Case Report: Detection of Insulinomas with High Spatiotemporal Resolution Using Compressed Sensing, Parallel Imaging, and Continuous Golden-Angle Radial Sampling

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Patient history

A 45-year-old female presented with recurrent episodes of aphasia, hyperhidrosis and palpitations. Known familiar predisposition led to genetic testing which revealed a germline mutation in the multiple endocrine neoplasia type 1 (MEN1) tumor suppressor gene responsible for the MEN1 syndrome. These patients are known to develop neuroendocrine tumors such as insulinomas in a high incidence [1]. Subsequent fasting test was aborted after 10 hours due to neuroglycopenic symptoms, low blood glucose levels (2.9 mmol/l), elevated insulin (6.9 pmol/l), elevated c-peptide (519 pmol/l) and as proof of an endogenous hyperinsulism and highly suggestive for an insulinoma. Previously performed magnetic resonance imaging (MRI) and computed tomography (CT) revealed several lesions in the pancreas and duodenum.

Sequence details

Abdominal MRI acquisition was performed on a commercially available 3T system (MAGNETOM Prisma, Siemens Healthcare, Erlangen, Germany) in supine position using a multichannel body surface coil. The protocol aims for high spatial resolution and robustness with regard to breathing and motion artefacts. The body surface coil was placed firmly across the abdomen and the patient was asked to breathe in a calm and shallow way to avoid excessive abdominal excursion during breathing.

The protocol included standard sequences:

a) Coronal half fourier acquisition single shot turbo spin echo (HASTE) localizer

b) Coronal breath-hold T2-weighted HASTE

c) Transverse breath-hold T2-weighted HASTE

d) Transverse, fat-suppressed T2-weighted turbo spin echo (TSE) images in breath-hold

e) Breath-hold in- and out-of-phase T1-weighted gradient-echo sequence

f) Free-breathing echo planar diffusion-weighted images in the transverse plane using five b-values (0, 50, 200, 400, and 800)

g) Transverse, free-breathing (respiratory-triggered, navigator-echo technique) fat-suppressed T2-weighted sequence

h) Fat-suppressed, T2-weighted spin echo sequences images using periodically rotated overlapping parallel lines with enhanced reconstruction (BLADE)

i) Fat-suppressed, T1-weighted DCE-MRI using a prototype implementation of of Golden Angle Radial Sparse Parallel MRI (GRASP)[1] [8].
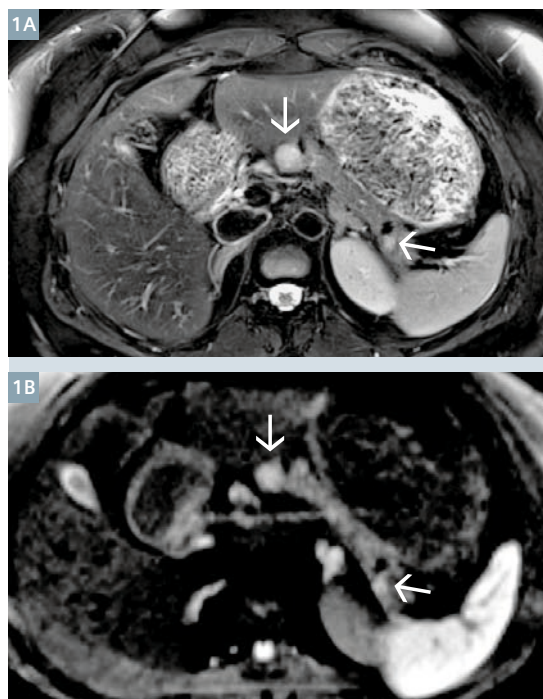
1 (1A) T2-weighted images depict a 16 mm lesion in the cranial portion of the pancreatic head (arrow) as well as a 6 mm lesion in the dorsal portion of the pancreatic head (arrow). (1B) In the diffusion-weighted images both lesions show a diffusion restriction.

[1] WIP, the product is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.
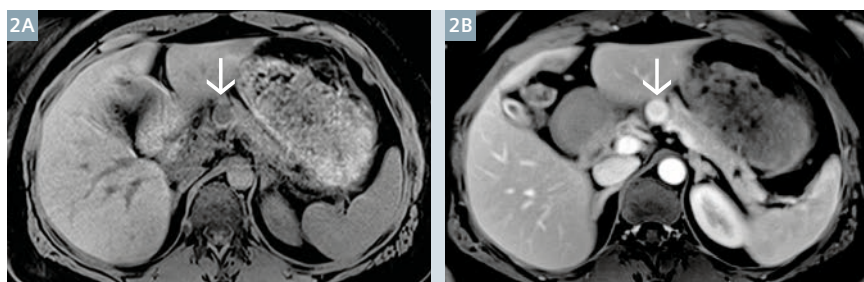
2 (2A) Precontrast T1-weighted images depict the 16 mm hypointense lesion in the cranial portion of the pancreatic head (arrow). The smaller lesion in the dorsal portion of the pancreatic tail is not delineated clearly. (2B) Postcontrast T1-weighted images show early arterial enhancement in the lesion in the pancreatic head (arrow). The lesion in the pancreatic tail is not delineated clearly.

GRASP is based on a fat-suppressed VIBE sequence using the 'stack-of-stars' sampling scheme, which employs radial sampling in-plane and Cartesian sampling in the slice direction [2]. A total of 1,456 radial spokes were acquired continuously using the golden angle scheme (GRASP) over the course of 3 minutes and 45 seconds, which incorporated the precontrast portion of the acquisition; the contrast administration occurred following a 20-second injection delay. Additional parameters were as follows: TR 3.48 ms; TE 1.63 ms; flip angle 12°; matrix 256 x 256; FOV 328 x 328 mm; slice thickness 2.5 mm. Dynamic injection of 0.1 mmol Dotarem (Gd-DOTA) per kilogram body weight was administered through power injector at a rate of 3 ml/s followed by a 20 ml saline flush also at a rate of 3 ml/s. The GRASP dataset can then be sent to a dedicated processing server allowing to set the preferred temporal resolution, starting from 2 s temporal resolution. A retrospective gating algorithm can be applied to the data processing which rejects 50% of the raw data and keeps the remaining 50% at the lowest position of the diaphragm during exspiration.

Imaging findings

A 16 mm lesion is visualized in the cranial portion of the pancreatic body – which is hypointense in T1-weighted images, hyperintense in T2-weighted images, and hyperintense in diffusion-weighted images – shows an early arterial enhancement and venous pooling after contrast media application. Another 6 mm lesion is visualized in the dorsal portion of the pancreatic tail which is hypointense in T1-weighted images, hyperintense in T2-weighted images, and slightly hyperintense in diffusion-weighted images, and shows a faint arterial enhancement with venous pooling after contrast media application.

Figure 4 shows continuous imaging with GRASP (Golden-angle Radial Sparse Parallel) starting 20 seconds before injection and ending in the late portal venous phase. Assessment is performed via a region-of-interest placed in the lesions. As reference, a region-of-interest is placed in the proximal and middle portion of the tail. This quantitatively depicts early arterial enhancement and venous pooling of the lesions in comparision to normal pancreatic parenchyma in the tail.

Discussion

Insulinomas are small tumors, usually < 2 cm at presentation [3, 4] predominantly located in the pancreas. As neuroendocrine tumors, a large proportion exhibits an enhancement after contrast media application. The assessment of arterial and venous phases aids lesion detection, characterization and differentation from normal pancreas parenchyma. The trade-off between spatial and temporal resolution in the detection of these small tumors presents a challenge in dynamic contrast-enhanced MRI.

3-dimensional fat-suppressed T1-weigthed interpolated spoiled gradient-echo (VIBE, volumetric interpolated breath-hold examination) sequences are the conventional sequences widely used for contrast-enhanced MR examinations of the
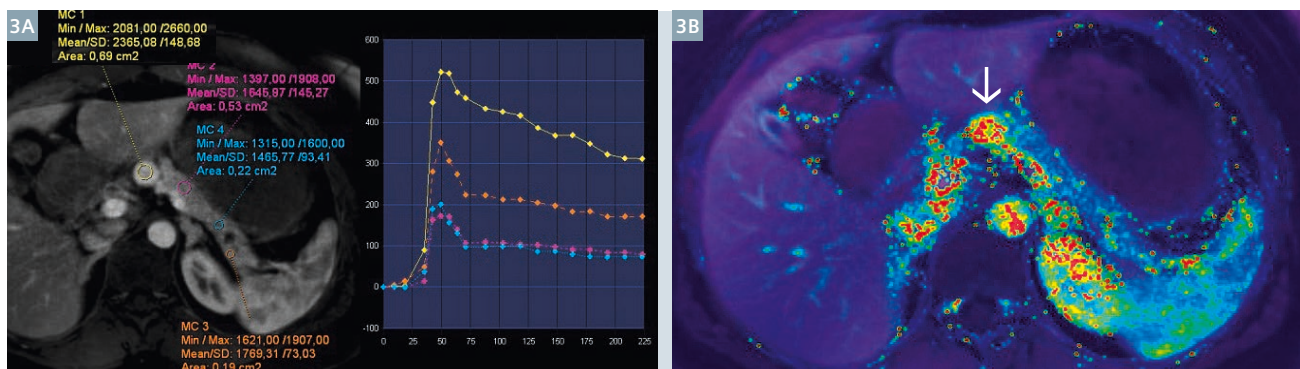
3 (3A) Signal over time evaluation based on mean curve ROIs: A region-of-interest is placed in the lesion in the pancreatic head (yellow) and pancreatic tail (orange). Reference regions-of-interest are placed in the panreatic tail (purple + blue). The lesion in the pancreatic head and tail shows early arterial enhancement in comparison to normal panreactic parenchyma. (3B) Color maps with dynamic contrast information.
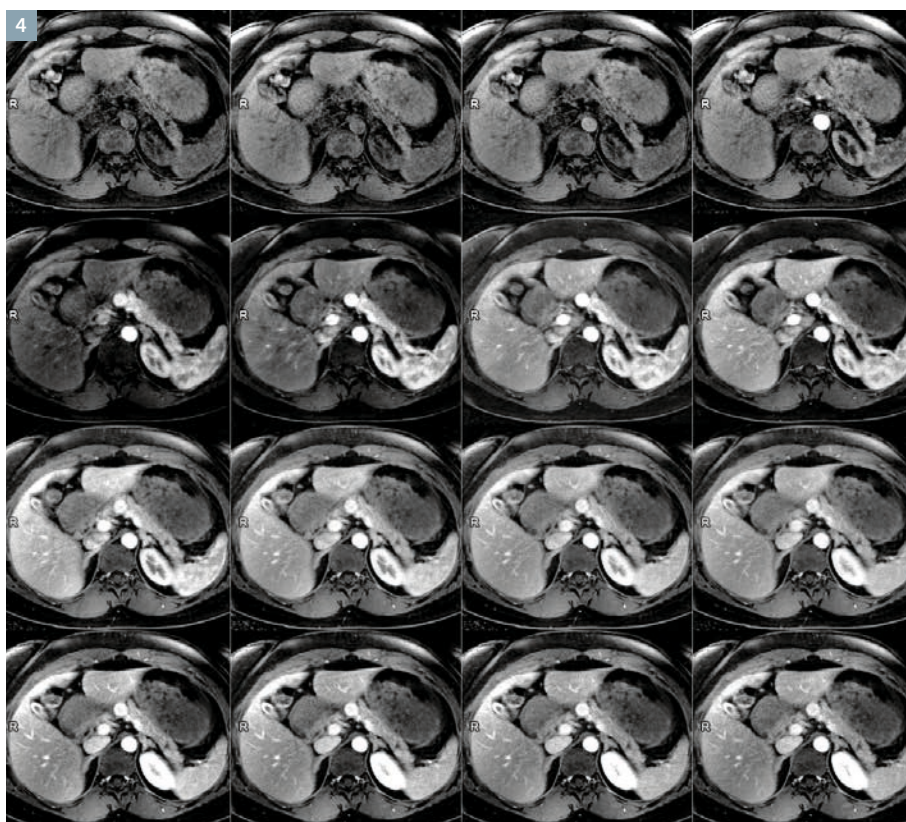
4 Contrast enhancement changes over time displayed on GRASP datasets, each calculated to represent a temporal resolution of 8 seconds with retrospective gating only including 50% of the data based on the lowest position of exspiration.

liver and pancreas [5]. Motion artifacts, such as respiratory motion, cardiac pulsation and bowel peristalis, however, limit the detectability of small lesions as well as vascularization characterisation and can even render images nondiagnostic [6].

With GRASP a high temporal resolution can be achieved by using Compressed Sensing which exploits spatial correlation within images or spatiotemporal correlations among sequentially acquired images [7]. Thus, in combination with parallel imaging, continuous golden-angle sampling and retrospective gating offers both the high temporal and spatial resolution as depicted in Figures 3 and 4.

This case demonstrates that high spatiotemporal resolution dynamic contrast-enhanced pancreas MRI is possible with GRASP. It has the potential to improve image quality and lesion depiction compared to standard dynamic contrast-enhanced MRI.

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