Improved Echo Planar Diffusion-Weighted imaging of the Head and Neck using *syngo* ZOOMit

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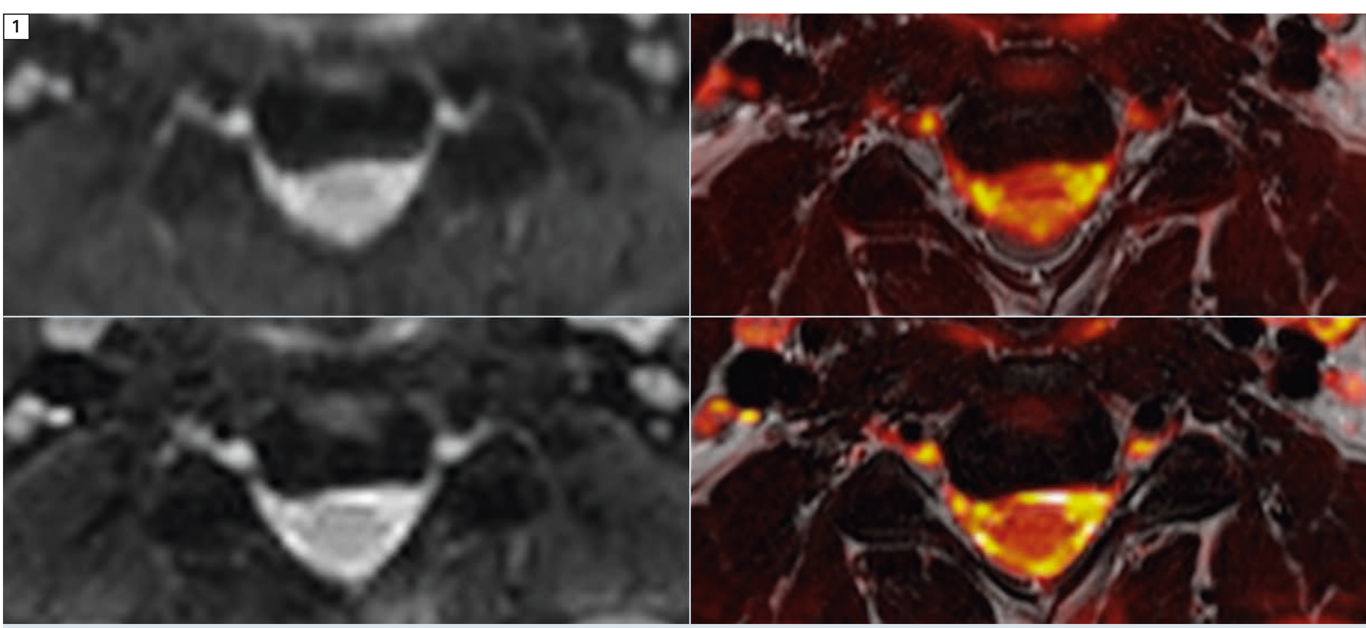
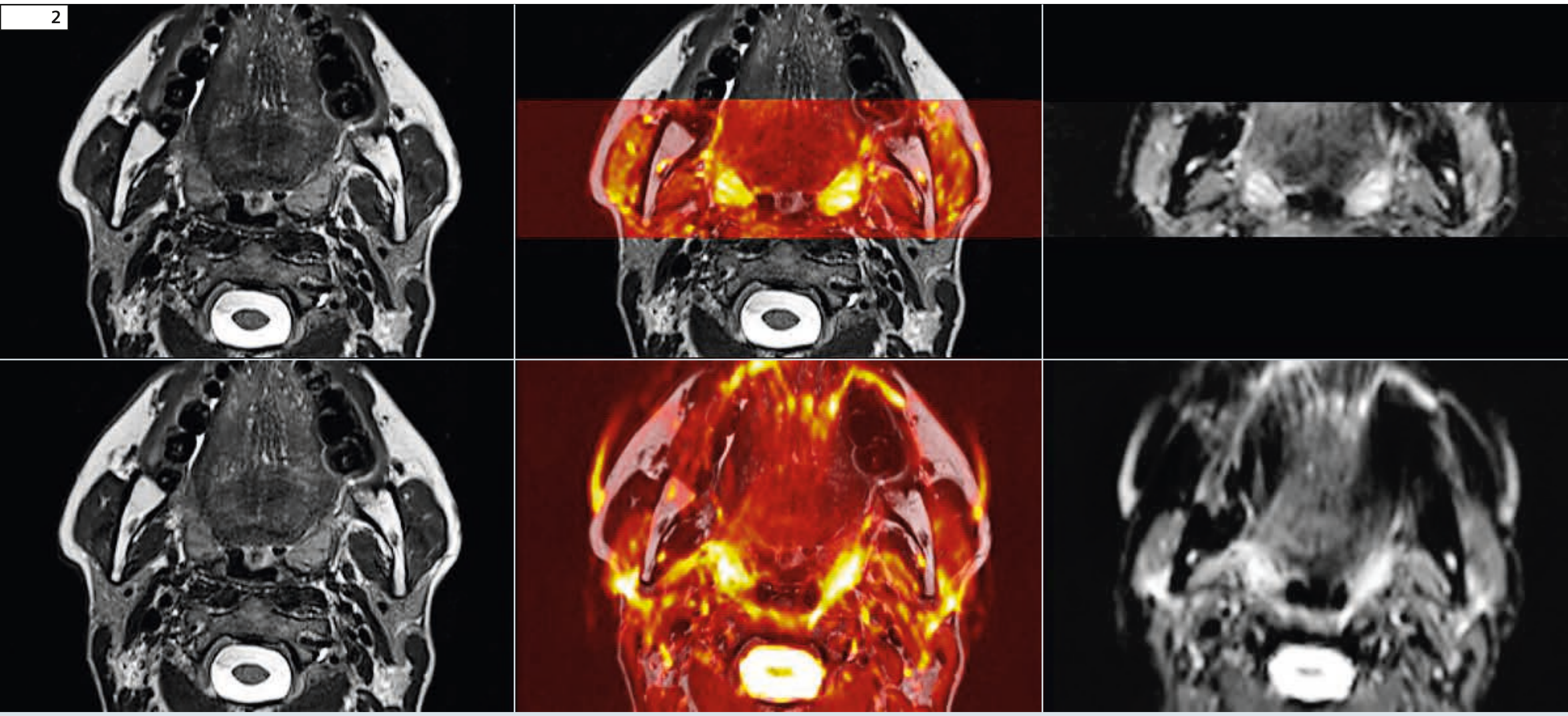
DWI as a cancer biomarker

Echo-planar imaging (EPI) is a single-shot MR imaging (MRI) technique based on the rapid acquisition of a train of sign-alternating gradient echoes [1]. EPI sequences offer high signal-to-noise ratio (SNR) and imaging speed (volume coverage) which render them attractive for functional neuroimaging and diffusion-weighted magnetic resonance imaging (DWI). Imaging biomarkers are important tools for the detection and characterization of cancers as well as for monitoring the response to therapy. DWI is rapidly gaining popularity for the assessment of oncologic and non-oncologic pathologies. DWI depends on the microscopic motion of water. This motion, called Brownian motion, is due to thermal agitation and is highly influenced by the cellular environment of water. Thus, findings on DWI could be an early harbinger of biologic abnormality [2]. Once a technique primarily used in neuroradiology, diffusion-weighted MRI is already being incorporated into general oncologic imaging practice because of its many clinical advantages. Recently, Padhani and Koh have alluded to the promising future of DWI as a cancer biomarker in tumor staging with an improved tissue characterization (differentiating benign from malignant lesions), in monitoring response to chemotherapeutic agents, and in differentiating post-therapeutic changes from residual active tumor [2].



1 Fused images of T2 TSE with corresponding conventional diffusion-weighted (top row) and zoomed diffusion-weighted images (bottom row). The conventional images show a significant displacement between the diffusion-weighted images and the corresponding morphology. The zoomed diffusion-weighted images enable exact correlation between DW images and anatomy.

2



2 Zoomed diffusion-weighted images (top row) show a better correlation with T2 TSE compared to conventional diffusion-weighted images (bottom row). The improved image quality is especially obvious in areas prone to artifacts such as the tongue and hard palate.

EPI-DWI in the head and neck

DWI is potentially useful in the evaluation of head and neck lesions [3, 4] and ADC measurements have suggested that this imaging method may be useful for their characterization [4]. Although results of initial studies were both challenging and promising, one drawback was the technical difficulty in assessing diffusion by echo-planar DW imaging. Applications of EPI may be affected by inherent problems, such as ghosting artifacts, as well as by geometric distortions and signal losses caused by chemical shift and susceptibility differences. These effects degrade the achievable image quality and limit the spatial resolution. This is especially valid for the head and neck area. Due to the presence of dental work, as well as adjacent air and bone, it may be difficult to obtain precise ADC measurements in lesions located in these regions. Therefore in the majority of studies only lesions larger than 1 cm were evaluated. Currently the determination of accurate ADC values in smaller tumors and lymph nodes seems to be unreliable [3-5]. Therefore, DWI techniques that are less sensitive to susceptibility artifacts are mandatory for the evaluation of head and neck lesions.

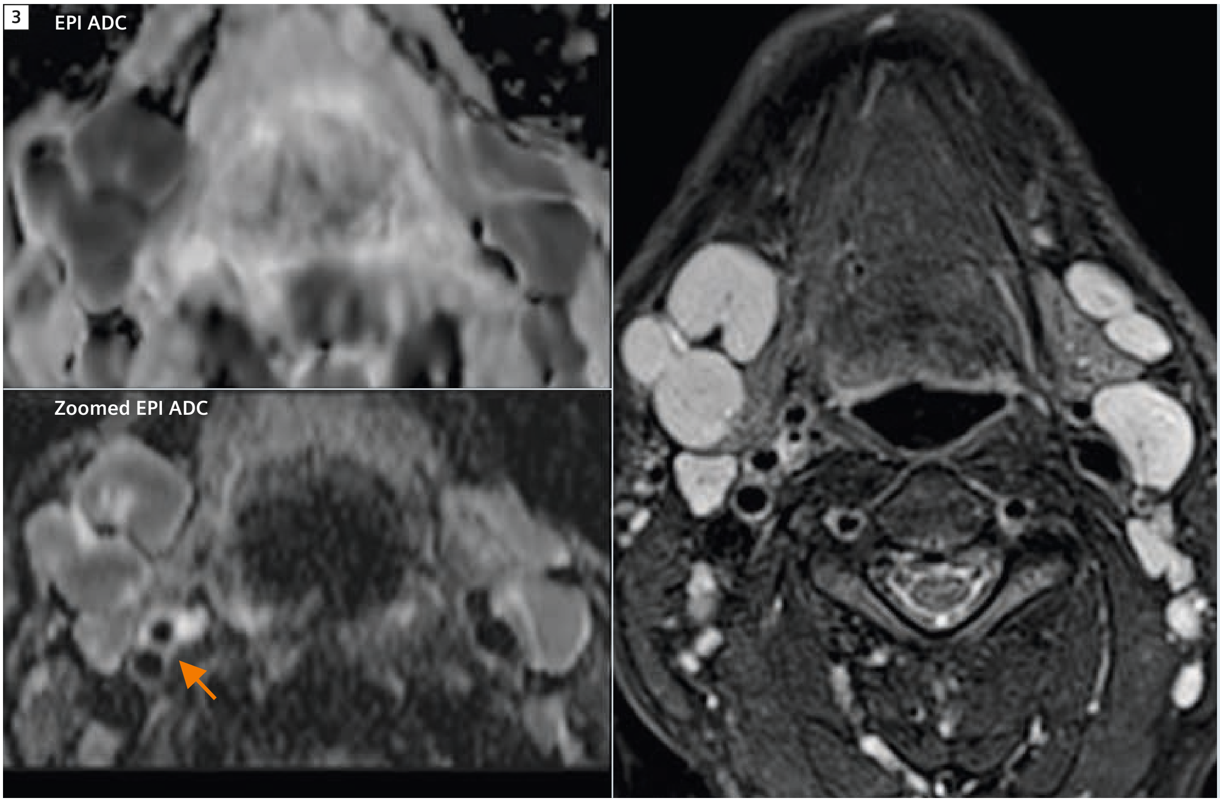
Solution approaches

Physically, the above mentioned artifacts are caused by phase distortions, which increase with longer echo time and mimic the encoding of spatial information during image reconstruction. Therefore, fundamental to overcoming these limitations is the use of shorter echo trains [6]. There are several possibilities for reducing these artifacts and conventional DWI has seen many improvements. Latest developments include, for example, read-out segmented EPI [7]. In combination with navigator-based phase corrections and re-acquisition, read-out segmented EPI can effectively reduce susceptibility artifacts [8] and is now commercially available as *syngo* RESOLVE. Nevertheless, this approach may increase acquisition time and is best applied in the imaging of non-moving organs.

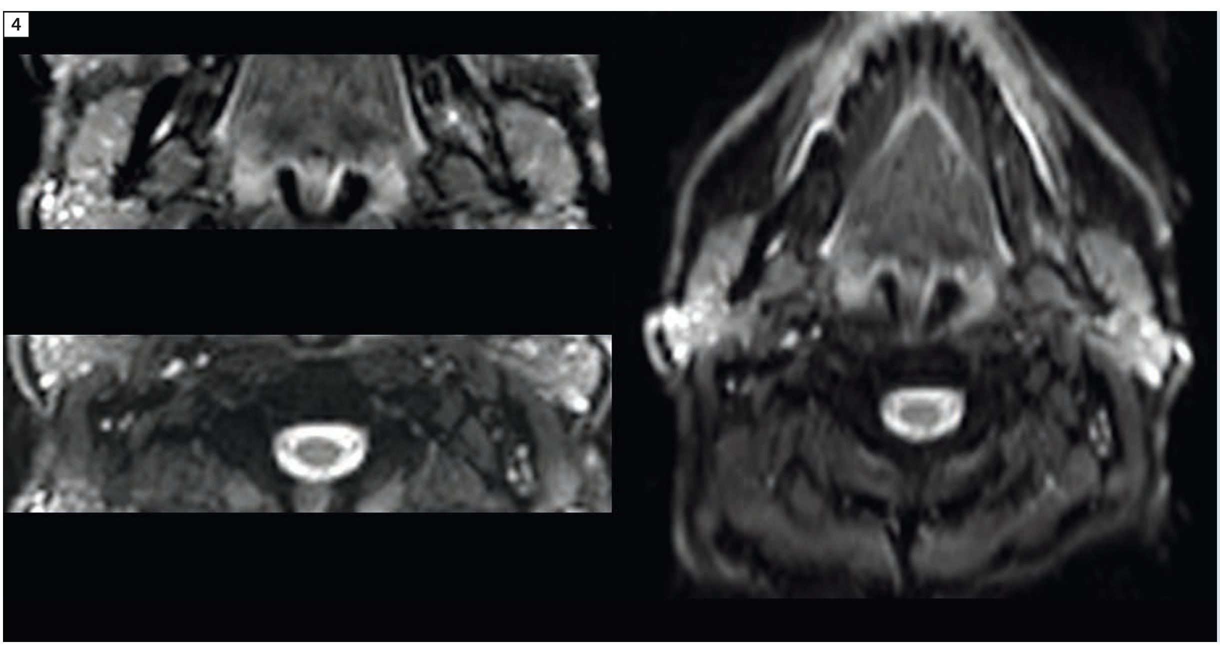
A complementary way of decreasing the echo train is to reduce the field-of-view (FOV) along the phase-encoding dimension of the image while simultaneously avoiding image aliasing. First attempts used spin-echo and stimulated-echo EPI sequences with orthogonal RF pulses to excite an inner-volume FOV and then reduce the number of *k*-space lines required for image reconstruction [9].

A major drawback of these techniques is the restricted volume coverage due to neighboring sections becoming presaturated by one of the RF excitations [6].

With the clinical availability of parallel RF transmit coils and the potential to utilize its spatial information in an array during RF transmission, it is now possible to move beyond the uniform slice-select excitation and to generate spatially-tailored RF pulses. Two-dimensional spatially-selective RF excitation pulses for



3 Malignant lymph nodes in a 42-year-old patient. There is good differentiation between lymph node and vessels (arrow) in the zoomed ADC parameter map.



4 By composing two images with spatially shifted fields-of-view, a larger coverage can be achieved.

single-shot echo-planar imaging combined with reduced FOV – i.e. zooming – in the phase-encoding direction leads to a decreased number of acquisition *k*-space lines and significantly shortens the length of the EPI echo train [6, 10]. The numerically calculated two-dimensional RF pulse provides, in addition, superior flip angle homogeneity, since it is optimized using the B_1 field information of the two independent RF channels. To summarize, zoomed imaging provides largely improved homogeneity with decreased distortion artifacts, opening new clinical applications. We have investigated the applicability of zoomed diffusion imaging of the neck, to examine its potential for reduced susceptibility artifacts in regions close to major air cavities and the associated clinical relevance.

Initial results of zoomed DWI in the head and neck

All examinations were performed on a 3T whole-body MR system (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) equipped with a two-channel fully dynamic parallel transmit array, termed TimTX TrueShape. The excitation of the standard diffusion-weighted EPI sequence was extended by the two-dimensional spatially-selective RF pulse using an echo-planar transmit trajectory. We found that *syngo* ZOOMit bears considerable potential for overcoming some of the inherent limitations of conventional EPI techniques. In particular, for a reduced FOV, zoomed DWI allows for improved image quality in terms of markedly reduced susceptibility artifacts. Zoomed images allows for an excellent correlation between the zoomed DW images and the morphological T2 TSE images (Fig. 1). This is especially obvious in regions prone to artifacts, e.g. in the tongue or the hard palate (Fig. 2). As head and neck squamous cell carcinomas (HNSCC) are often located in those anatomical distributions, zoomed imaging could potentially improve diagnostic accuracy in the assessment of cancers in early stage in those areas.
Additionally, due to the improved image quality with less distortions, zoomed images provide perfect delineation of cervical lymph nodes and an exact co-registration with morphological images. Figure 3 shows images of a patient with malignant lymph nodes. While the malignant lymph nodes could also be seen on the conventional diffusion-weighted images, the differentiation between lymph node and vessels could only be achieved with zoomed DWI. Due to the reduced distortion artifacts, the external carotid artery delivers a sharply delineated flow void, which allowed the radiologist to absolve the vessel of tumor infiltration.
The achieved improvements in image quality originate from both the shorter echo train (at a given TE) and the possible reduction of the TE. On the other hand, the improved image quality is at the expense of a smaller FOV and a lower SNR due to the decreased number of acquired echoes. To cover a larger FOV several images of spatially shifted fields-of-view may be composed (Fig. 4).

Conclusions

These initial data are encouraging as they demonstrate that zoomed imaging (*syngo* ZOOMit) may be a very robust method for DW imaging of challenging areas such as the head and neck, enabling more reliable imaging, particularly in areas close to major air cavities. With improved correlation with anatomy, zoomed DWI may assist in the detection and assessment of early cancers in regions where the application of conventional DWI may have been limited. Such developments are crucial, especially given the need to counteract the much more pronounced susceptibility problems in high-field MRI systems at 3T and beyond.

References

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