Original Paper

Pancreatology

Pancreatology 2011;11:588–594
DOI: 10.1159/000334547

Received: July 11, 2011
Accepted after revision: October 17, 2011
Published online: January 11, 2012

Variability of CT Contrast Enhancement in the Pancreas: A Cause for Concern?

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Key Words
Density measurements · Dual-energy CT · Dual-energy iodine mapping · Iodine concentration mapping · Multidetector X-ray computed tomography · Pancreatic tissue contrast enhancement · Perfusion CT

Abstract
Background: Multidetector CT is a valuable technique for diagnosis/staging in several pancreatic pathologies. Diagnosis is usually based on tissue density measurements. Recently, newer functional CT techniques have been introduced. The aim of this study was to assess variability in perfusion and dual-energy CT data, and to compare these data with density measurements in the pancreas of a healthy population. ***Methods:*** Two groups were included: 20 patients underwent perfusion CT imaging, and 10 patients were scanned using a dual-energy protocol. In both groups, tissue density [Hounsfield units (HU)] was measured in the pancreatic head, body and tail. Functional data were calculated (blood flow/blood volume in the perfusion CT group, iodine concentration in the dual-energy group), and variability was assessed. ***Results:*** Density measurements were comparable for the perfusion and dual-energy CT groups, and ranged from 14 to 60 HU. Maximal enhancement differences between the head/body/tail of the pancreas ranged between 2 and 21 HU. Considerable variability was observed, both in density measurements (ranging from 3 to 34%) and in functional parameters (mean variability in perfusion CT parameters blood flow and blood volume was 21.3 and 10% respectively; mean variability in dual-energy iodine-mapping results was 24.4%). ***Conclusion:*** This study demonstrated the presence of important intraindividual variability in pancreatic tissue contrast enhancement, regardless of the CT technique used. Considering the variability observed in this study, the use of cut-off values to characterize pancreatic pathologies seems troublesome, and morphologic primary and secondary changes will remain important, even when using novel functional imaging techniques.

Introduction

Multidetector X-ray computed tomography (MDCT) is a valuable technique for diagnosis and staging in a wide range of pancreatic diseases. The imaging modality can be performed with and without intravenous (IV) contrast administration. Non-enhanced CT images are applied to detect pancreatic calcifications as a cause of acute

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pancreatitis (lithiasis), and in chronic pancreatitis. CT images without IV contrast can give diagnostic direction, but are rarely sufficient to establish a complete diagnosis. IV contrast is usually administered to improve the diagnostic yield of the examination, because abnormalities in contrast enhancement of pancreatic tissue are indicative of pancreatic disease. Different enhancement patterns characterize different diseases [1, 2]. Hypovascular tumors such as primary adenocarcinoma, lymphoma and most metastases can be discovered with great conspicuity when displayed in a highly enhanced pancreas (presenting as hypodense lesions). Hypervascular lesions (e.g. endocrine carcinoma) are best discovered on an earlier CT contrast phase when they appear hyperdense compared to normal parenchyma, which is still hypodense at that moment. Contrast-enhanced CT is also indispensable in confirming the diagnosis of acute pancreatitis, identifying cause and assessing local complications such as pancreatic necrosis (visible as lack or diminution of enhancement [3, 4]), infections [5] or pseudocysts [6].

The CT Severity Index developed by Balthazar et al. [6] and the Modified CT Severity Index described by Mortele et al. [7] are partly based on the detection of necrosis by contrast-enhanced CT [8]. Balthazar [3] described pancreatic tissue necrosis as an enhancement of <30 Hounsfield Units (HU). The Atlanta definitions considered tissue necrosis to be present when contrast density failed to exceed 50 HU [9]. Historically, tissue density measurements (expressed in HU) are used to diagnose pathologies using CT. Recently, newer CT techniques have been introduced, adding additional (functional) information to the classic tissue density measurements. Examples include iodine contrast material mapping using dual-energy CT, and perfusion CT imaging [which can assess parameters like blood flow (BF), blood volume (BV) and tissue permeability].

Dual-energy CT systems allow simultaneous acquisition of dual-energy images, typically acquired at 80 and 140 kVp, enabling measurements of iodine contrast material concentrations, without a substantial increase in radiation dose due to the use of an additional tin filter [10]. Moreover, the non-contrast-enhanced image set can be obtained by digital subtraction of the iodine contrast component ('virtual unenhanced images'), reducing radiation dose to the patient. Nowadays, state-of-the-art CT scanners enable dynamic perfusion measurements in tissue, creating parametric maps of for example BF and BV using post-processing techniques [11, 12]. Parametric maps have shown their importance in identifying tumors appearing isodense on CT images [13–15].

Data concerning the variability of contrast enhancement in healthy pancreas are scarce; moreover, inconsistencies in literature exist concerning variations in enhancement and perfusion between the head, body and tail of the pancreas. This study was set up to investigate variability in contrast enhancement of the pancreas using 128-slice CT, and two different CT techniques. Variability was assessed with density measurements (HU) in two groups of healthy patients (one group underwent perfusion CT, the other group was scanned using dual-energy CT). These data were compared with variability in perfusion CT parameters BF and BV, and with dual-energy iodine-mapping data.

Material and Methods

Patient Selection

Our study protocol was approved by the Ghent University Hospital institutional review board; all patients were 18 years or older and provided written informed consent, which included information about potential side effects from CT examinations. Standard contrast-enhanced CT exclusion criteria for patients in the study were used [pregnancy, age <18, history of anaphylaxis in reaction to administration of iodine contrast agents, elevated serum creatinine levels (>1.2 mg/dl), asthma]. Strict inclusion criteria were used for the healthy population (no pancreatic pathology, no abdominal findings on CT/endoechography/ultrasound, normal blood laboratory results). Furthermore, pathologies having potential impact on pancreatic perfusion were also excluded (celiac disease, superior mesenteric artery disease, irritable bowel).

Two study groups were defined: one group consisted of 20 patients scanned using perfusion CT and the other group consisted of 10 patients scanned using a dual-energy CT protocol. All 30 patients were also evaluated using classic density measurements on the axial image datasets.

Perfusion CT Protocol

Between March 2010 and February 2011, 60 patients underwent abdominal body perfusion CT at the Department of Radiology and Medical Imaging (Ghent University Hospital, Ghent, Belgium) after informed consent (patients were suspected of having an abdominal pathology). From this population, 20 patients without pancreatic pathology were retrospectively selected for inclusion in the study (inclusion criteria are described above).

Before examination, patients received water (500 ml) as an oral contrast agent to distend the stomach and duodenum for better delineation of the pancreatic gland. Patients were prepared with oxygen hyperventilation (12 l/min) to support the relatively long breath-hold sequence (48 s).

CT parameters are summarized in table 1. The injection protocol consisted of the administration of 50 ml of non-ionic iodinated contrast material (Visipaque 320; GE Healthcare) (iodixanol, 320 mg iodine/ml) using a dual-headed pump injector (Dual Shot Alpha, Nemoto; GE Healthcare) at a rate of 5 ml/s through an 18-gauge IV cannula. This was followed by a flush with sterile saline solution (50 ml, 5 ml/s).