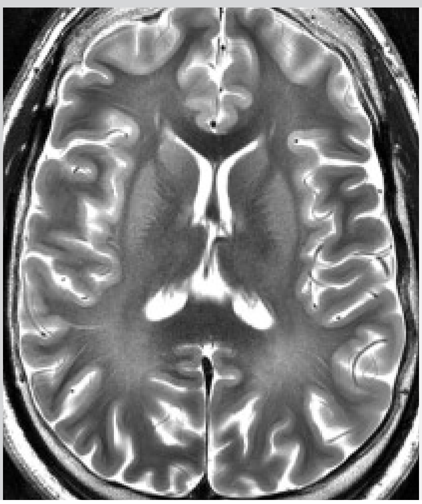
MRI Hot Topics



3T Unlimited
Leadership in Clinical Applications

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Leadership in Clinical Applications

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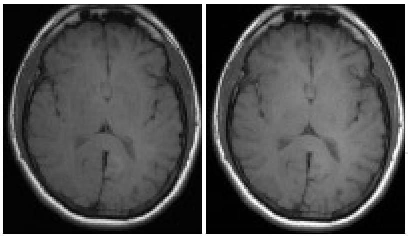

Figure 1: *Using a shorter echo time (TE) at 3T can significantly improve the gray/white matter contrast. This improved contrast is shown when comparing clinical images at (a) spin echo at TE 18 msec and (b) a similar spin echo acquisition at TE 9.4 msec.*

A 3 Tesla (3T) magnetic resonance system is the logical next step in a continuum of high quality MR imaging tools. The relative strengths as one goes from 0.2 Tesla through 1 Tesla to the standard 1.5 Tesla are well known. However, as the field strength increases to 3T, this continual improvement, with twice the Signal-to-Noise Ratio (SNR) of 1.5T and 15 times that of 0.2T along with better spectral separation for spectroscopy, can only be realized by the leader in both hardware and software MR technology. While in theory the advantages of higher field strength are well established, their practical implementation at 3T requires superior innovation in MR applications to realize this potential. A strong link between technical development and advanced applications are essential for making 3T systems a clinical imaging success. While hardware technology provides the framework for next generation systems, software innovation is necessary to bind this technology together, producing next-generation applications. Technological leadership in magnet design is necessary to realize the potential of 3T in clinical applications that demand improved image quality through both increased resolution and superior image uniformity. Technological leadership in gradient design is necessary to realize the potential of 3T in clinical applications designed to increase exam speed and patient throughput. Technological leadership in radio frequency (RF) subsystems is necessary to realize the potential of 3T in software applications such as integrated Parallel Acquisition Techniques "iPAT", increasing both speed and quality while staying within FDA-approved operating guidelines for the specific absorption rate (SAR).

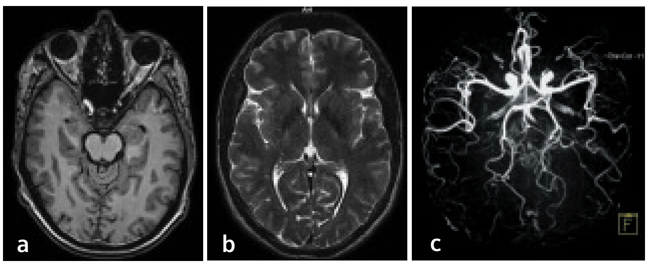

Figure 2: *Clinical neuroimaging on a 3T MAGNETOM Trio is performed routinely, with consistently superior results. The image quality you can achieve from patient to patient across a breadth of protocols is shown in (a) a T1 weighted axial MPRAGE image at 1 mm slice thickness, (b) a T2 weighted spin echo image with high in-plane resolution and a low slice thickness, and (c) a high resolution time of flight MRA showing improved visualization of distal vessels.*

3 Tesla Means Better Image Quality: *syngo* User Flexibility and Improved Magnet Design

While 3T field strength promises improved SNR, which can be translated into higher quality imaging, this can be compromised if the application is inappropriately designed; protocol parameters, field of view limitations, and magnet homogeneity are all issues to consider. Using the inherent flexibility of the *syngo* user interface, protocol parameters can be optimized to compensate for the longer tissue relaxation times that occur at 3T (Figure 1). While accounting for the longer relaxation times, Figure 2 shows that optimized techniques can be implemented for all standard neurological protocols yielding the expected benefits of 3T, namely higher SNR, better Time of Flight effects, better contrast, etc. A whole-body system with a full 40 cm field of view also allows for the entire range of clinical applications. This capability is important for standard sagittal spine imaging, and is necessary to achieve full field of view coronal body imaging for the newest applications, such as MR colonography. Another important design criterion is to maintain the highest possible magnet homogeneity. This is essential in applications that require fat suppression, such as 2D gradient echo breath-hold imaging of the abdomen, as well as spectroscopy. The superior homogeneity of the MAGNETOM Trio can achieve excellent fat suppression over a large field of view for abdominal studies as shown in Figure 3. Figure 4 shows how this same excellent uniformity can be used in short TE spectroscopy where spectral resolution is improved due to the larger spectral dispersion at 3T.

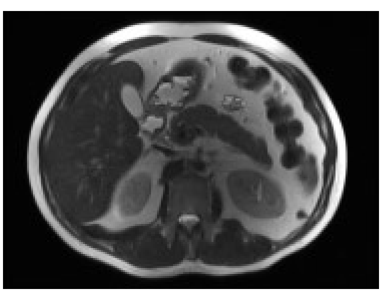

Figure 3: *Clinical abdominal imaging on a 3T MAGNETOM Trio is performed using protocols similar to standard 1.5 Tesla body breath-hold techniques. The fat suppressed image quality you can achieve using advanced shimming methods is shown in this breath-hold t1 weighted example.*

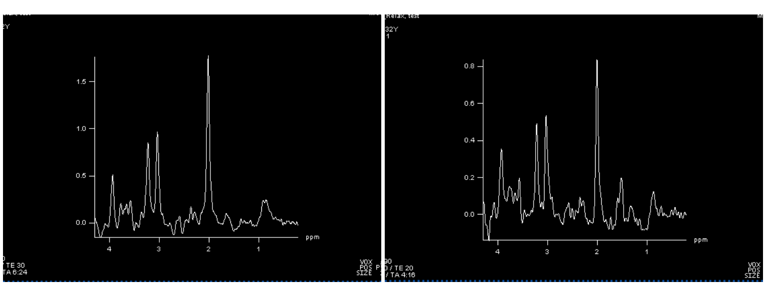

Figure 4: *The SNR and spectral definition are improved at 3 Tesla as shown in this STEAM single voxel spectroscopy (SVS) study in the brain with TE = 30 msec (a). However, at 3T it is important to keep TE minimized to maintain optimal quality as shown in (b), a PRESS spectrum acquired at a TE of 20 msec.*

Figure 5: *At 3T it is possible to obtain high-resolution proton density (PD) weighted knee images. This 512x512 image obtained at a 2 mm slice thickness shows the achievable high SNR for high-resolution applications.*

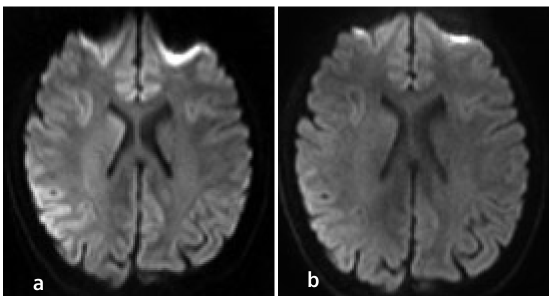

Figure 6: *Susceptibility is a well-known challenge at 3T; this is particularly evident around the sinuses due to the air-tissue interface (a). However, by decreasing the echo time with integrated parallel acquisition techniques iPAT (b) a portion of the signal can be recovered and the distortion can be significantly reduced.*

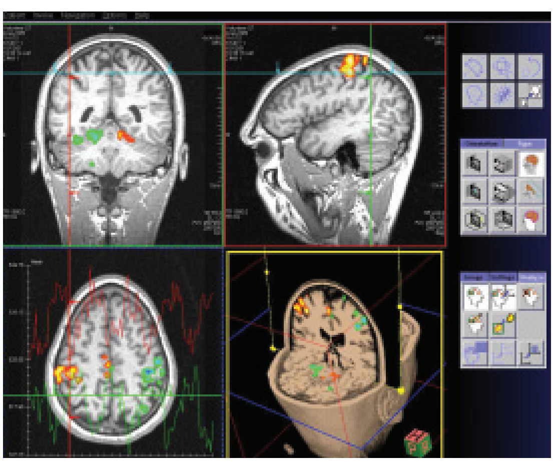

Figure 7: *fMRI has a clear advantage at 3 Tesla due to increased BOLD effects at higher field strengths. With this additional SNR, it is easy to visualize brain functional areas using Siemens integrated post processing software.*

Figure 8: *Body imaging has always been a challenge with respect to SAR limitations, and this is particularly true of the Turbo Spin Echo (TSE) sequence with its long train of refocusing pulses. However, with iPAT, the number of refocusing pulses is significantly reduced, making it possible to produce high-resolution HASTE images using iPAT at 3T. This technology, coupled with hyperechoes, means that 3T is a fully functional clinical system with no limitations. Therefore, all body applications are possible and full liver studies are achievable on a MAGNETOM Trio.*

3 Tesla Means Faster Imaging: High Performance Gradients and Parallel Acquisition Techniques

A common justification for 3T imaging is that the inherent increase in SNR can be used to obtain faster individual exams or increased patient throughput. However, this can only be accomplished if the gradient hardware and applications software technology has been developed to allow such advanced functionality. It is well known that susceptibility artifacts are much more pronounced at 3T, and state-of-the-art gradient performance (which allows faster rise times and higher overall gradient strength) is required to minimize susceptibility artifacts. Faster rise times are used to reduce echo times and shorten echo spacing to decrease the dephasing associated with susceptibility induced field variations. Higher gradient strengths allow thinner slices that not only minimize susceptibility artifacts but also improve diagnostic capability due to the higher resolution this affords. Figure 5 shows what is possible at 3T with thinner slices and high resolution for clinically demanding orthopedic applications. Reduced echo times play a significant role in reducing susceptibility artifacts as shown in Figure 6. In echo planar applications, there are other methods that can be used to reduce susceptibility artifacts even further. These include using an extremely high bandwidth for reduced echo spacing and shorter echo times as well as iPAT. As a result, the quality of fMRI results is improved as shown in Figure 7. High gradient strength coupled with iPAT parallel imaging allows the superior speed of the gradients to be used for shorter breath-hold exams, such as a coronal HASTE scan (Figure 8).

3T Care: Innovations in RF Coils and Novel Acquisition Strategies

Using 3T can result in better overall imaging but this will be compromised if the FDA guidelines for Specific Absorption Rate (SAR) do not allow full flexibility in parameter selection. Here too, technological hardware solutions, as well as optimized or novel acquisition strategies have emerged to allow imaging at higher fields. Hardware advances include modified RF coil designs based on advanced simulation models. Innovations in software strategies, such as variable flip angle turbo-spin echo sequences, parallel imaging techniques, and more sophisticated pulse sequences such as Hyperechoes, have been developed to significantly reduce the amount of RF required. SAR limitations typically occur with high turbo-factor techniques, in rapid cardiac applications, or in breath-hold applications. However, high-resolution brain and thin slice high-resolution spine imaging are also areas where SAR is known to influence parameter selection. Figure 9 shows an example of TSE T2 Hyperecho imaging with significantly reduced SAR (60% savings over standard TSE). Figure 10 shows how the use of optimized RF coil designs, as well as iPAT has facilitated high quality spine applications. Finally, even for cardiac MR, the SNR advantage of 3T can be exploited without SAR concerns (Figure 11).

Figure 9: *With Hyperecho sequence strategies, it is possible to reduce the SAR to approximately 40% of equivalent TSE techniques. This SAR reduction strategy can produce strong T2 weighting, as well as high resolution in clinical neurological imaging.*

Figure 10: *Sagittal T2 weighted TSE spine imaging is one application where iPAT plays a role. One can use the additional time savings to either increase the resolution of a standard protocol or to decrease the overall exam time. In (a), TR of 5500, TE 142, FOV 300x300 mm, 512 Matrix, and 4 mm slice thickness were used to obtain the original scan at an imaging time of 3min28s. In (b), it was possible to reduce the scan time to 1min17s by using iPAT x3 while preserving the resolution.*

Conclusion

3T magnetic resonance imaging is no longer just a research tool for universities; 3T MRI is an advanced clinical diagnostic tool. The advantages based on higher SNR made possible by higher field strength are obvious: improved resolution and greater speed. In addition however, as overall MR technology evolves, even more sophisticated clinical applications are being developed that can take advantage of 3T physical principles. With the combination of hardware technology, such as new coils and gradient systems, and software, such as new sequences and processing techniques, many of the previous challenges of implementing clinically superior applications are overcome. Today, 3T not only improves most clinical applications, but also unlocks the potential for new applications not possible on lower field systems.

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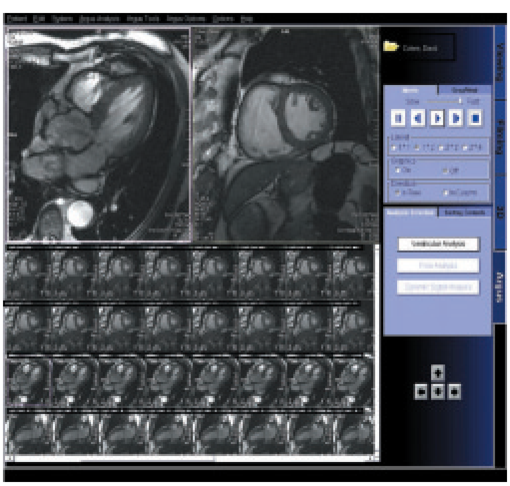

Figure 11: *Using a trueFISP sequence at 3T, one can obtain high SNR images for use with the integrated Cardiac analysis package Argus, which performs functional cardiac analyses based on image information. The SNR increase will provide more accurate results and higher resolutions allow you to more precisely measure quantities such as ejection fraction or wall thickness.*

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