Association of Pancreatic Steatosis with Visceral Obesity, Age, Sex and Metabolic Syndromes

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BACKGROUND

Pancreatic steatosis is an accumulation of fat in the pancreatic gland and is associated with obesity and substance abuse [1], where increased fat deposition is a major indication of chronic pancreatitis (CP). Prolonged pancreatic inflammation results in permanent damage to endocrine and exocrine function, irreversible fibrosis, and malabsorption directly leading to diabetes and metabolic syndromes [1]. Worldwide, CP incidence was 1.6 to 23 per 100,000 population per year and in the US, and results in more than 122,000 outpatient visits and greater than 56,000 hospitalizations annually [2]. Common symptoms include: abdominal nociception, dyspepsia, pancreatic duct dilation, and pancreatic pseudocyst formation [3]. Treatments target symptomatic relief, Endoscopic Retrograde Cholangiopancreatography (ERCP), pancreatic stent, and Extracorporeal Shock Wave Lithotripsy, and exogenous pancreatic enzymes [4, 5]. Symptomatology alone cannot confirm a diagnosis of CP; therefore, noninvasive imaging studies, including US, CT, and MRI, are most widely used. MR is the most reliable method for early diagnosis of fat infiltration in visceral organs [5] as it poses no radiation risk and high resolution. Invasive techniques including ERCP, and endoscopic US are also used to detect complications in the pancreatic duct and parenchyma [5]. Previous quantitative imaging studies have focused on examining the liver to evaluate hepatic steatosis grade; whereas, studies evaluating the impact of steatosis in CP are limited due to the complexity of the organ. Therefore, the purpose of this study is to analyze MR imaging to assess possible correlation between pancreatitis grade and fraction of pancreatic fat.

IMAGE PROCESSING WORKFLOW

A two point VIBE Dixon MR sequence using a Siemens Verio 3T (Tesla) scanner, with IU IRB (1704167600) approval, was used to image 120 subjects. Subjects were categorized into 4 grades of disease: normal; mild; moderate; and severe. The Dixon technique allows for the separation of fat-only and water-only images thus permitting direct fat quantification [6]. Using two independent observers, all DICOM fat-only and water-only VIBE Dixon images were de-identified using the Clinical Trials Processor (CTP) developed at IUSM and imported into Analyze 12.0 (AnalyzeDirect, Stilwell, KS) for subsequent image processing.

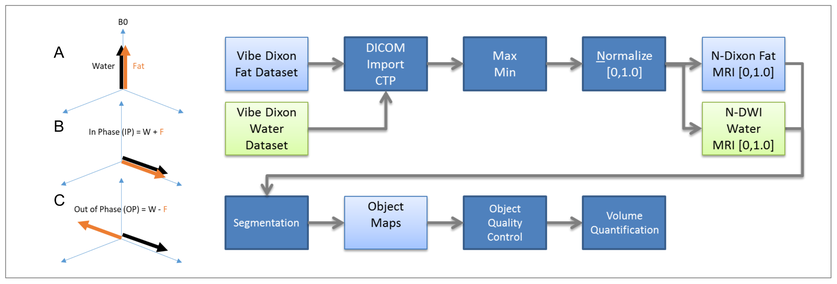

Figure 1. Two Point Dixon net proton momentum for (A) steady state for Water and Fat; (B) In-phase (IP) for Water and Fat; and (C) Out of Phase (OP) for Water and Fat. Image processing workflow for Pancreatic Steatosis

MATERIALS AND METHODS

Fat-only and Water-only VIBE Dixon images were segmented into independent pancreatic head, body, and tail region images. Images were then intensity normalized over the interval [0.0, 1.0] by dividing each image volume by the maximum value of the VIBE Dixon image set. The fat-only images were used to segment Background, Subcutaneous Fat, and Visceral Fat regions using the Volume Edit tool (Analyze 12.0). The Background region was extracted using a 0.0-0.1 threshold range, while Subcutaneous fat regions were extracted using a 0.1-1.0 threshold range. The Visceral fat regions were extracted using a manual spline edit technique and were then locked and applied to the water-only images to manually-segment the Liver and Pancreas regions. All regions were edited to ensure proper classification. Fat pixel values of the final fat and water images were extracted using the Region of Interest tool on Analyze 12.0. Fat fractions were calculated according to the following formula:

$$F_f(i,j) = \frac{I_{fat}(i,j)}{\left[I_{fat}(i,j) + I_{water}(i,j)\right]} \quad (1)$$

Where, F_f is fat fraction, i is subject, j is region, I_f is VIBE Dixon fat image, and I_w is VIBE Dixon water image. Mean fat fraction data was then categorized according to CP grade for visceral, liver fat, and pancreatic fat, while Bland-Altman inter-observer comparison was performed.

RESULTS

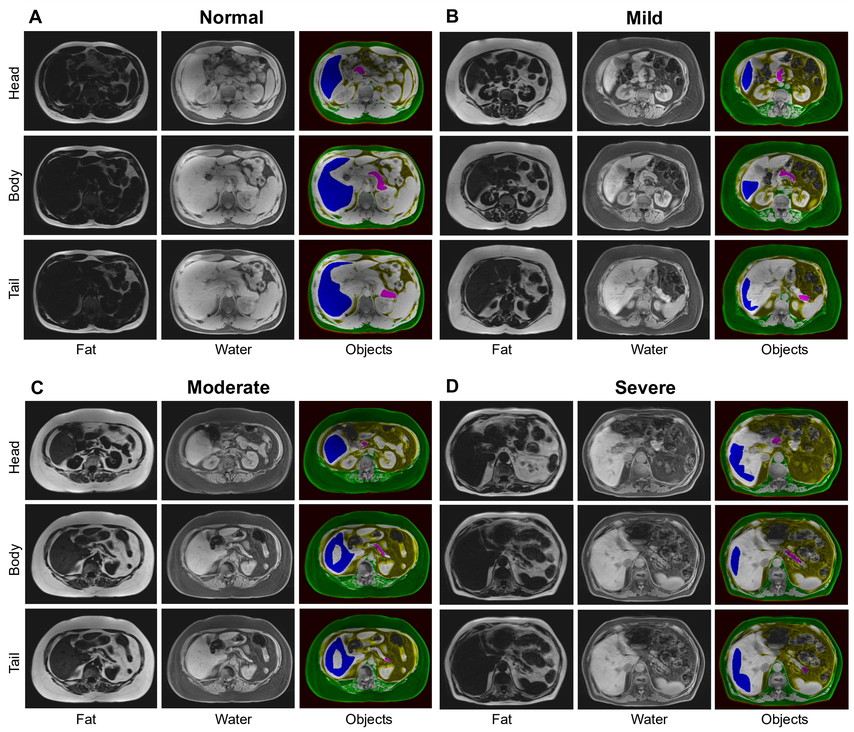

Figure 2. Two point VIBE Dixon Fat, Water, and Object Maps overlaid on Water Images for 4 Pancreatitis subjective groups (A) Normal (B) Mild (C) Moderate (D) and Severe CP. Images are shown at 3 slice levels which represent the head, body, and tail of the pancreas as defined by a board certificated abdominal radiologist. Object Map colors are red, green, yellow, blue and magenta for the background, subcutaneous, visceral, liver, and pancreas.

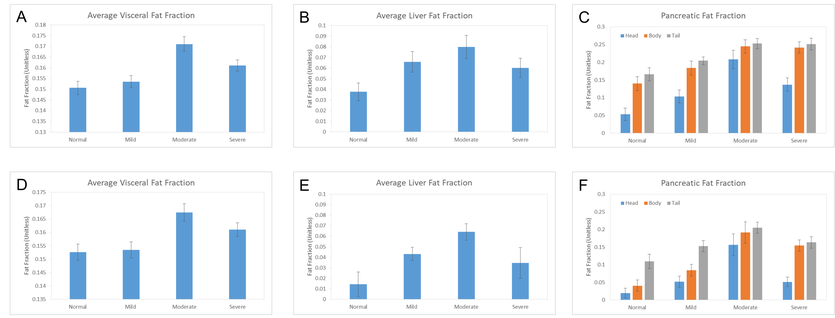

Figure 3. (A) Average visceral fat fraction for observer 1 (B) Average liver fat fraction for observer 1 (C) Average pancreatic fat fraction for observer 1 (D) Average visceral fat fraction for observer 2 (E) Average liver fat fraction for observer 2 (F) Average pancreatic fat fraction for observer 2

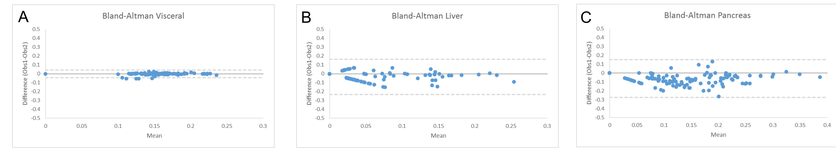

Figure 4. This is some sample text for (A) Bland-Altman Visceral for observer 1 and 2 (B) Bland-Altman Liver for observer 1 and 2 (C) Bland-Altman Pancreas for observer 1 and 2 . Bland-Altman analyses indicated minimal bias between the two observers for visceral (Lower LOA = -0.02052, Upper LOA = 0.0182, Bias = -0.00116), liver (Lower LOA = -0.11372, Upper LOA = 0.06763, Bias = -0.02304), and pancreas measurements (Lower LOA = -0.18718, Upper LOA = 0.04703, Bias = -0.07008).

CONCLUSIONS

- Mean pancreatic and liver fat fractions reveal a positive trend with the severity of CP; as CP progresses in grade, visceral, pancreatic, and liver fat tend to increase indicating greater extent of steatosis.
- Between moderate and severe CP grades, visceral, pancreas, and liver fat fractions all decrease suggestive of severe fibrosis in severe CP patients.
- Bland-Altman results reveal good agreement between observer 1 and 2 with minimal bias.
- These data suggest that MR imaging can be used to correlate the extent of steatosis to the severity of CP in patients through quantification of fat accumulation in the pancreas.

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