

Value of split-bolus multidetector-row CT technique in the quantitative assessment of pancreatic enhancement

Pankreatik tutulumun kantitatif değerlendirilmesinde bölünmüş-bolus multidetektör-dizi BT tekniğinin değeri

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ABSTRACT

The aim of this study is to quantitatively assess radiation coma, and pancreatic enhancement by split-bolus intravenous injection of contrast material using 64-slice CT. Single-pass split-bolus MDCT of the chest and abdomen was performed in 37 patients (female: 18, male: 9; mean age, 66.1±14.2 years; range 17-80 years) without pancreatic disease. Regions of interest in the pancreatic head, body and tail were drawn, and mean attenuation values for pancreatic parenchymal phase (PPP) of the standard MDCT protocol and split-bolus were calculated. $P < 0.05$ was considered statistically significant. Mean effective dose by split-bolus was measured. In all MDCT examinations split-bolus protocol allowed acquisition of optimal images. Mean pancreatic enhancement was higher by split-bolus with respect to PPP of standard triphasic MDCT (131.35 HU±20.63 vs 126.1 HU±20.01). Reduction of dose using MDCT split-bolus was approximately 17%. In conclusion MDCT split-bolus protocol provides an optimal pancreatic enhancement, significantly greater than the enhancement of standard MDCT on PPP which confers an advantage for the detection and staging of pancreatic tumors.

Keywords: Pancreas, multidetector-row computed tomography, radiation dose, oncology

ÖZ

Bu çalışmanın amacı, bölünmüş-bolus intravenöz kontrast madde kullanılarak yapılan 64 kesitli BT ile pankreatik artışı ve radyasyon dozunu kantitatif olarak değerlendirmektir. Pankreatik bir hastalığı olmayan 37 hastaya (kadın: 18, erkek: 9, ortalama yaş: 66,1±14,2 yaş, aralık 17-80 yaş) göğüs ve abdomen tek geçiş bölünmüş-bolus MDBT uygulandı. Pankreas başı, gövdesi ve kuyruğundaki ilgili bölgeler değerlendirildi ve standart MDBT protokolünün pankreatik parankimal faz (PPF) için ortalama zayıflama değerleri ve bölünmüş-bolus dozları ölçüldü. $P < 0.05$ değeri istatistiksel olarak anlamlı kabul edildi. Bölünmüş-bolus uygulamasının ortalama efektif dozu ölçüldü. Tüm MDBT incelemelerinde bölünmüş-bolus protokolü kaliteli görüntülere izin verdi. Ortalama pankreatik artış PPF için bölünmüş-bolus uygulamasında standart trifazik MDBT e göre daha yüksekti (131,35 HU±20,63 vs 126.1 HU±20.01). bölünmüş bolus dozlu MDBT 'de dozda azalma yaklaşık olarak %17 idi. Sonuç olarak, bölünmüş-bolus protokolü MDBT optimal pankreatik artış sağlar, pankreatik parankimal faz için özellikle standart MDBT değerlendirmesine göre önemli ölçüde üstünlük sağlar ve pankreas tümörlerinin belirlenmesi ve evrelemesi için avantajlıdır.

Anahtar kelimeler: Pankreas, multidetektör-dizi bilgisayarlı tomografi, radyasyon dozu, onkoloji

INTRODUCTION

Currently radiological techniques are the procedures of choice in the identification of malformative, inf-

lammatory and neoplastic diseases¹⁻³; histopathological analyses confirm the radiological diagnosis^{4,5}.

Multidetector-row Computed Tomography (MDCT) is

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the most widely used method for the evaluation of pancreatic and non-pancreatic neoplastic diseases⁶⁻⁸. In this setting the knowledge of magnitude and consistency of the normal pancreatic enhancement and of optimal contrast differences between pancreas tumor and pancreas parenchyma is essential to ensure detection of lesions and accurate evaluation of peripancreatic vessels or lymph nodes^{9,10}.

In the literature a multitude of CT protocols for the assessment of pancreatic enhancement and staging of pancreatic tumors has been reported. Standard CT protocols involve bi- or triphasic techniques with different results; one of the most relevant limitation of multiphase CT technique is the patient's exposure to increased radiation doses¹¹⁻²⁴.

Recently, instead of standard pancreatic multiphase or pancreatic CT, split-bolus MDCT (SB-MDCT) technique for detection, staging and follow-up of pancreatic tumors has been proposed²⁵. SB-MDCT, combining arterial phase (AP) and portal venous phase (PVP), allows a better tumor conspicuity reducing radiation dose.

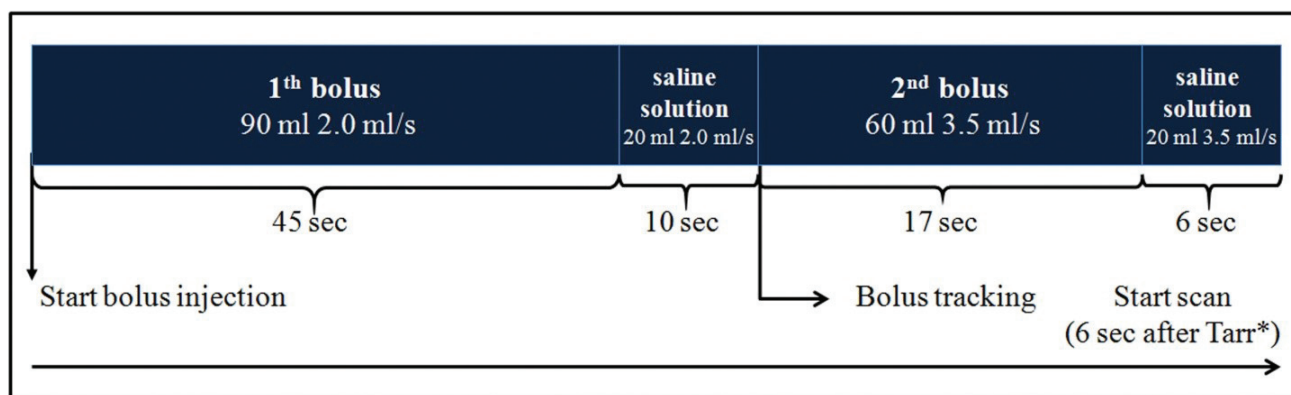
At our institution, we implemented the SB-MDCT protocol for oncologic patients that combines AP and PVP in a single-pass enabling, in addition to images of diagnostic quality, a relevant reduction in radiation exposure and in the number of images to be read and stored²⁶.

Our aim was to quantitatively assess pancreatic enhancement by split-bolus intravenous injection of contrast material using 64-section CT scanner, comparing the results with those obtained during late arterial or pancreatic parenchymal phase (PPP) of the standard multiphase MDCT.

MATERIAL and METHODS

Patients

For this retrospective study the institutional review board approval was obtained. We retrospectively reviewed follow-up thoracic, and abdominal SB 64-slice CTs (Philips Healthcare, Best, The Netherlands) of 37 patients (female: 18, male: 9; mean age, 66.1±14.2 years; range 17-80 years) with normal pancreas performed at our institution between February 2012



*Contrast arrival time

Figure 1. Schematic view of split-bolus 64-detector row CT scanning of the chest and abdomen in a 75 Kg patient. First bolus [at the start of bolus injection (or time zero)]: 90 mL of contrast medium at 2.0 mL/sec, followed by 20 mL of saline solution at same flow rate, is injected to obtain adequate abdominal parenchymal and venous system enhancement; second bolus: 60 mL of contrast medium at 3.50 mL/s followed by 20 mL of saline solution at the same flow rate to obtain hepatic arterial phase. We used bolus tracking set (raising the threshold value at 500 HU) with a circular region-of-interest (ROI) placed in the descending aorta. Approximately at the end of the second bolus injection of contrast medium, the scan started cranio-caudally after a delay of at least 6 sec from the arrival of the contrast medium in the aorta. Using the scout film, a scan range from the pulmonary apex to the pubic symphysis was determined. A single acquisition from the pulmonary apex to the pubic symphysis was performed, resulting in a simultaneous contrast enhancement of the arterial and venous system.

and July 2014. These patients had undergone triphasic MDCT scanning for primary non-malignant pancreatic tumors between January 2011 and April 2013. No patient had history of pancreatic or liver disease or marked atrophy of the pancreatic parenchyma.

SB-MDCT protocol provided unenhanced scans of the upper abdomen and acquisition of the chest-abdomen-pelvis in a single-pass after intravenous injection of contrast material (Iopamidolo, Iopamiro® 370 mgI/mL; Bracco, Milano, Italy and Iopromide, Ultravist® 370 mgI/mL Schering AG, Berlin, Germany), splitted into two boluses (Figure 1) by a power injector (Stelland CT; Medrad, Indianola, Pennsylvania).

In the SB-MDCT protocol, by applying simultaneous injections of two contrast material boli, provided a late arterial (or PPP) and a PVP, in a single-pass.

Volume of the contrast material was calculated as 2 mL/Kg, with a maximum dose of 150 mL. A schematic representation of SB-MDC single pass in a 75 Kg patient is shown in Figure 1.

Flow rate of the contrast material, duration of injection and injection times were established according to the literature data^{24,26-28}, and broad clinical experience. Hepatic enhancement during PVP occurred about 80-85 seconds after the start of intravenous injection of a bolus of contrast material and the PPP occurred about 35 seconds after the start of intravenous injection

of a bolus of contrast material.

Thus, with the first dose of 90 mL of contrast material, 20 mL of saline were delivered at a flow rate of 2 mL/sec within 55 seconds; the second dose of 60 mL of contrast material and 20 mL of saline was subsequently injected, and scanning (from the pulmonary apex) was performed 30 seconds after the second bolus for PPP or 85 seconds after the first bolus for PVP.

We used manual bolus-tracking technique for the start of the scan. Threshold value at 500 Hounsfield Units (HU) was raised and a circular region of interest (ROI) in the descending aorta was determined. The scan was started manually 6 seconds after the arrival of the second bolus of contrast material in the aorta, and from the pulmonary apex to the pubic symphysis was scanned.

In a single-pass a synchronous optimal hepatic enhancement during PVP and PPP was obtained.

For SB-MDCT technique, the following acquisition parameters were set: slice thickness 2.5 mm; gantry rotation speed 0.75 seconds; pitch 0.935:1; reconstruction index 1.25; tube voltage 120 kVp; for the tube current was used the automatic milliampere setting, based on patient's weight.

MDCT examinations were completed with sagit-

Table 1. Mean attenuation values (in HU) in 37 patients with normal pancreatic parenchyma at split-bolus and on pancreatic parenchymal phase of standard MDCT in our experience and in literature.

	Mean attenuation values on PPP*	Mean attenuation values on PPP			Mean attenuation values on split-bolus		
	Mean value	Maximum mean value	Minimum mean value	Mean value	Maximum mean value	Minimum mean value	Mean value
Pancreas	122	165.80	65.7	126	165.80	65.7	126
Celiac axis	228	474.81	205.3	324.3	474.81	205.3	324.3
SMA	245	420.10	179	314.39	420.10	179	314.39
SMV	171	269.5	119.8	180.79	269.5	119.8	180.79
Portal vein	180	240.22	115.6	190.48	240.22	115.6	190.48

*Data reported by Mc Nulty et al.⁹; SMA: superior mesenteric artery; SMV: superior mesenteric vein.

tal, coronal and curved multiplanar reconstructions (MPR).

Analyses of Images

All CT images were transferred from local digital media to a viewing station (Advantage Workstation 4.2; Magicview Philips, Netherlands) and independently reviewed by two radiologists (M.S., A.D.A.) with at least 25, and 15 years of experience in interpreting body CT images, respectively.

Image quality was rated on the following 5-point scale:

1. Excellent (excellent delineation of the pancreas and of the surrounding structures);
2. Good (good pancreas delineation, low background noise);
3. Adequate (adequate delineation of the pancreas and of surrounding structures, mild background noise);
4. Poor (poor definition of pancreas, low attenuation and difficult delineation of the structures, increased image noise, diagnostic confidence reduced); poor delineation of the pancreas and peripancreatic structures, considerable background noise);
5. Very poor, not diagnostic.

The two radiologists also reported all factors influencing quality of images (obesity, metallic and motion artifacts, contrast timing and contrast material flow-related).

The attenuation values of the pancreas in HU, were measured positioning three circular ROIs of equal size, in the most homogeneous regions of the head, the body and the tail of the pancreas, respectively, and then the mean attenuation in HU was calculated.

Mean attenuation values of the SB-MDCT were compared with the values of the PPP obtained in our experience and reported in the literature^{9,25}.

The statistical significance of the comparison was as-

sessed by Student's t test. P value <0.05 was considered statistically significant.

Dose Radiation Analysis

The dosimetric evaluation was performed analyzing the MDCT examinations with SB protocol in the patients enrolled in the study. Radiation dose measurement was based on volume CT dose index (CTDIvol) and dose-length-product (DLP). The effective dose (ED; Sievert, Sv) was calculated using the following equation:

$$ED = k \times DLP \quad k = 0.015 \text{ (conversion coefficient)}^{30}.$$

RESULTS

SB- MDCT technique provided imaging of high quality in all cases.

Mean attenuation values in HU, concentration and volume of contrast material in 37 patients with normal pancreatic parenchyma who underwent SB-MDCT and those obtained on PPP in our experience and in the literature are shown in Table 1.

The mean enhancement value of normal pancreatic parenchyma (mean values in the head, body, and tail) by SB-MDCT was 131.35 HU±20.63 (ranged from 84.15 to 187.3 HU), and it was higher than that of the mean enhancement value on PPP of standard multiphase MDCT technique reported in the literature (122 HU) and in our experience (126.1 HU±20.01, ranged from 65.7 to 165.80 HU). Difference between the mean attenuation values of SB-MDCT and PPP of standard MDCT technique in our experience was not statistically significant (P=0.27). These values were higher comparing with those reported on PPP in the literature (average 122 HU)⁹.

Maximal enhancement of the celiac axis observed on SB-MDCT and on PPP of standard triphasic MDCT in our experience (456.9 HU vs 474.81 HU) was substantially similar, and statistically significant difference was not detected between the mean attenuation

values of celiac axis at SB-MDCT and those of the standard multiphase protocol at PPP (310.6 HU vs 324.3 HU respectively; $P=0.34$).

Maximal enhancement of superior mesenteric artery observed during SB-MDCT and PPP of standard MDCT was 420 HU vs 420.1 HU respectively; any statistically significant difference was not observed between the mean attenuation values at SB-MDCT and those of the standard multiphase protocol at PPP (298.77 HU vs 314.39 HU respectively; $P=0.27$).

Maximal enhancement of the superior mesenteric vein and portal vein was observed during the SB-MDCT. A statistically significant difference was not observed between the mean attenuation values of

superior mesenteric vein at SB-MDCT and those of the standard multiphase protocol at PVP (195.85 HU vs 180.79 HU respectively; $P=0.06$).

The attenuation values of the main portal vein at SB-MDCT were significantly higher than those of the standard multiphase protocol at PVP (215.03 HU vs 190.48 HU, respectively; $P=0.001$).

A representative case of pancreas with normal contrast enhancement at SB-MDCT is shown in Figure 2.

In our 37 patients, whole-body SB-MDCT in a single-pass provided a radiation dose in mSv ranged from 12.14 to 27.01 mSv (average 19.3 ± 6.3 mSv) with a reduction of approximately 17% with respect to stan-

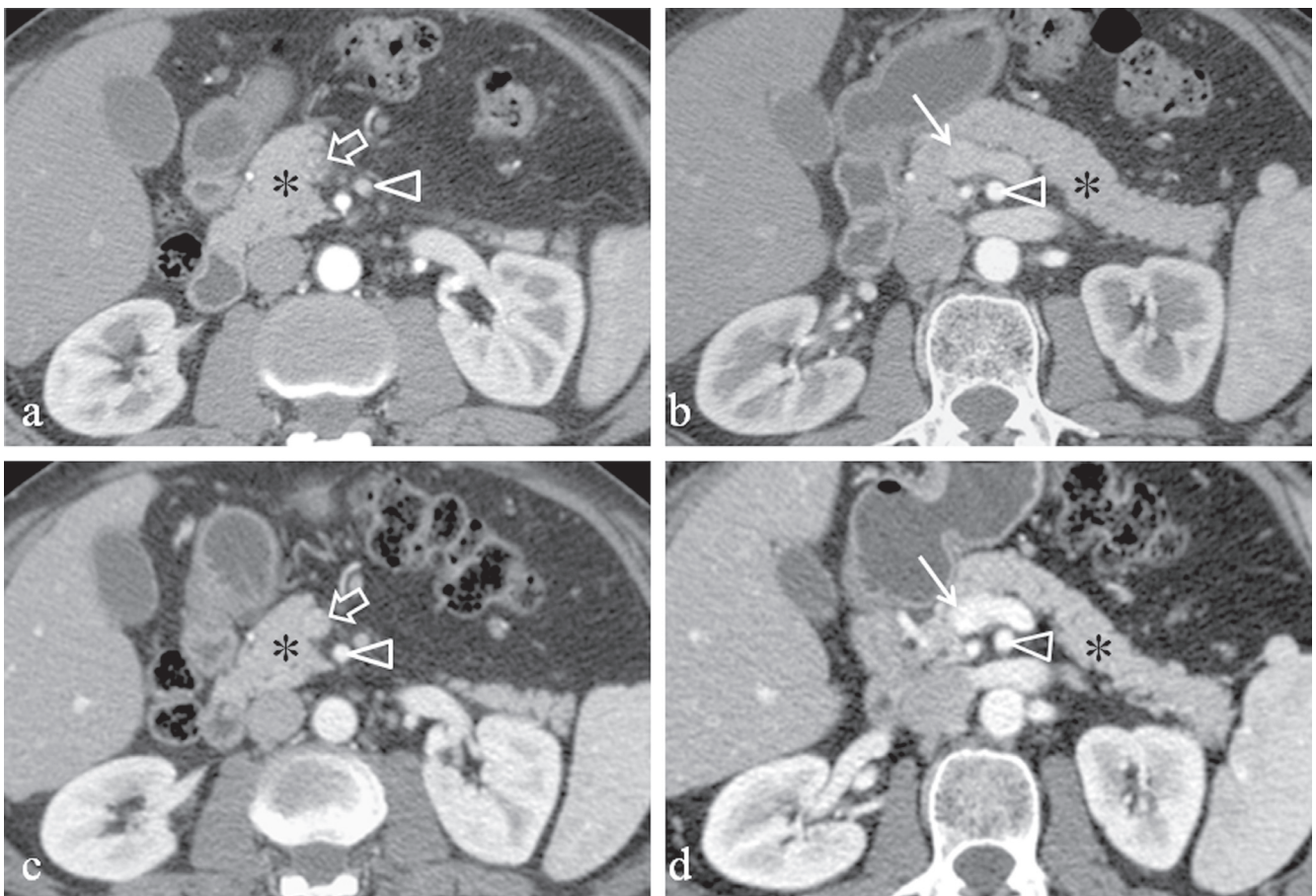


Figure 2. 60-year-old man with normal pancreas. Pancreatic parenchymal phase during triphasic (a,b) MDCT and combined arterial-venous phase of the split-bolus (c,d) MDCT technique. Pancreatic parenchymal phase (a,b) shows pancreatic parenchyma (*) which is 114.6 HU compared with 141.2 HU of combined arterial-venous phase of the split-bolus (c,d). On combined arterial and venous phase of split bolus (c,d) MDCT, there is also greater enhancement of the superior mesenteric artery (arrow head in c,d) and mesenteric vein (arrow in c) and portal vein (thin arrow in d).

standard triphasic MDCT in our experience. A potentially dose reduction can be obtained when compared with an unenhanced acquisition, and SB of the upper abdomen. Our results were lower than those reported in the literature²⁵.

DISCUSSION

MDCT is the procedure of choice in the identification of pancreatic malignancy⁶ and other unusual tumors^{7,8}. CT, in particular, is the method of choice in the assessment of normal pancreatic parenchyma and in the detection and staging of pancreatic adenocarcinoma^{9,12,20}. The majority of standard CT protocols^{9,11,12,31-34}, entails an unenhanced acquisition followed by pancreatic parenchymal phase (PPP), portal venous phase (PVP) and delayed phase.

This combination of contrast phases, although performed with different CT scanners, flow rates and volumes of contrast material, provides perfect conspicuity of pancreatic tumor, its proximity to vessels and detection of metastases. PPP during the standard bi- or triphasic CT, is the most sensitive phase for the evaluation of pancreatic parenchyma^{9,20}. An average volume of 135 mL of contrast material delivered at a flow rate of 4 mL/sec, provides a pancreatic enhancement ranging from 82.2 HU to 122 HU (average 105.7 HU)⁹.

Nevertheless, multiphase CT also exposes the patient to very high radiation doses.

Recently, to reduce the radiation exposure and to maintain diagnostic value of CT and its image quality, split-bolus (SB) contrast injection with spectral MDCT imaging of the normal pancreas and pancreatic adenocarcinoma has been proposed²⁵.

As radiologists we need to reduce the radiation exposure, due to its known risks, without deterioration of the image quality and, most importantly, maintaining diagnostic efficacy of the CT scan. Among CT protocols for pancreas evaluation, the aim is to obtain an optimal pancreatic enhancement to identify

normal pancreatic parenchyma and to maximize the attenuation difference between the tumor and the surrounding pancreatic parenchyma.

In addition, assessment of peripancreatic vessels, lymph nodes and detection and characterization of focal liver lesion are needed.

Our aim is to evaluate the feasibility of SB 64-multidetector row CT compared to PPP of the standard MDCT scan protocol in the evaluation of the enhancement of the normal pancreatic parenchyma.

In the study of Brook et al.²⁵, using CT unit with spectral imaging, SB spectral CT was combined with pancreatic and portal venous phases in a single scan through two contrast material injections separated by a short pause: 70 seconds before CT, 100 mL of contrast materials were injected for the PVP, followed by a second injection of 40 mL of contrast material approximately 35 seconds later, to boost the pancreatic phase. Using the bolus-tracking technique scanning started 15 seconds after aorta attenuation reached 280 HU. Mean values of enhancement of normal pancreatic parenchyma for SB and standard protocol in PPP were 212.2 HU±64.7 vs 105.1 HU±29.3 respectively and the mean effective dose by SB was 20 mSv²⁵.

Our results, with respect to the normal pancreatic enhancement, differ from those of Brook because our study included patients of different ages and weights. Besides, we did not use CT unit with spectral imaging and, finally, injections of two contrast materials were not separated by a short pause and flow rate and volume of contrast materials were different.

These results have encouraged the use of SB-MDCT technique in the evaluation of the pancreas because this improvement in enhancement can enable a greater conspicuity and visualization of the pancreatic neoplasm and other pancreatic abnormalities. SB-MDCT also provides an accurate evaluation of the peripancreatic arterial and venous vessels and lymph nodes, that is essential to stage pancreatic cancer. In

addition synchronous phases (arterial and parenchymal hepatic enhancement during PVP) provide an optimal evaluation of both pancreas and liver (ie detection of hypervascular and hypovascular metastases). A further advantage of the SB-MDCT protocol is reduction of the effective dose of radiation compared to bi- or triphasic MDCT technique.

A potential reduction of radiation dose down to 60% should be obtained if the SB-MDCT protocol was used in the study of the upper abdomen. This is important for example in the follow-up of the patients with necrotizing pancreatitis, in whom it is necessary to rescan them 7-10 days later, to evaluate size, extension and characteristics of the postnecrotic fluid collections.

Study limitation: our study included a small number of patients with different ages and body weights without pancreatic abnormalities, who had undergone whole body CT in the follow-up for malignant tumor.

In conclusion, these preliminary results demonstrated the effectiveness of SB 64-section MDCT scanner in the evaluation of the pancreas. The advantages of SB-MDCT protocol in the study of the pancreas are its ability to provide an optimal enhancement of the normal pancreatic parenchyma that allows detection of the tumor, in addition to the possibility to minimize radiation dose and number of images and data to be stored.

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