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Parallel-transmit-accelerated spatially-selective excitation mri for reduced-fov diffusion-weighted-imaging of the pancreas

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ABSTRACT

Objectives: To find out whether the use of accelerated 2D-selective parallel-transmit excitation MRI for diffusion-weighted EPI (pTX-EPI) offers advantages over conventional single-shot EPI (c-EPI) with respect to different aspects of image quality in the MRI of the pancreas.
Materials and methods: The MRI examinations of 33 consecutive patients were evaluated in this prospective and IRB-approved study. PTX-EPI was performed with a reduced (zoomed) FOV of $230 \times 118\,mm^2$. The 2D-RF pulse of pTX-EPI was accelerated, i.e. shortened by a factor of 1.7 (pTX-acceleration factor). C-EPI used a full-FOV of $380 \times 285\,mm^2$. In a qualitative analysis, two experienced readers evaluated 3 different aspects of image quality on 3- to 5-point Likert scales. Additionally, apparent diffusion coefficients (ADCs) were determined in both c-EPI and pTX-EPI in normal-appearing pancreatic tissue using regions of interests (ROIs). Mean ADC values and standard deviations were compared between the two techniques.
Results: The reduced-FOV pTX-EPI was superior to c-EPI with respect to overall image quality ($p < 0.0001$) and identifiability of the pancreatic ducts ($p < 0.01$). Artifacts were significantly less severe in pTX-EPI ($p < 0.01$). The mean ADC values of c-EPI ($1.29 \pm 0.19 \times 10^{-3}\,mm^2/s$) and pTX-EPI ($1.27 \pm 0.17 \times 10^{-3}\,mm^2/s$) did not differ significantly between the two techniques ($p = 0.44$). The variation within the ROIs as measured by the standard deviation was significantly lower in pTX-EPI ($0.095 \times 10^{-3}\,mm^2/s$) than in c-EPI ($0.135 \times 10^{-3}\,mm^2/s$), $p < 0.05$.
Conclusions: PTX-accelerated EPI with spatially-selective excitation and reduced FOV leads to substantial improvements in DWI of the pancreas with respect to different aspects of image quality without significantly influencing the ADC values.

1. Introduction

Standard pancreatic magnetic resonance imaging (MRI) comprises anatomic T1-weighted (T1w) and T2-weighted (T2w) imaging. Diffusion-weighted MR imaging (DWI), on the other hand, is a functional technique that is increasingly used in pancreatic imaging [1–3]. In a recent meta-analysis, DWI demonstrated a sensitivity of 86% and a specificity of 91% for the discrimination of pancreatic lesions [4].

DWI of the upper abdomen, however, is known to be technically challenging due to respiration, intestinal peristalses, and blood flow [5]. Nevertheless, the implementation of ultrafast imaging techniques, physiological gating, and breath holding techniques, have made DWI a feasible option with promising results in different pathologic entities [2,5–9].

Despite the increasing clinical acceptance of conventional echo-planar diffusion-weighted imaging (c-EPI), its low in-plane spatial resolution has prevented a broad integration into standard pancreatic imaging. Moreover, conventional single-shot EPI sequences are prone to susceptibility artifacts, which are most

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pronounced in areas with large variations in magnetic susceptibility such as the adjacent duodenum and jejunum.

To mitigate these artifacts, a reduced ("zoomed") field of view (FOV) along the phase-encoding direction can be acquired [10,13]. Unlike conventional MR imaging of small structures within a large object, the phase FOV does not have to be much larger than the region of interest, since specific excitation RF pulses ensure that no fold-over (aliasing) artifacts occur. This is achieved by applying two-dimensional (2D) spatially-selective excitation pulses, which actively excite only those parts of the volume (in slice and phase-encoding direction) that will be used for imaging. Thus, the readout echo train length (ETL) can be shortened, which enables an increased resolution while reducing geometric distortions. However, 2D spatially-selective pulses are considerably longer than conventional slice-selective pulses, which increases the minimum echo time and thus reduces the obtainable signal-to-noise ratio.

Only recent technical developments in MRI have led to scanners with fully dynamic two-channel transmit arrays, thus enabling a pTX-accelerated spatially-selective excitation (parallel-transmit technology, pTX). With pTX, the increase of echo times due to the 2D spatially-selective excitation can be at least partially compensated, thus enabling zoomed imaging with only little increase in echo times compared to conventional excitation.

First results have shown that the use of parallel-transmit for zoomed DWI is promising for the examination of the pancreas, a relatively small organ whose imaging often suffers from susceptibility artifacts [10,13]. These studies, however, did not use pTX-acceleration and evaluated only image quality in relatively small numbers of patients.

The aim of this work was to evaluate whether DWI of the pancreas benefits from a reduced-FOV approach realized by a pTX-accelerated 2D-selective echo-planar imaging (pTX-EPI) sequence with respect to image quality and apparent diffusion coefficient (ADC) variability.

2. Materials and methods

This prospective study was approved by the institutional review board and informed consent was obtained from all patients. Between March 2013 and January 2014, 33 consecutive patients underwent multimodal MRI of the pancreas including DWI. We excluded patients in which the pancreas was not fully covered in at least of the DWI sequences or the anatomic T2-weighted sequence.

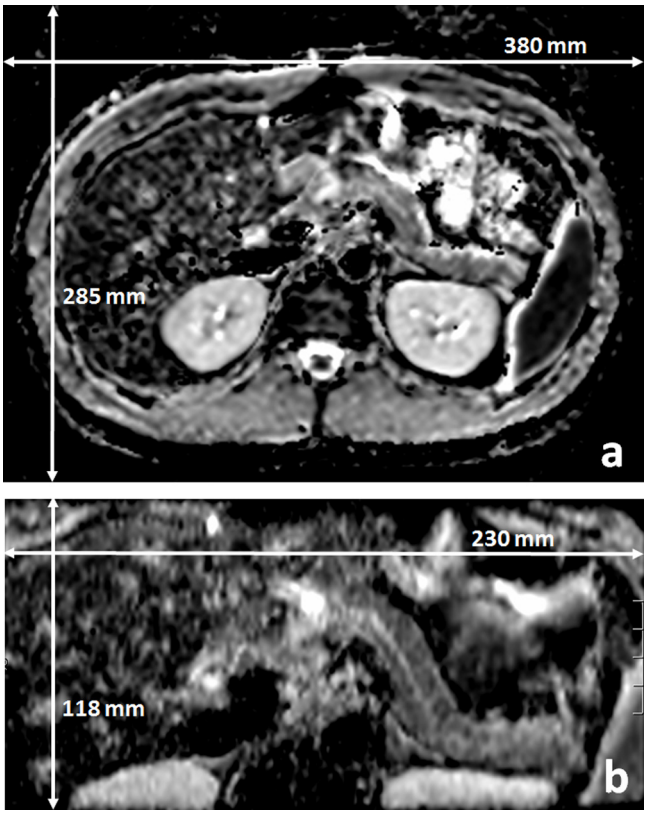

Fig. 1. (a) Conventional full-FOV ($380 \times 285\,mm^2$) abdominal EPI and (b) high-resolution reduced-FOV ($230 \times 118\,mm^2$) parallel-transmit-accelerated EPI centered on the pancreas. The two images show the respective ADC maps.

2.1. MR imaging protocols

We intra-individually evaluated different image quality aspects and compared ADC values of conventional full-FOV EPI (c-EPI) and pTX-accelerated zoomed EPI (pTX-EPI). Imaging was performed on a 3-Tesla whole body MR scanner (MAGNETOM Skyra; Siemens Healthcare, Erlangen, Germany). This scanner is equipped with two independent transmit channels that are fully integrated into the system architecture (TimTX TrueShape, Siemens Healthcare,

Table 1
MR imaging sequence parameters.

Parameter	Conventional EPI	Zoomed pTX-EPI	T2w anatomic imaging (HASTE)
Field of view (mm^2)	380×285	230×118 (ZOOMit)	380×297
Imaging matrix	128×96	164×84	320×259
Slice thickness (mm)	5.0	5.0	6.0
Voxel size (mm^3)	$3.0 \times 3.0 \times 5.0$	$1.4 \times 1.4 \times 5.0$	$1.2 \times 1.2 \times 3.0$
No. of slices	35	20	35
b value (s/mm^2)	50, 400, 800	50, 400, 800	n. a.
PAT mode	GRAPPA	None	GRAPPA
Acceleration factor PE	2	n.a.	2
Echo time (ms)	50	67	96
Echo train length	32	44	9
Echo spacing (ms)	0.50	0.94	4.58
Time to repeat (ms)	1900	2000	1400
Bandwidth (Hz/px)	2442	1172	710
Respiration control	Trigger	Trigger	Breath-hold
Fat suppression	SPAIR	SPAIR	n. a.
pTX acceleration factor	n. a.	1.7	n. a.
Acquisition time (min)	3:32	5:19	1:19

DWI: Diffusion-weighted imaging; EPI: Echo-planar imaging; GRAPPA: Generalized autocalibrating partially parallel acquisitions; HASTE: Half-Fourier-acquisition single-shot turbo spin-echo; PAT: Parallel acquisition technique; pTX-EPI: Parallel-transmit pTX-accelerated EPI; SPAIR: Spectral attenuated inversion recovery; TSE: Turbo-spin-echo.