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Image quality of mean temporal arterial and mean temporal portal venous phase images calculated from low dose dynamic volume perfusion CT datasets in patients with hepatocellular carcinoma and pancreatic cancer

X. Wang (MD)[a,1], T. Henzler (MD)[b,*,1], J. Gawlitza[b], S. Diehl (MD)[b], T. Wilhelm (MD)[c], S.O. Schoenberg (MD)[b], Z.Y. Jin (MD)[a], H.D. Xue (MD)[a], A. Smakic (MD)[b]

[a] Radiology Department, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences, Beijing, China
[b] Institute of Clinical Radiology and Nuclear Medicine, University Medical Center Mannheim, Medical Faculty Mannheim, Heidelberg University, Germany
[c] Department of Surgery, University Medical Center Mannheim, Medical Faculty Mannheim, Heidelberg University, Germany

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ABSTRACT

Purpose: Dynamic volume perfusion CT (dVPCT) provides valuable information on tissue perfusion in patients with hepatocellular carcinoma (HCC) and pancreatic cancer. However, currently dVPCT is often performed in addition to conventional CT acquisitions due to the limited morphologic image quality of dose optimized dVPCT protocols. The aim of this study was to prospectively compare objective and subjective image quality, lesion detectability and radiation dose between mean temporal arterial (mTA) and mean temporal portal venous (mTPV) images calculated from low dose dynamic volume perfusion CT (dVPCT) datasets with linearly blended 120-kVp arterial and portal venous datasets in patients with HCC and pancreatic cancer.

Materials and methods: All patients gave written informed consent for this institutional review board–approved HIPAA compliant study. 27 consecutive patients (18 men, 9 women, mean age, 69.1 years ± 9.4) with histologically proven HCC or suspected pancreatic cancer were prospectively enrolled. The study CT protocol included a dVPCT protocol performed with 70 or 80 kVp tube voltage (18 spiral acquisitions, 71.2 s total acquisition times) and standard dual-energy (90/150 kVpSn) arterial and portal venous acquisition performed 25 min after the dVPCT. The mTA and mTPV images were manually reconstructed from the 3 to 5 best visually selected single arterial and 3 to 5 best single portal venous phases dVPCT dataset. The linearly blended 120-kVp images were calculated from dual-energy CT (DECT) raw data. Image noise, SNR, and CNR of the liver, abdominal aorta (AA) and main portal vein (PV) were compared between the mTA/mTPV and the linearly blended 120-kVp dual-energy arterial and portal venous datasets, respectively. Subjective image quality was evaluated by two radiologists regarding subjective image noise, sharpness and overall diagnostic image quality using a 5-point Likert Scale. In addition, liver lesion detectability was performed for each liver segment by the two radiologists using the linearly blended120-kVp arterial and portal venous datasets as the reference standard.

Results: Image noise, SNR and CNR values of the mTA and mTPV were significantly higher when compared to the corresponding linearly blended arterial and portal venous 120-kVp datasets (all $p < 0.001$) except for image noise within the PV in the portal venous phases ($p = 0.136$).

Objective: image quality of mTA and mTPV were rated significantly better when compared to the linearly blended 120-kVp arterial and portal venous datasets. Both readers were able to detect all liver lesions found on the linearly blended 120-kVp arterial and portal venous datasets using the mTA and mTPV datasets. The effective radiation dose of the dVPCT was 27.6 mSv for the 80 kVp protocol and 14.5 mSv for the 70 kVp protocol. The mean effective radiation dose for the linearly blended 120-kVp arterial and portal venous CT protocol together of the upper abdomen was 5.60 mSv ± 1.48 mSv.

* Corresponding author at: Institute of Clinical Radiology and Nuclear Medicine University Medical Center Mannheim Medical Faculty Mannheim – Heidelberg University Theodor-Kutzer-Ufer 1-3 D-68167 Mannheim, Germany.
E-mail address: thomas.henzler@medma.uni-heidelberg.de (T. Henzler).
[1] These author contributed equally to this work.

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Conclusion: Our preliminary data suggest that subjective and objective image quality of mTA and mTPV datasets calculated from low-kVp dVPCT datasets is non-inferior when compared to linearly blended 120-kVp arterial and portal venous acquisitions in patients with HCC and pancreatic cancer. Thus, dVPCT could be used as a stand-alone imaging technique without additionally performed conventional arterial and portal venous CT acquisitions.

1. Introduction

Dynamic volume perfusion computed tomography (dVPCT) is a rapidly developing imaging technique for the quantification of tissue perfusion. Improved lesion characterization, quantitative response evaluation to targeted or minimally invasive therapies as well as prognosis prediction are the main advantages of dVPCT in patients with hepatocellular carcinoma (HCC) or pancreatic cancer [1,2]. However, despite all promising advantages that have been demonstrated for dVPCT in the abdomen, one has to acknowledge that the technique has not moved into broad clinical routine outside of controlled studies. One of the main reasons why the technique is currently not widely used in clinical routine is that dVPCT examinations usually require modern cutting-edge scanners, which are still not widely spread. Moreover dVPCT examinations are still mainly performed in addition to conventional CT acquisitions since low kV dose optimized dVPCT datasets suffer from higher image noise that are of less image quality for morphologic imaging. This leads to a high radiation dose, an additional contrast injection as well as significantly longer examination times since the second examination has to be performed after the contrast equilibrium phase of the first examination.

Thus, the aim of this study was to evaluate whether mean temporal arterial (mTA) and mean temporal portal venous (mTPV) morphologic datasets calculated from dVPCT datasets can lead to a non-inferior image quality when compared to linearly blended 120-kVp arterial and portal venous CT acquisitions in patients with HCC or pancreatic cancer.

2. Materials and methods

2.1. Study design

This prospective HIPAA compliant single-center study was approved by the institutional review board and complies with the Declaration of Helsinki. Informed consent was obtained from all participating patients. Patients were included in the study if they fulfilled all of the following criteria: (1) histologically confirmed diagnosis of HCC and candidates to transarterial chemoembolization (TACE) or (2) clinically suspected pancreatic cancer. A priori exclusion criteria were a history of contrast material reaction and impaired renal function (creatinine higher than 1.5 mg/dl and/or glomerular filtration rate lower than 60 mL/min).

2.2. Study CT protocol

2.2.1. Dynamic volume perfusion CT protocol

All patients underwent a dVPCT acquisition on a 3rd generation dual-source CT systems (FORCE, Siemens Healthcare Sector, Forchheim, Germany) using the following scan paramaters: 70 or 80 kVp tube voltage (80 kVp in patients with an body mass index >33), 190 mAs tube current time-product at 70 kVp; 220 mAs tube current time-product at 80 kVp, 48 × 1.2 collimation, 4-dimensional spiral mode with variable pitch with a z-axis coverage of 22.4 cm. In all patients 18 spiral acquisitions were performed with a variable inter-scan delay (2 × 3 s; 10 × 1.5 s; 3 × 6 s; 2 × 15; 1 × 18) resulting in a total acquisition time of 71.2 s. The first acquisition was started 10 s after the start of the contrast injection. For contrast injection, 50 mL of nonionic iodinated contrast medium (Iomeprol 400, Bracco Imaging S.p.A., Milan, Italy) were injected through an 18-gauge needle in a antecubital vein with a flow-rate of 5 mL/s using a power injector (Stellant® D CT Injection System MEDRAD, Inc., Warrendale, USA) followed by a 50 mL saline chaser injected at the same flow rate.

All patients were instructed to hold their breath as long as possible in a mid-exhalation state. If breath hold was not possible anymore throughout the scan, patients were instructed to perform shallow breath only through their nose in order to minimize motion.

The CT raw data of dVPCT were reconstructed using filtered back projection and a medium sharp convolution kernel (Br 36) at a slice thickness of 1.5 mm and a 1.3 mm increment.

The dVPCT images were then transferred to a multi-modality workstation (SyngoVia, Siemens Healthcare Sector, Forchheim, Germany) equipped with dedicated software for the evaluation of dVPCT data (Dynamic Angio, Siemens Healthcare Sector, Forchheim, Germany). Dynamic data were corrected for motion with an integrated non-rigid registration technique. After the motion correction a 4D noise reduction algorithm was applied. All images were then reviewed by an experienced radiologist with 7 years of experience in abdominal imaging. The 3–5 best single arterial and 3–5 best single PV phases from the whole dVPCT datasets were manually selected and merged to a mTA and mTPV dataset (Fig. 1).

2.2.2. Standard dual-energy CT protocol

25 min after the dVPCT acquisition all patients underwent our institutional standard abdominal CT protocol for patients with HCC or pancreatic cancer. This protocol includes a standard dual-energy arterial and portal venous CT acquisition of their upper abdomen. Tube voltages were set to 150 kV (tube A) and 90 kV (tube B) using a 0.6 mm tin filter behind tube A for improved spectral differentiation. To compensate for the lower photon output of tube B, the quality reference tube current was set to 110 mAs for tube B and 85 mAs for tube A. The tube rotation time was 0.25 s. Automated tube current modulation (CARE Dose 4D, Siemens) was used for all patients. For contrast injection, 80 mL of nonionic iodinated contrast medium (Iomeprol 400, Bracco Imaging S.p.A., Milan, Italy) were injected through an 18-gauge needle in an antecubital vein at a flow-rate of 4 mL/s using a power injector (Stellant® D CT Injection System MEDRAD, Inc., Warrendale, USA) followed by a 50 mL saline chaser injected at the same flow rate. Arterial phase scans were performed after a threshold density of 100 HU in the abdominal aorta was detected by the bolus tracking system. Portal venous phase scans were performed 50 s after completion of the arterial phase scans.

The dual-energy CT raw data was reconstructed using an iterative reconstruction technique (ADMIRE, Siemens Healthcare Sector, Forchheim, Germany) with a slice thickness of 1.5 mm and a 1.3 mm increment with a medium sharp kernel (Qr40). The dual-energy weighting factor (M factor) for the reconstruction of 120 kVp