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Original article

Pancreas volume measurement in patients with Type 2 diabetes using magnetic resonance imaging-based planimetry

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A B S T R A C T

Background/objectives: To compare pancreas volume (PV) measurement using MRI-based planimetry in patients with Type 2 diabetes mellitus (DM) to PV in normoglycemic individuals.
Methods: Our institutional review board granted approval of this retrospective study with waiver of informed consent. We searched 2296 consecutive abdominal MRI studies performed at our hospital on patients with no pancreas pathology between September 1, 2010 and February 28, 2013, for those who also had a fasting plasma glucose and/or hemoglobin A1C within six months of the MRI examination. For those patients who met biochemical criteria for DM, we used medication and clinical records to confirm that 32 of these patients had Type 2 DM. The pancreas contours of 32 Type 2 diabetics and 50 normoglycemic individuals were then traced on non-gadolinium T1-weighted 3D fat suppressed gradient echo images by a radiologist trained in abdominal MRI to calculate PV. PV index (PVI) was calculated as PV/weight to adjust PV for each patient's weight. PVs and PVIs in both cohorts were compared using *t*-tests and regression models correcting for weight, age and gender.
Results: Patients with Type 2 DM had significantly lower PVs than normoglycemic individuals (72.7 ± 20.7 cm^3 versus 89.6 ± 22.7 cm^3, $p < 0.001$), and significantly lower PVIs (1.0 ± 0.3 cm^3/kg versus 1.3 ± 0.3 cm^3/kg, $p < 0.001$). Using regression models, we found that given the same age, weight and gender, the PV in a patient with Type 2 DM was 17.9 mL (20%) lower compared to a normoglycemic individual ($p < 0.001$).
Conclusion: PV is reduced in Type 2 DM compared to normoglycemic individuals and can be measured using MRI without contrast injection.

1. Introduction

Pancreas volume (PV) is altered by normal events such as aging or weight gain. For example, PV increases in a linear fashion from birth to age 20; decreases following age 60 [1,2] and PV shows a linear correlation with body weight [3,4]. Pancreatic atrophy has been associated with a variety of pathological conditions, such as cystic fibrosis, pancreatic adenocarcinoma, and Type 1 and 2 diabetes mellitus (DM) [5–8]. There has been an evolving interest in PV alteration over the course of DM [2,3,8–11]. Both Type 1 and Type 2 DM are associated with decreased PV, attributed in part to chronic inflammation [11,12] and loss of the trophic effects of insulin [8,9,11,13].

The majority of studies measuring PV in diabetes have been conducted using computed tomography (CT) [2,10,11,13] or ultrasonography [14]. Ultrasonography only provides a rough estimation of PV due to the lack of standardized measurement capability and operator dependence. It is difficult to visualize the pancreas on ultrasound especially in obese individuals. Very often there may be overlying bowel gas limiting visualization. The distal part of the tail of the pancreas is commonly not well visualized on ultrasound [14]. CT utilizes ionizing radiation that may be harmful with repeated scans for monitoring or screening [3].

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To our knowledge, the use of magnetic resonance imaging (MRI) in measuring PV has been limited. Only a few studies to date have investigated the use of MRI for PV measurement [3,4,15,16] in DM. Moreover the focus of those studies was normal subjects, Type 1 DM [3,4] or cystic fibrosis-related diabetes [15] and the cohort sizes were small.

The few studies using MRI to measure PVs in DM have done so in Type 1 DM, though Type 2 DM is much more common. PVs in Type 1 DM are significantly lower than that of normoglycemic individuals [3]. The volume difference between normoglycemics and Type 2 diabetics has been less striking [2,10] and has only been measured with CT to date.

We believe that it is important to measure this difference in PVs between Type 2 diabetics and normoglycemic individuals with MRI, without radiation exposure as in CT. Type 2 DM is important to study in this context because it is more prevalent, it poses a large health and economic burden on society, and it is more representative of the distribution of DM subtypes in a typical adult population.

The principal advantages of MRI over other imaging modalities are that: it does not involve ionizing radiation; spatial resolution in 3D MRI acquisitions has evolved to the point that volumetric image data sets can be manipulated in any plane; and there are numerous inherent contrast mechanisms that allow for excellent contrast resolution without administration of an exogenous contrast agent. Though there are many potential clinical applications of measuring PV with such a safe and accessible technique [17,18], our aim in this study was to measure PV using planimetry based on a simple but accurate MRI pulse sequence in patients who have Type 2 DM, compared to patients who are normoglycemic. We hypothesized that PV will be decreased in patients with Type 2 DM compared to normoglycemic patients.

2. Methods

This retrospective study was approved by our institutional review board with a waiver of informed consent.

2.1. MRI protocol

All abdominal MRI studies were performed on a 1.5 T Philips Achieva MRI scanner. Our abdominal MRI protocol includes an axial three dimensional (3D) T1-weighted fat suppressed gradient echo sequence called T1 High Resolution Isotropic Volume Examination (THRIVE, Philips Medical Systems). The THRIVE sequence is routinely performed before and after intravenous administration of a gadolinium-based contrast agent (GBCA). These are rapid MRI acquisitions which are done during a single breath hold (acquisition time <20 s), using SENSE parallel imaging, and have the following approximate parameters: TR 3.5, TE 1.7, SENSE factor = 2, FOV ~ 39 × 39 cm, matrix 256 × 256, slice thickness 2.5 mm. We sought to compare volumes in two cohorts with the most simple and accessible pulse sequence, where pancreatic contours were delineated clearly, and where a GBCA is not required. Hence we chose to evaluate the pre-GBCA T1-weighted images that formed part of our routine protocol.

2.2. Planimetry method

The basis of planimetry in cross-sectional imaging is that the volume of abdominal organs can be measured by calculating the cross sectional area of an organ on CT or MRI on a single slice through the organ, multiplying this area by the width between organ slices, and summing across all slices that cover the organ to reach a total volume [2,3,11]. The cross-sectional area of an organ on a single CT or MRI slice can be traced manually using free-hand region-of-interest post-processing software tools.

A phantom study was initially conducted to assess the accuracy and reproducibility of volume measurement by MRI-based planimetry using our MRI scanner. Plastic syringes were filled with blueberry juice, which contains a high concentration of paramagnetic ions and hence resembles the hyperintense pancreas on T1-weighted MRI. Four different syringes containing 3, 10, 20, and 60 mL of blueberry juice respectively were imaged using the same MRI T1-weighted THRIVE sequence as outlined above. The volumes of these syringes were calculated by two experienced abdominal radiologists (6 years and 3 years of experience, respectively, including fellowship training in abdominal MRI and MRI post-processing techniques) using MRI-based planimetry. The borders of the blueberry juice in the syringe on each MRI slice were delineated by these radiologists independently using a free hand tool and post-processing software package (Aquarius iNtuition, TeraRecon, Foster City, CA). This software package used each reader's tracings to calculate the volume of blueberry juice in the syringe by multiplying the cross-sectional area of the phantom in each slice by the slice thickness, and then summing these values. The readers were blinded to each other's measurements. The calculated volumes for the 4 different syringes containing 3, 10, 20, and 60 mL of blueberry juice using MRI planimetry were 3.1, 10.0, 20.2, and 60.8 mL for the first radiologist, and 3.0, 9.7, 19.6, and 59.0 mL for the second radiologist, respectively. These were compared with the actual volumes of juice contained within the syringe. A linear regression was applied to the plot of actual versus calculated blueberry juice volume across 4 data points and showed almost perfect concordance between the radiologists using MRI-based planimetry (R^2 = 1.00, slopes = 0.98 and 1.01, and intercepts = 0 for both radiologists). This proved accuracy of the planimetry technique for volume calculations.

A junior radiologist with 1 year of abdominal MRI experience was then trained by the two senior radiologists in MRI-based planimetry. In order to assess the reliability of this technique specifically for PV calculation and validate the junior reader to measure PVs using this technique, these three radiologists traced pancreas contours independently on 26 consecutive abdominal MRI studies performed at our hospital between June 21, 2010 and July 22, 2010 on patients who were referred for MRI with indications other than pancreas pathology. An axial T1-weighted THRIVE pulse sequence was used for the pancreas tracings, again using the same software and methods as in the phantom study.

Each radiologist was blinded to PVs generated by the other two. The PVs generated by the three radiologists were 91.5 mL and 87.2 mL for the two senior readers and 89.9 mL for the junior reader. Agreement between the three readers was assessed by calculating the intraclass coefficient (ICC) using absolute agreement in a two way mixed model for single measures. This analysis yielded an ICC of 0.87 (CI: 0.75, 0.93), representing near-perfect agreement in PV measurement using this technique between all three readers [19]. This validated the use of one of these as the single reader going forward for the measurement of PVs in the Type 2 DM and normoglycemic cohorts.

An example of a slice is shown in Fig. 1. The use of MRI-based planimetry for PV measurement has been reported as feasible and reproducible in small cohorts in recent literature [3,4].

2.3. PV measurements in diabetic and normoglycemic cohorts

Following the training period, and after ascertaining near-perfect inter-observer agreement for PV measurement with this technique, the junior radiologist subsequently used our MRI-based planimetry method on axial T1-weighted THRIVE pulse sequences

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