investment in resources that clinical scanner manufacturers are usually not willing to make. Thus, most sites have to accept these disadvantages and settle with the slightly longer TE and TR. There are practical ways to overcome the larger effect of magnetic field susceptibility. In some areas of the anatomy like the brain, the magnetic field susceptibility is low enough to make SI and EPI-based Diffusion Weighted sequence practical. In other areas, susceptibility matching medium that can be liquid, gel or solid can be used.

An option for translational research that is commercially available is to combine a clinical scanner console with a small animal imaging magnet, gradient and rf coil system. This provides the increase performance of small animal systems with the more advanced software and sequence capabilities of a clinical scanner. Imaging protocols used in animal imaging would more closely match those used for humans and they should translate easily. Technically, however, this is no longer a clinical system but an animal system.

The physiology monitoring (respiration, temperature, cardiac, blood pressure), gas anesthesia, heating and contrast injection systems are similar to those used in small animal systems. Since the respiration rate and cardiac cycle of a mouse are much faster than a human, the built-in physiology monitors in clinical systems do not usually work without additional hardware and/or software. The additional hardware are usually be in the control room with hoses and connections that go into the rf screened magnet room through a waveguide and research penetration panel. Multiple mice imaging requires multiple monitor channels and connections. To minimize set-up and takedown procedure when switching between patient use and animal use, closets on either side of the research panel in the control and magnet room can be built to house them so that they are hidden when not in use.

Before any live mouse can be imaged in a clinical scanner, approval would need to be obtained not only from the institutional ACUC but also the from the appropriate clinical safety committee. A standard operating procedure that includes animal transport, scanner room operations, and clean up to prevent contamination of animals and patient exposure to allergens would facilitate ACUC approval of animal study protocols.

In summary, a clinical scanner has proven to be an effective alternative to dedicated small animal imaging systems in performing animal studies. Its application to single mouse or multiple mice imaging is also benefiting from ongoing improvements in magnet, gradient, coil, transmitter and receiver technology that are being driven by the demand to advance clinical imaging.

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