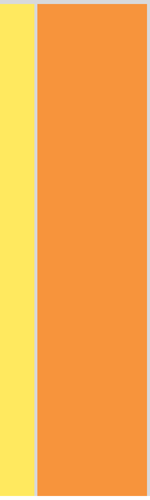
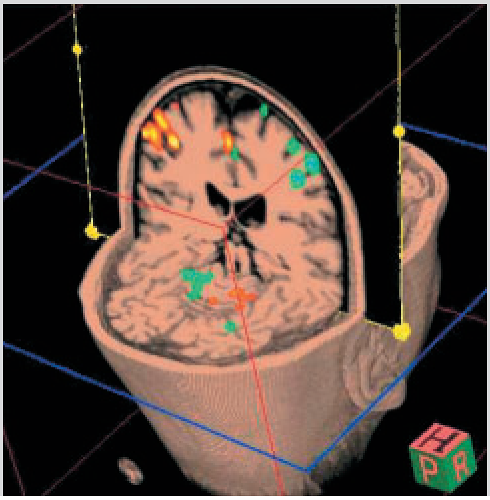
MRI Hot Topics





Motion under Control
with Prospective Acquisition Correction (PACE)

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Motion under Control
with Prospective Acquisition Correction (PACE)

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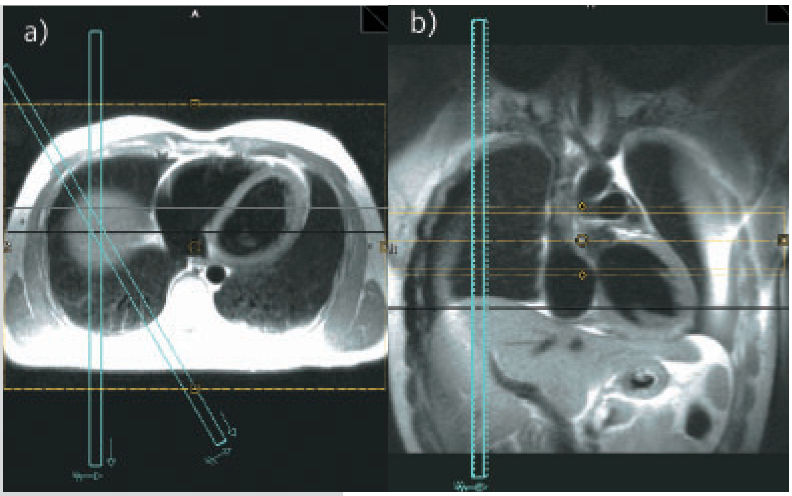


Figure 1:
Positioning of the pencil-shaped volume across the diaphragm for 1D-PACE in an axial (a) and coronal (b) plane. The cross-section of the pencil-shaped volume is defined by the intersection of the two turquoise boxes in the axial plane. The length of the pencil-shaped volume is depicted in the coronal plane (turquoise box).

In a variety of MRI applications, motion can adversely affect image quality. Since patient motion cannot be controlled sufficiently in all cases, Siemens has developed strategies to maintain image quality despite motion. Correction of motion effects at the post-processing stage would be one approach. However, there is nothing better than acquiring good data in the first place, and strategies to account for motion during acquisition are currently offered on Siemens MR scanners. These "Inline" techniques for coping with motion are collectively termed PACE (Prospective Acquisition Correction). Corresponding to the spatial dimensions of the dataset used for calculating the adjustment, these techniques are termed 1D-PACE, 2D-PACE, and 3D-PACE. The first two are used mainly to deal with breathing motion, while the third one is applied for motion adjustment in neurological studies.

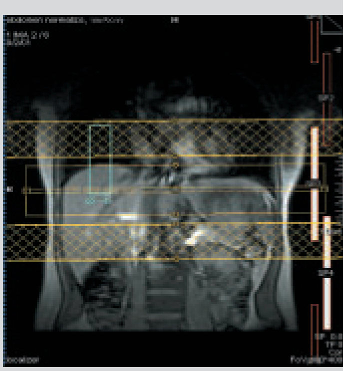


Figure 2:
Selection of the 2D area (turquoise box) used for detection of the diaphragm position when using 2D-PACE. Half the box should cover the lungs, the other half the liver.

1D-PACE and 2D-PACE

Method

The fastest method of detecting motion is 1D-PACE (also known as a "navigator" technique). It typically requires only 30 ms and is used primarily for minimizing the effects of breathing motion in cardiac exams. For this purpose, a single line of data from a pencil-shaped volume that crosses the diaphragm is acquired. The volume is interactively placed (Fig. 1) in such a way that the position of the diaphragm can be calculated and used for motion correction – in real time.

In 2D-PACE, an image is acquired by means of a low-resolution gradient echo sequence featuring a low flip angle; this ensures that magnetization is not saturated, so that dark lines in the image are avoided. The user places a small box across the diaphragm on the 2D-image (Fig. 2). The change in signal intensity along the axis of the box is used to determine the position of the diaphragm. Since a 2D image provides more information than a single line, this method is very robust. The time needed to acquire an image for 2D-PACE is around 100 ms. The highly reliable 2D-PACE technique is unique to Siemens.

The advantages afforded by 1D- and 2D-PACE can be used in a variety of ways.

Application: Multiple Breath-hold Examinations

For patients who can hold their breath for only a short time, the acquisition can be split up into multiple breath-holds. The information about the diaphragm position allows the operator to monitor the breathing pattern of the patient online. Furthermore, acquisition of slices during different breath-holds can be aligned in order to compensate for imperfect reproducibility of the breathhold position.
In this way, gaps between slices or overlaps are avoided.

Without PACE, the operator would have to visually inspect the image-stacks and determine if there are gaps or overlaps between them – a tedious process that is highly operator-dependent. During this time the patient would have to remain in the scanner, since it might be necessary to cover gaps with additional scans. Therefore, a lack of PACE capabilities would cause unnecessary and costly prolongation of the total exam-time, which in turn would lead to decreased patient compliance and comfort.

Application: Breathe Freely with PACE

For some patients, even the shortest breath-hold duration might be too demanding; or, patients may be unable to follow breathing commands due to impairments in mental status. In such cases, PACE allows for imaging while the patient is breathing freely. During a short "learning phase", the breathing of the patient is analyzed and the central position of an "acceptance window" is calculated automatically. Next, the gated acquisition begins: slices are acquired only when the diaphragm position falls within the acceptance window. Here, the slice positions of different scans can also be aligned based on information about the position of the diaphragm. Without PACE, it would be extremely difficult (or even impossible) to perform useful MR studies in patients who cannot hold their breath.

1D-PACE or 2D-PACE

Whether 1D-PACE or 2D-PACE should be used depends on the application. Cardiac exams benefit from the speed of 1D-PACE. In order to obtain cine-images with high frame rates, motion detection should be as fast as possible. Also, saturation in the pencil-shaped volume is not a problem, since it can be placed outside the heart. Fig. 3 shows images of coronary arteries acquired in this way. For abdominal imaging, 2D-PACE is the best choice, since the scan time extension is not significant. On multi-breathhold exams, for example, breath-hold times are extended only by a tenth of a second as a result of using 2D-PACE.

3D-PACE

Functional MR imaging (fMRI) is another application where motion detection, and instantaneous adjustment of the acquisition according to this information, are crucial. Here, complete multi-slice EPI datasets of the head are acquired in rapid succession during presentation of various stimuli. In order for the statistical analysis to be successful, the datasets need to be aligned perfectly. For this purpose, each 3D dataset is compared with the previous one and the translation as well as the rotation of the head are calculated (and displayed) in real-time. The software is able to compensate for rotations and translations in all 6 degrees of freedom (a feat that is unmatched in the MR industry). The technique can therefore account, in real time, for any so-called "rigid-body motion". For acquisition of the next dataset, slice position and orientation are adjusted according to the altered position of the head.

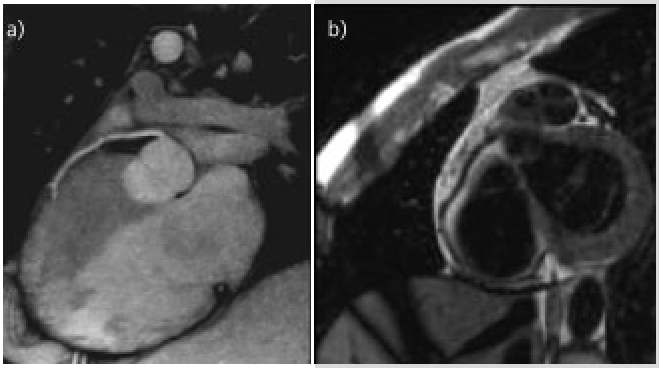


Figure 3:
Images of coronary arteries acquired using 1D-PACE. In (a) the left coronary artery is visible brightly due to the bright-blood contrast inherent to the TrueFISP sequence. In (b) the right coronary artery is displayed as a dark line, since the black-blood contrast preparation of the TSE sequence makes the blood signal disappear.

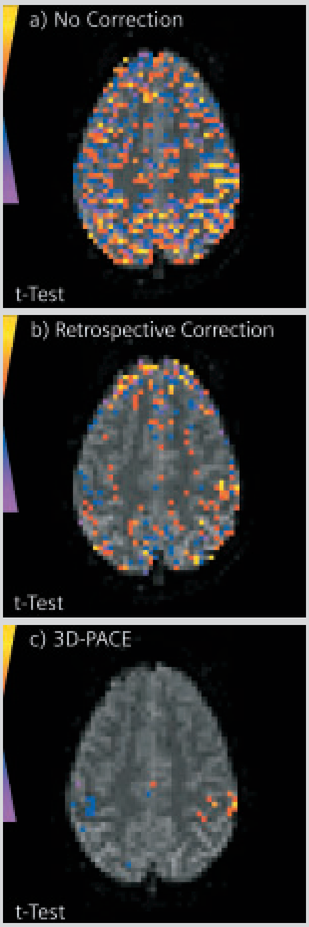


Figure 4:
Activation maps of an fMRI study, during which the volunteer performs nodding head motions of 1.5 degrees in correlation with a stimulus. Data were acquired without motion correction at all (a), with retrospective motion correction only (b), and with 3D-PACE (c). The virtual elimination of pixels falsely showing activation is clearly seen in the 3D-PACE image. Only the real differences between regional activations are shown in (c).

For 3D-PACE, no additional data acquisition is needed since the detection of motion is done on the actual imaging data, which is typically reacquired every 2-4 seconds. To account for potential motion effects even within this short period of time, a further retrospective correction is applied (in realtime) to the data. The interval between acquisitions can be as low as 100 ms for the hardware to be able to adjust to the movement. 3D-PACE is a feature unique to Siemens scanners. Its usefulness can be seen in Fig. 4: without motion correction at all, or with retrospective correction only, the fMRI activation maps are much less meaningful (statistically significant differences are "lost" in the motion-induced "noise"). Without 3D-PACE, fMRI studies such as the one shown in Fig. 5 would be much noisier and may even turn out to be entirely useless due to motion artifacts.

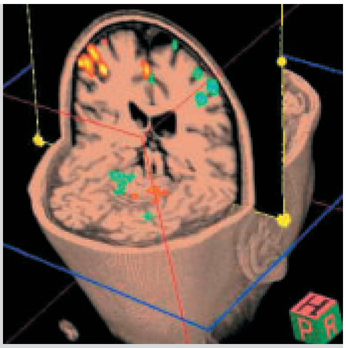
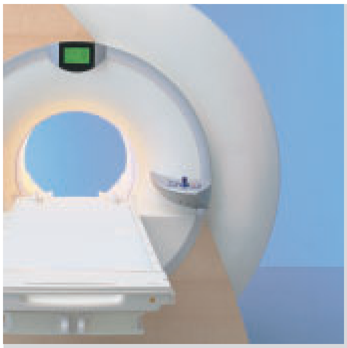


Figure 5:
Activation of right and left primary motor cortex as detected by fMRI on a 1.5 T Sonata system. The paradigm was alternating (30s/30s) left- and right-handed finger tapping. For the functional study, which took 4.0 min to acquire, 3D-PACE real time motion correction was employed. An anatomical dataset was pre-acquired in 6.3 min. The use of 3D-PACE improves fMRI results by ensuring more robust activation detection and better suppression of motion artifacts. This software for displaying combined anatomical and functional data is a "work-in-progress" package under syngo MR 2002B.

Conclusion

The essential feature of Siemens' PACE technology is the prospective adjustment of an acquisition's scan parameters in order to minimize motion artifacts. With the help of 1D- and 2D-PACE, breathing motion can be monitored and corrected, and the variability of breath-hold positions in multiple breath-hold exams can be eliminated. 1D-PACE takes very little extra time, making it ideal for cardiac MR exams. 2D-PACE features small flip-angles, leaving the magnetization in the volume of interest practically undisturbed. It is also a very robust technique, making free-breathing abdominal MR imaging a clinical reality. 3D-PACE is capable of detecting, and correcting for, linear and rotational motion in 6 degrees of freedom and in real-time – a feature found only on Siemens MR scanners. The advanced real-time feedback capabilities of Siemens MR systems are fully exploited in the three versions of PACE to provide a more comfortable exam for patients and to produce sharper, more meaningful diagnostic images.



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References

[1] Ehman RL, Felmlee JP, Adaptive technique for high-definition MR imaging of moving structures, Radiology 1989 Oct; 173(1):255-63

[2] Thesen S, Heid O, Mueller E, Schad LR, Prospective acquisition correction for head motion with image-based tracking for real-time fMRI, Magn Reson Med 2000 Sep; 44(3):457-65

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