

Helical Computed Tomography of the Abdomen: Evaluation of Image Quality Using 1.0, 1.3, and 1.5 Pitches

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Background: The purpose of this study was to investigate whether trained radiologists can distinguish minor differences among computed tomography (CT) images of extended helical pitches of 1.0 to 1.5.

Methods: Between September 2000 and February 2001, 72 patients were randomized into 1 of 3 equal groups: helical pitches of 1.0, 1.3, and 1.5. The imaging parameters of all patients were kept constant. Twelve of the 72 patients were excluded because of various pathological conditions. In a total, 60 examinations were enrolled in the evaluation study. Three radiologists blinded to the image parameters were asked to independently evaluate 9 normal structures and overall images of 60 studies using a scale from 1 (worst) to 5 (best).

Results: There were no statistically significant differences in evaluation of image quality among helical pitches 1.0, 1.3, and 1.5 of abdominal CT when assessing 9 normal structures and overall images independently ($p > 0.05$).

Conclusions: Abdominal CT performed with helical pitches of 1.0, 1.3, and 1.5 were equivalent in this study. With the use of a helical pitch greater than 1, clinicians can benefit from increased scan coverage in less time and with less radiation than can be achieved with standard helical pitch-1.0 protocols. (*Chnag Gung Med J 2002;25:104-9*)

Key words: computed tomography, abdomen CT, helical pitch.

Helical or spiral computed tomography (CT) offers continuous volume scanning of complete organs or body sections within a single holding breath, eliminating slice-to-slice misregistrations.⁽¹⁻³⁾ In addition, it also affords the opportunity to scan an even greater patient volume by increasing the pitch over 1.0. (Pitch ratio is defined as the ratio of the table increment per 360° gantry rotation to the collimation setting).

Theoretically, increased helical pitch will increase longitudinal (z-axis) blurring as a result of

the broadened section-sensitivity profile inherent to helical acquisition. However, this has been improved by the development of the 180° linear interpolation algorithm.^(4,5) The purpose of this study was to evaluate whether trained radiologists can distinguish minor differences among images using different pitches.

Although several investigators have reported success in using an extended pitch (>1.0) for thoracic and abdominal CT,⁽⁶⁻¹⁰⁾ a comprehensive prospective clinical trial comparing 1.0-pitch with 1.3- and 1.5-

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pitch abdominal CT scans has not been performed. This study subjectively compared the image quality of 1.0-, 1.3-, and 1.5-pitch abdominal helical images, then determined the practical application of extended-pitch helical CT.

METHODS

During a 6-month period from September 2000 through February 2001, 72 outpatients (41 male and 31 female patients; age range, 35-72 years; mean age, 54 years) with clear consciousness and well capable of performing a breath-holding technique were enrolled in this study. All patients underwent contrast-enhanced abdominal CT and were randomized equally into 3 groups: helical pitches 1.0, 1.3, and 1.5 CT. They were imaged on a GE Advantage HiSpeed Scanner (General Electric Medical Systems, Milwaukee, WI, USA) using 220 mA and 120 kVp, with a 10-mm thickness and a 10-mm reconstruction interval. One hundred milliliters of iodinated contrast medium (Optiray 350, 74%, Mallinckroft Canada Inc., Quebec, Canada) was intravenously administered at a rate of 2.5 ml/sec through a 20-gauge needle; scanning was started 25 seconds after initiation of the contrast injection. The same (standard) reconstruction algorithms were used for all studies. All images were photographed with the same window (270), level (+70), and format (12 on 1), using a 34-cm field of view.

Twelve of the 72 patients were excluded from the study evaluation because of conditions believed to affect blood flow in the abdomen, including cirrhosis, cardiac disease, or a history of hypotension, a central hepatic tumor obstructing portal vein flow, extensive hepatic involvement by a tumor, massive pleural effusion, and ascites. As a result, 60 patients were included in the evaluation.

The scanning parameters of all studies were masked with a randomized order. Three radiologists were asked to independently grade the studies on a scale of from 1 (worst) to 5 (best) for overall quality and delineation of 9 normal anatomical structures (main portal vein, liver parenchyma, celiac artery, superior mesenteric artery, renal veins, adrenal gland, renal corticomedullary differentiation, psoas muscle, and pancreas). Prior to formal scoring of the CT scans obtained in patients enrolled in this study, the 3

reviewers observed 5 CT scans obtained in patients not in the study population and assigned scores in consensus to ensure consistency in the use of the grading scheme.

Data were analyzed using one-way analysis of variance (ANOVA) to compare image quality scores among the 3 pitches. The chi-square test of homogeneity was used to test whether variations in scores given by the 3 reviewers significantly differed. A *p* value of <0.05 was considered statistically significant.

RESULTS

There were no statistically significant differences in visualization of any of the normal anatomic structures among the 3 pitches (Table 1) (Fig. 1). In the evaluation of individual structures, the superior mesenteric artery, renal veins, and adrenal gland were best visualized with the pitch-1.0 study. The main portal vein, celiac artery, and pancreas were best visualized with the pitch-1.3 study, while the

Table 1. Calculated Mean Scores (SD*) for 9 Normal Anatomic Structures

Region	Pitch			<i>p</i>
	1.0 (N=60)	1.3 (N=60)	1.5 (N=60)	
Main portal vein	3.75 (0.51)	3.83 (0.46)	3.65 (0.63)	0.178
Liver parenchyma	3.42 (0.65)	3.37 (0.71)	3.45 (0.83)	0.822
Celiac artery	3.95 (0.67)	4.02 (0.77)	3.88 (0.67)	0.586
Superior mesenteric artery	3.70 (0.79)	3.62 (1.09)	3.68 (0.83)	0.870
Renal veins	3.65 (0.95)	3.57 (1.05)	3.50 (0.91)	0.699
Adrenal gland	3.32 (1.11)	3.28 (0.90)	3.22 (0.94)	0.853
Renal corticomedullary differentiation	4.30 (0.67)	4.23 (0.67)	4.32 (0.78)	0.792
Psoas muscle	4.42 (0.56)	4.48 (0.57)	4.52 (0.60)	0.626
Pancreas	3.37 (0.76)	3.43 (0.7)	3.38 (0.61)	0.860
Overall	3.70 (0.65)	3.57 (0.72)	3.62 (0.61)	0.538

*SD = standard deviation.

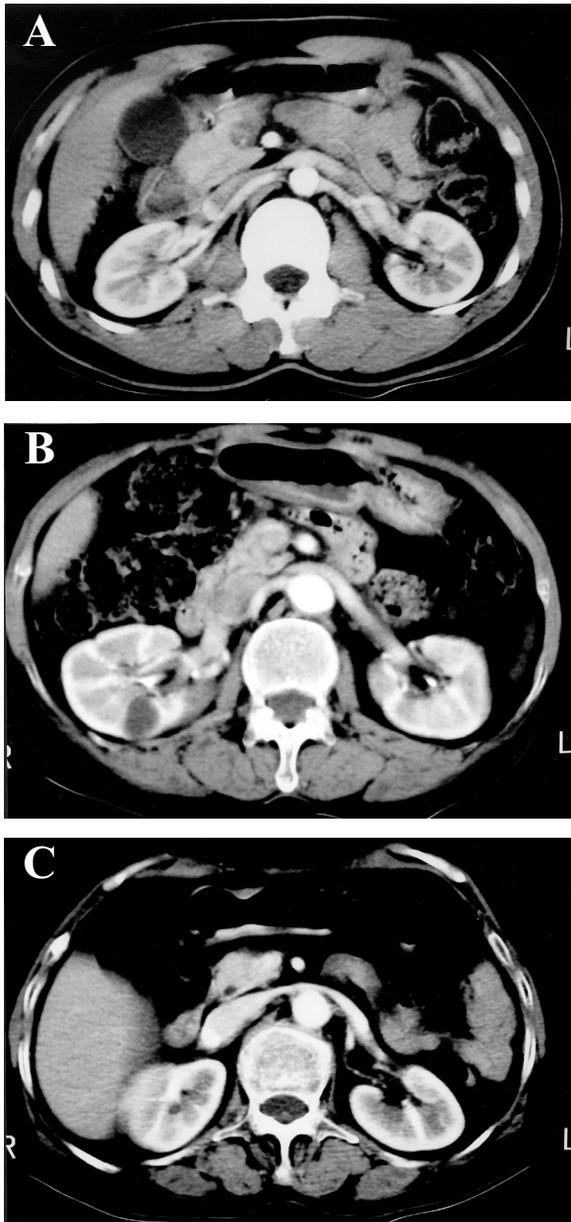


Fig. 1 Contrast-enhanced helical CT images of the abdomen at the level of the renal pelvis performed with helical pitches of (A) 1.0, (B) 1.3, and (C) 1.5. The mean image quality scores for individuals were 3.7, 3.7, and 4.3, respectively, for the renal vein, and 4.0, 3.7, and 3.7, respectively, for renal corticomedullary differentiation.

liver parenchyma, corticomedullary differentiation, and psoas muscle were best demonstrated with the pitch-1.5 study. However, these differences were not

statistically significant.

Individual questions subjectively assessing overall image quality (edge definition, noise, and low contrast sensitivity) were assessed using the same grading scale of from 1 (worst) to 5 (best). The mean score for helical pitch 1.0 was 3.70 compared to 3.57 and 3.62 for pitches 1.3 and 1.5, respectively. There was generally a small drop-off in the mean score with increasing pitch. However, the difference was not statistically significant ($p=0.538$).

Distribution of the scores for the 3 reviewers is given in Table 2. The chi-square test for homogeneity indicated that the variation of the scores among the 3 reviewers did not significantly differ ($X^2=11.445, df=8, p=0.178$).

Table 2. Score Distribution among the Three Reviewers

Reviewer	Score				
	1	2	3	4	5
A	6	38	177	209	110
B	9	32	210	188	101
C	11	47	208	192	82

DISCUSSION

Because many helical CT applications require both good longitudinal resolution and fast volume-coverage speed, it becomes very important to understand how helical pitch and X-ray collimation affect the object contrast and slice profile in order to optimize helical scan parameters for specific clinical applications. With 180° linear interpolation, the effective section thickness as measured by the full width at half maximum (FWHM) of the section sensitivity profile is not measurably broadened with a pitch of 1.0, but is broadened 30% with a pitch of 2.0.⁽¹¹⁾ This loss of resolution due to broadening of the section sensitivity profile is compensated by the ability to retrospectively reconstruct images with a high degree of overlap.⁽⁶⁾ Although several investigators have examined the use of extended pitch (>1.0) helical CT for image noise or the detection of lesions with low lesion-to-background contrast,^(9,12) few have focused on image appearance when scanning the abdomen with pitches of greater than 1.0.

In this study, 3 radiologists subjectively exam-

ined image appearance of abdominal helical CT using 3 different pitches. Ideally, each patient should have had repeat CT scans with all 3 pitches so that each structure could have been directly compared using the 3 different pitches. However, we did not obtain permission from our Institutional Review Board for the 2 additional contrast abdominal CT scans. Irregardless, this study shows equivalence in image quality for helical CT pitches of between 1.0 and 1.5 when evaluating visualization of 9 normal structures in the abdomen. Several advantages are described below when using a greater pitch for helical CT; therefore, we advocate it for routine use in abdominal CT scans rather than the standard helical pitch-1.0 protocols.

First, for a given scan range, one can increase scan coverage to reduce scan time and radiation dose. This is especially applicable for children and those who are unable to cooperate with breath-holding instructions. Vade et al.⁽¹³⁾ described that 1.5: 1-pitch helical CT provides comparable quality images and a smaller radiation dose than does 1 : 1 pitch for examining children aged 0-4 years. Posniak et al.⁽⁸⁾ indicated that scans taken in 0.6 sec (pitch of 1.67) provide better-quality images because of the diminished motion artifacts when compared with those obtained in 1.0 sec (pitch of 1) in patients being treated with mechanical pulmonary ventilation who are unable to hold their breath. For those who can cooperate with breath-holding, the use of extended-pitch helical CT in the abdomen or thorax reduces the time which patients must hold their breaths which is comfortable for them.

Second, regarding the radiation dose to the patient, it has been reported that for pitches greater than 1.0, the radiation dose to the patient is decreased according to the ratio of s/d , where s is the section thickness, and d is the table feed distance per 360° rotation for comparable current (mA),⁽¹⁴⁾ and the scanning time is inversely related to the increase in pitch.

Third, rapid helical scanning also allows imaging during optimal vascular and parenchymal enhancement. For example, pancreatic and hepatic enhancement with dynamic helical scans is known to depend on the rate of contrast injection as well as the volume of contrast medium injected and the timing of acquisition.⁽¹⁵⁻¹⁷⁾ Clinically, one would expect to

have the period of scanning time fast enough to discriminate the biphasic arterial and venous-phases separately. Use of extended pitch helical scans are preferable to reach the peaks of both phases more precisely and efficiently during biphasic or triphasic helical CT scans.

In addition, for a given volume coverage rate (i.e., a given table speed), narrow-collimation high-pitch helical scans provide higher longitudinal resolution than do wide-collimation low-pitch ones.⁽¹⁸⁾ Rubin and Napel offered a practical flow chart for determining optimal spiral scan parameters using extended-pitch CT.⁽¹⁰⁾

They first determined the length of time that patients can hold their breath and divided that number into the desired scan coverage to compute the table speed. The collimation was then reduced by the use of an extended helical pitch greater than 1.0. Brink et al. also reached a similar conclusion⁽¹²⁾ that helical CT should be performed with the thinnest tolerable collimation, using pitches of up to 2.0 to supply adequate coverage. We, however, did not investigate the ability to reduce collimation while still scanning the same volume in abdominal CT. Generally, there is a tradeoff between collimation and table speed. One can not increase longitudinal resolution and table speed at the same time. Further studies are required on this aspect.

Based upon this study, the equivalence of extended helical-pitch CT using pitches up to 1.5 in the abdomen is obvious. As a result, we advocate its routine use to increase scan coverage in less time and with less radiation than can be achieved with standard helical pitch-1.0 protocols.

Finally, our results are applicable to single-detector helical CT. Early results with multi-detector helical CT suggested that pitch-related section profile broadening is not as severe as with single-detector scanners.^(19,20) Further studies are required to determine the optimal scan pitch with multi-detector helical CT.

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螺旋式電腦斷層攝影於腹部使用1.0、1.3及1.5螺距之 影像品質探討

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- 背景：** 本研究的目的主要是探討在螺旋式電腦斷層中使用螺距大到1.5時，人眼是否能夠區分出其中些微的差別。
- 方法：** 從2000年9月至2001年2月，我們針對72名病患，隨機分為三組，分別使用螺距1.0、1.3和1.5進行腹部電腦斷層掃描，在剔除掉其中12名因各種疾病而會影響影像評估的病患之後，其餘60名病患的影像由三位放射科醫師在未告知其影像參數的情況下針對9個正常部位及整體影像品質作評分，評分方式為1(最差)到5(最好)。
- 結果：** 三位醫師在判斷三種螺距對腹部9個正常部位及整體影像品質的差別時，在統計學上並無意義($p>0.05$)。
- 結論：** 本研究在腹部螺旋式電腦斷層中使用螺距1.0、1.3及1.5的影像品質相當，故我們在臨床上可藉由增加螺距的方式來增加螺旋式電腦斷層掃描的速度及減少病人劑量。
(長庚醫誌 2002;25:104-9)

關鍵字： 電腦斷層攝影，腹部電腦斷層攝影，螺距。