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Original Research Article

Optimization of Scan Delay in Contrast Enhanced Computed Tomography of Pancreas Using Bolus Tracking

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ABSTRACT

Introduction: Pancreatic pathologies present a challenge for the medical imaging professionals for detection, classification and staging. Multiphasic multidetector computed tomography provides detailed visualization and definition of deeper and smaller structures and enhancement pattern of tumors during different phases. The objective of this study was to optimize the scan delay time for contrast enhanced computed tomography of pancreas after the use of bolus tracking technique.

Materials and methods: Triphasic MDCT of the pancreas was performed on 109 patients after administration of 300-350 mgI/mL contrast medium injected at 3.5 mL/s. Patients were prospectively randomized into three groups with different scanning delays for the three phases (arterial, pancreatic, and venous) after bolus tracking was triggered at 100 HU of aortic contrast enhancement. Mean attenuation values of the abdominal aorta, superior mesenteric artery, pancreatic parenchyma, splenic vein, portal vein, and hepatic parenchyma were measured. Increases in attenuation values after contrast administration were assessed.

Results: Mean contrast enhancement in the aorta (change in attenuation, 313–320 HU) and the superior mesenteric artery (change in attenuation, 291–302 HU) approached peak enhancement 4-7 seconds after bolus tracking was triggered. Pancreatic parenchyma became most intensely enhanced (change in attenuation, 107–110 HU) 20-25 seconds after triggering, and then the enhancement gradually decreased. Enhancement of the splenic vein and portal vein peaked at 22 seconds. Liver parenchyma reached 71 HU, 25 seconds after triggering and reached a plateau (change in attenuation, 81-76 HU) at a further

scanning delay of 45–50 seconds.
Conclusion: Based on the protocol used in this study, the optimum scan delay were 4-7 seconds for arterial phase, 10-22 seconds for pancreatic parenchymal phase and 40-50 seconds for the hepatic parenchymal phase; after bolus tracking triggered at 100 HU in the abdominal aorta.
Keywords : Bolus tracking, Computed Tomography, Optimization, Pancreas, Scan delay

I. INTRODUCTION

Detection, classification and staging of various pancreatic pathologies are a major challenge for professionals associated with the medical imaging. Ultrasonography (USG) has been used to evaluate abdominal pathologies, and its advantages include wide availability, low cost, and lack of radiation. Despite significant improvements and refinements in ultrasound technology, there are still inherent problems when imaging deep in the abdomen, especially in large patients. Detailed visualization and definition of deeper and smaller structures and of subtle changes in density of the normal and abnormal pancreas are now possible with images generated by multidetector computed tomography (MDCT) scanners. The scope of multiplanar reconstruction with MDCT scanners has added remarkably to the ability to visualize and understand complex anatomic structures and relationships.1,2,3.

Contrast enhanced CT of the pancreas has been widely accepted for depiction and preoperative staging of various pancreatic pathologies. Although it is suggested that single-phase scanning is effective for the diagnosis and assessment of resectability of suspected pancreatic carcinoma, CT images of the pancreas often are acquired at different phases of contrast enhancement with a single bolus of intravenous contrast medium; that is, at peak enhancement of the pancreas and peak enhancement of the peripancreatic vessels; to maximize the conspicuity of pancreatic tumors and visualization of peripancreatic vessels.4,5 A multiphasic CT technique allows evaluation of tumors and adjacent regions at different enhancement times and thus improves the delineation of tumors and local extent. Appropriate scan timing to achieve adequate contrast enhancement at each phase is more difficult and critical with multidetector row CT than with single detector row CT.6,7 Conventionally, with single detector row CT, a fixed scan delay was used for the assessment of pancreas after injection of contrast medium. The routine scan delays used were determined as fixed values without consideration of individual variations in cardiovascular circulation time. However those scan delays are not appropriate due to physiological and pathological variation of hemodynamics. It is thus essential to use a test bolus or a bolus tracking technique to measure contrast arrival time in order to acquire images at predetermined phases.

II. METHODS AND MATERIAL

This was a quantitative, descriptive, cross-sectional study performed in Department of Radiology and Imaging, Tribhuvan University Teaching Hospital, Nepal. The study population consisted of all the patients referred to the department for triple phase contrast enhanced CT of abdomen within the 4 months study period (April 2022- August 2022).

Probability sampling technique was used in sampling of the population. The total sample size consisted of all patients referred for triple phase CECT abdomen. All the patients above 16 years of age were included in the study, however patients with known pancreatic pathologies and who have undergone major abdominal surgery (partial hepatectomy, total splenectomy) were excluded from the study. Images not appropriate for diagnosis (eg. improper scan technique, images with artifacts) were also excluded. The study variable chosen for this study was mean attenuation value (Hounsfield Units, HU) of various anatomical structures.

Tools and techniques for data collection:

The study was conducted in Siemens Somatom Definition AS+ 128 slice CT scanner (Siemens Healthcare, Erlangen, Germany). The patients were well explained about the procedure and after obtaining written consent, all patients were given non-ionic iodinated contrast media (300-350 mgI/ml) at a rate of 3.5 ml/s. The volume of contrast media was determined according to patient weight (1 ml/ kg). Bolus tracking software inherent in the scanner was used for the study. The threshold value for bolus tracking software was kept at 100 HU. Contrast medium volume and delivery rates were pre-recorded on an automatic pressure injector system (Mallinckrodt co.). Patients were prospectively assigned among the following three groups according to weight such that three-phase scanning (arterial, pancreatic parenchymal, and venous phases) commenced from the start of contrast medium injection at the following times (after bolus tracking):

–group 1 (4, 20, 45 seconds)
–group 2 (7, 22, 47 seconds), and
–group 3 (10, 25, 50 seconds)
The images were analyzed both quantitatively and qualitatively.

Quantitative analysis:
Mean CT numbers (in HU) of the abdominal aorta, spleen, pancreatic parenchyma, superior mesenteric artery and vein, splenic vein, and hepatic parenchyma were measured on the CT monitor with circular ROI on the first, second and third phase images. Attenuation values of the abdominal aorta were measured at the level of the diaphragmatic dome. Pancreatic parenchymal values were measured in three regions (pancreatic head, body, and tail) and then averaged. Portal venous values were measured in two regions (right and left main branches) and then averaged. All of the measurement locations were same in the image sections acquired at different enhancement phases. Hepatic parenchymal values were measured in three regions (right anterior segment, right posterior segment, and left lobe) and averaged. Focal lesions, blood vessels, biliary and pancreatic ducts, calcifications, and artifacts were excluded from the measurement areas.

Qualitative analysis:

Two independent radiologists blinded to the quantitative analysis results reviewed the enhancement pattern in four grades:
0: Almost no enhancement; 1: Minimal to mild enhancement; 2: Moderate enhancement; 3: Intense enhancement.

III. RESULTS AND DISCUSSION

RESULT

A total of 109 patients underwent routine triple phase CECT of abdomen and pelvis, who were suspected of abdominal pathologies without any prior history of pancreatic abnormalities. The three groups of patients consisted of 58, 31 and 20 patients respectively.

The patients' age ranged from 18-82 years with a mean age of 46.23 (SD ±18.669) years. According to

gender wise distribution, 47 (43.11%) were male and 62 (56.88%) were female. The maximum and minimum weight of the patients was 42 and 78 respectively with a mean weight of 58.40 (SD ±8.709) kg.

Mean contrast enhancement in attenuation values (HU) in different phases of contrast enhancement were analyzed in this study. The mean enhancement values composite of all three phases is shown in the table below:

Table 1. Mean attenuation values in different phases (three groups combined)

Anatomic area	4 sec delay	7 sec delay	10 sec delay	20 sec delay	22 sec delay	25 sec delay	45 sec delay	47 sec delay	50 sec delay
Abdominal aorta	313.96 (37.39)	320.83 (29.89)	285.65 (22.60)	245.10 (42.34)	218.65 (33.31)	192.6 (22.90)	154.22 (42.34)	139.4 (33.31)	117.45 (22.90)
Superior Mesenteric Artery	302.58 (38.29)	291.66 (30.63)	284.10 (24.50)	215.54 (38.26)	191.66 (30.63)	165.81 (24.24)	125.04 (38.26)	109.16 (30.63)	106.31 (24.24)
Liver	45.86 (7.58)	48.22 (7.10)	51.37 (5.5)	65.86 (7.58)	68.22 (7.10)	71.37 (5.58)	76.06 (7.58)	78.42 (7.10)	81.57 (5.58)
Pancreas	76.41 (7.8)	76.18 (8.33)	75.62 (7.29)	110.92 (7.82)	110.68(8.33)	107.63 (7.29)	75.58 (7.82)	73.21 (8.33)	72.22 (7.29)
Portal Vein	44.80 (7.05)	48.22 (7.10)	47.30 (7.57)	73.00 (7.01)	76.42 (7.10)	75.5 (7.57)	105.4 (7.01)	108.82 (7.10)	107.9 (7.57)
Splenic Vein	73.46 (6.15)	72.65 (6.12)	68.74 (3.02)	125.4 (6.15)	124.65 (6.1)	120.74 (3.02)	155.67 (6.15)	154.85 (6.12)	150.94 (3.02)

Note: Numbers in parenthesis denote SD.

The mean change in attenuation of abdominal aorta peaked (320 HU) at 7 seconds after bolus tracking was triggered and then decreased constantly with time. The mean change in attenuation of the abdominal aorta was significantly higher ($p<0.05$) 7 seconds than 10 seconds after bolus tracking. The mean change in attenuation of SMA showed a peak (302 HU) 4 seconds after triggering and decreased constantly with time. The mean change in attenuation was significantly higher ($p<0.01$)7 seconds than it was 10 seconds after bolus tracking was triggered. The mean change in attenuation of pancreatic parenchyma increased constantly between 4 and 10 seconds after triggering of bolus tracking, peaked (107-110 HU) at 20-25 seconds, and decreased constantly. The mean change in attenuation of pancreas was significantly higher ($p< 0.01$) 20-25 seconds, than it was in the first phase of the study. Thus we considered this phase to be optimal for depiction of pancreas.

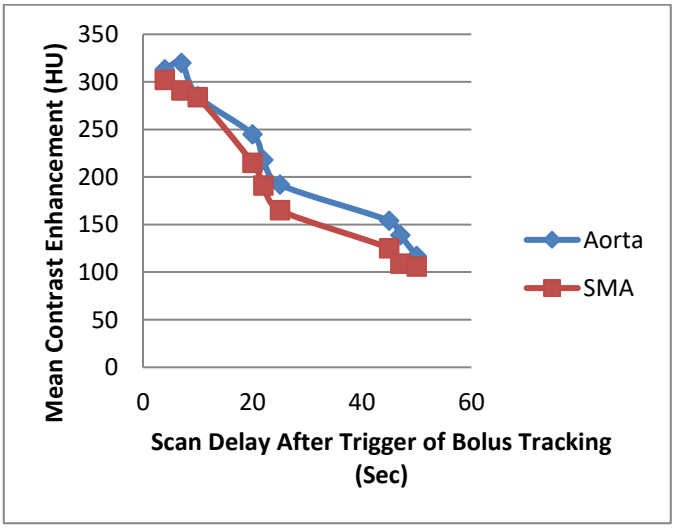

Fig. 1 : Curves of scanning delay vs. mean contrast enhancement values for abdominal aorta and SMA.

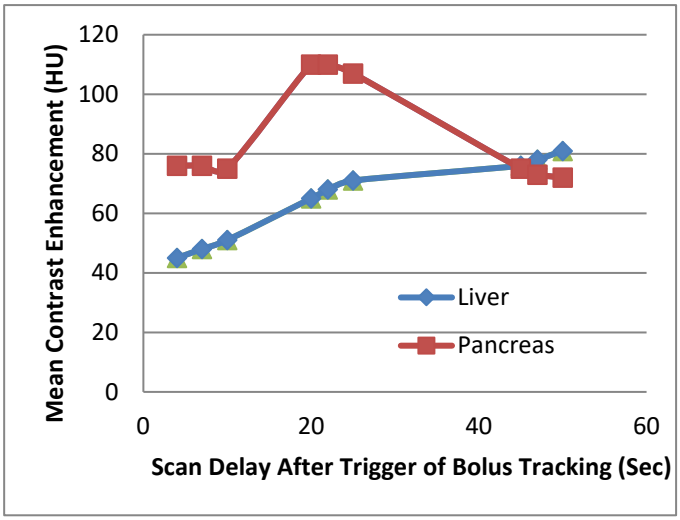

Fig.2 : Curves of scanning delay vs. mean contrast enhancement values for liver and pancreas.

Qualitative analysis of the resultant images was also performed by grading the image quality. Inter-observer agreement was calculated by kappa statistics. A kappa value upto 0.20 indicated slight agreement; 0.21-0.40, fair agreement; 0.41-0.60, moderate agreement; 0.61-0.80, good agreement; and 0.81 or greater, almost perfect agreement.

The kappa values for independent rating by the two reviewers ranged from 0.6 to 0.8 (mean 0.7) indicating good to almost perfect agreement.

Table 2. Inter-observer agreement for enhancement of different anatomical structures

Anatomical area	Kappa score
Abdominal aorta	0.73
Superior mesenteric artery	0.75
Liver	0.68
Pancreas	0.78
Portal vein	0.65
Splenic vein	0.65

DISCUSSION

A study by Hu H. et.al.[8] showed that the quality of images generated by using multidetector row CT is comparable with that of images generated by using single– detector row CT, even with a threefold increase in volume coverage. Appropriate scan timing with multi detector row CT, however, is more difficult and critical than with single detector row CT and requires a redesign of imaging protocols and more attention to bolus timing[9].

Bae K.[10] demonstrated in a pharmacokinetic study with a porcine model that time to peak aortic enhancement increases linearly with injection duration and occurs shortly after injection completion when the injection duration is longer than the time to peak test bolus enhancement. The study confirmed that time to peak aortic enhancement was 4.3 seconds after the completion of either a 20- or 30-second injection, which implied that this theory could be applied to pancreatic CT scanning protocols. In our study, however we used the bolus tracking technique, which is a means of compensating for individual patient variations in determination of optimal delay.
Degree of contrast enhancement in the pancreas with different scanning delays has been investigated in several studies. Hollett et al.[11], using an injection of 150 mL of contrast material (300 mgI/mL) at a rate of 5 mL/s and single detector helical CT, found that pancreatic enhancement on images obtained with a delay of 20 seconds after the start of contrast injection was significantly greater than enhancement on images obtained with a standard delay of 49–71 seconds. Lu et al.[12], using an injection of 150 mL of contrast material (300 mgI/mL) at 3 mL/s and dual-detector CT, found that helical CT images obtained during the pancreatic phase (40–70 seconds after the start of injection) showed significantly greater tumor-to-pancreas contrast than did images obtained during the hepatic phase (70–100 seconds).

More recently, Kondo et.al.[4], using an injection of 150 ml of contrast material (300 mgI/mL) at a rate of 4 ml/s and 8 detector row MDCT found that optimal scanning delay after bolus tracking at 50 HU of aortic contrast enhancement found that 15-20 seconds was optimal for pancreatic parenchymal phase. Our study also resulted in similar findings as this study however, the 15-20 seconds as concluded in this study varies with our 20-25 sec findings due to the use of lower injection rate of 3.5 ml/s and lower contrast volume (85-100 ml) in our study.

McNulty et al.[13], using an injection of 150 mL of contrast material (300 mg I/mL) at 4 mL/s and 4-MDCT, found that pancreatic enhancement on images obtained with delays of 35 and 60 seconds (122 and 109 HU, respectively) after the start of contrast injection was significantly greater than enhancement on images obtained 20 seconds (70 HU) after the start of injection. The difference in attenuation value (32 HU) at 25 and 50 seconds in our study was greater (35 HU) than the 13 HU observed by McNulty et al. This difference may be attributed to the different scan durations of 4 and 128 detector row MDCT. The timing was approximately 10 seconds for the pancreatic phase of 4 MDCT but no more than 4.3 seconds for 128- MDCT. Increasing the number of detector rows reduced scanning time and enabled scanning of the entire pancreas during the most intense period of pancreatic enhancement.

Previous studies on pancreatic CT by Kondo et. al.[4] and Fletcher et.al.[5] stated that the attenuation of pancreatic parenchyma during the pancreatic phase range from 80-100 HU. These results are in slight disagreement with our study where we found out that the attenuation of pancreatic parenchyma during pancreatic phase range from 100-120 HU. The probable reason why this attenuation value was higher than previously reported is that we used thin sections of only 0.5 mm. This thin section evaluation allowed to keep the partial volume averaging to a minimal thereby no deterioration of CT numbers was evident. Our study also differentiated from the recent study by Goshima et. al.[14] who depicted mean attenuation of pancreas more than 120 HU in which they employed 320 detector row MDCT, however we used only 128 detector row MDCT.

In our study, the abdominal aorta showed peak enhancement at 7 seconds after bolus tracking was triggered and the superior mesenteric artery 4 seconds after triggering. Thus, instead of choosing a single time point, we suggest 4-7 seconds after bolus-tracking triggering as optimal scanning delays for peripancreatic arteries (i.e., combining aorta and superior mesenteric artery). However for 3D display of the arteries as in preoperative evaluations, a delay time of 5 seconds should suffice and will produce CT angiographic type images of the arteries. Our qualitative evaluation results support this deduction.

We used a relatively moderate injection rate of 3.5 mL/s. This rate was found to be clinically acceptable in all patients despite debate about contrast material injection rates. For example, Tublin et al.[15]reported that peak enhancement of the pancreas and liver were significantly different for two contrast injection rates (2.5 vs 5.0 mL/s), and Kim et al.[16] reported that contrast material volume and injection rate are directly related to pancreatic parenchymal enhancement; that is, pancreatic parenchymal enhancement increased as injection rate and volume were increased.

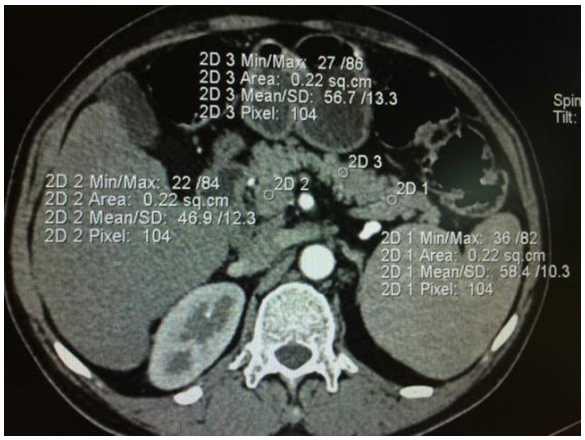

Fig 3. : Axial CT image showing different measurements

IV. CONCLUSION

Based on the protocol used in this study, the optimum scan delay were 4-7 seconds for arterial phase, 10-22 seconds for pancreatic parenchymal phase and 40-50 seconds for the hepatic parenchymal phase; after bolus tracking triggered at 100 HU in the abdominal aorta. Delay time can be varied based on various parameters like contrast concentration, volume, detector assembly etc; so department wise delays may be produced and used for multiphase scanning of various anatomy. These scan delays can be utilized in optimization of routine clinical abdomen and pelvis imaging protocol for better delineation of pancreatic pathologies. We assume that improvement in enhancement of the pancreatic parenchyma will help in diagnosis and staging of pancreatic tumors and further studies considering the pancreatic pathologies are recommended.

V. REFERENCES

[1]. Haaga John R., Charlez F. Lanzier; CT and MR Imaging of the whole body. 4th Edition USA. Mosby 2002

[2]. Adam A, Dixon AK; A textbook of Medical Imaging. 5th edition, USA, Churchill Livingstone

[3]. Ryan Stephanie, McNicholas Michelle, Eustace Stephen; The Abdomen. Anatomy for Diagnostic Imaging. 2nd Edition Ireland. C Elsevier Limited 2004

[4]. Kondo H, Kanematsu M, Goshima S et al. MDCT of the pancreas: Optimizing Scanning Delay with a bolus-tracking technique for pancreatic, peripancreatic vascular and hepatic contrast enhancement. AJR:188, March 2007

[5]. Fletcher JG, Wiersema MJ, Farrell MA, et al. Pancreatic malignancy: value of arterial, pancreatic, and hepatic phase imaging with multi–detector row CT. Radiology 2003; 229:81–90

[6]. Goshima S, Kanematsu M, Kondo H, et al. Pancreas: Optimal scan delay for contrast enhanced multi-detector row CT. Radiology 2006;241(1):167-174

[7]. Hollett MD, Jorgensen MJ, Jeffrey RB Jr. Quantitative evaluation of pancreatic enhancement during dual-phase helical CT. Radiology 1995;195:359–361.

[8]. Hu H, He D, Foley D, Fox SH. Four multidetector- row helical CT: image quality and volume coverage speed. Radiology 2000;215: 55–62.

[9]. Berland LL, Smith JK. Multidetector-array CT: once again, technology creates new opportunities. Radiology 1998;209:327–329.

[10]. Bae KT. Peak contrast enhancement in CT and MR angiography: when does it occur and why? pharmacokinetic study in a porcine model. Radiology 2003;227:809–816.

[11]. Hollet MD, Jorgensen MJ, Jeffery RB Jr; Quantitative evaluation of pancreatic enhancement during dual phase helical CT. Radiology 1995; 195(2):359-361

[12]. Lu DS, Vedantham S, Krasny RM, Kadell B, Berger WL, Reber HA. Two-phase helical CT for pancreatic tumors: pancreatic versus hepatic phase enhancement of tumor, pancreas, and vascular structures. Radiology 1996; 199:697–701

[13]. McNulty NJ, Francis IR, Platt JF, et al. Multi–detector row helical CT of the pancreas: effect of contrast- enhanced multiphasic imaging on enhancement of the pancreas, peripancreatic vasculature, and pancreatic adenocarcinoma. Radiology 2001; 220:97–102

[14]. Goshima S, Kanematsu M, Nishibori H, et al., CT of the pancreas; Radiology 2011; 260; 139-147

[15]. Tublin ME, Tessler FN, Cheng SL, Peters TL, McGovern PC. Effect of injection rate of contrast medium on pancreatic and hepatic helical CT. Radiology 1999; 210:97–101

[16]. Kim T, Murakami T, Takahashi S, et al. Pancreatic CT imaging: effects of different injection rates and doses of contrast material. Radiology 1999; 212:219–225

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