# Fat-Water Imaging

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Reliable and uniform fat-suppression is essential for accurate diagnoses in many areas of MR imaging. ***The purpose of this talk*** is to provide an overview of water-fat imaging in clinical practice. A review of the relevant physics of chemical shift between water and fat, and how this can be exploited to improve image quality through fat suppression and tissue characterization will be explored. Water-fat imaging exploits the fact that fat resonates 3.5ppm slower than water, or about -210Hz at 1.5T. Specific methods that are discussed will include: chemical selective saturation, STIR, spectral-spatial excitation, and water-fat separation ("Dixon") methods.

Spectrally selective saturation ($90^o$) or inversion ($180^o$) pulses are commonly used with many pulse sequences for reliable and effective suppression of fat-signal. These pulses transmit spectrally selective energy centered on the spectral peak of fat, in order to saturate the longitudinal magnetization of fat. The RF pulse is followed immediately by a crusher gradient, after which the standard imaging sequence is played. Such pulses are highly effective in regions where both the main magnetic field ($B_o$) and the RF field from the coil ($B_1$) are homogeneous. The primary disadvantages of fat-sat pulses is their relatively sensitive to field inhomogeneities that shift the position of the water and fat peaks with respect to the frequency of the fat-sat pulse. This can result in failed fat suppression, and even cause inadvertent suppression of water signal.

Effective fat-suppression can also be achieved by exploiting $T_1$ differences between fat and soft tissues containing water. Short tau inversion recovery or "STIR" pulses play a broad spectrum inversion pulse that inverts all magnetization (water and fat). Fat has a shorter $T_1$ than most soft tissues and if an image is acquired as the longitudinal magnetization of fat is crossing through zero ("zero-crossing"), the signal from fat will be nulled in the resulting image. The zero-crossing typically occurs at approximately 200ms (it will depend on the $T_1$ of fat). STIR is a highly reliable method of fat-suppression, and although it is sensitive to RF ($B_1$) inhomogeneities, it is very insensitive to field inhomogeneities, which are the most problematic. STIR can be used a wide variety of challenging applications such as foot/ankle, spine, neck, brachial plexus, orbits, and wrist, etc. An inherent disadvantage of STIR imaging is its inability to perform T1W imaging, particularly after IV contrast, so that STIR is limited to proton density or T2W imaging. In addition the SNR performance is relatively poor and the relatively long inversion time impairs speed performance and sequence efficiency.

A more advanced approach is to exploit differences in resonant frequency between water and fat by direct excitation of the water peak, rather than suppression of the fat peak. Spectral-spatial pulses are a very effective means of exciting water and are most commonly used with spiral imaging and echo planar imaging (EPI), although it can be combined with other sequences such as spoiled gradient echo and fast spin-echo imaging. Although spectral-spatial pulses are relatively insensitive to RF inhomogeneities, they remain sensitive to field inhomogeneities, similar to conventional fat-sat pulses. Complex and lengthy pulses are also a limitation, and for this reason are most commonly used with long TR sequences (eg. spiral, EPI).

Chemical shift based water-fat separation methods ("Dixon") acquire 2-3 images at slightly different echo times in order to generate phase shifts between water and fat that are used to separate the two species. In addition, these methods can measure the local field inhomogeneity ($B_o$) whose effects can be removed rendering this method insensitive to field inhomogeneities. All chemical shift based methods are also insensitive to B1 inhomogeneities and have the advantage of producing a fat-only image in addition to a water-only image. Although these methods are highly SNR efficient, the scan time is typically lengthened 2-3 fold, which is the primary disadvantage. Complex reconstruction software is also a limitation of this approach.