ISSN: 2581 – 3633
PubMed - National Library of Medicine - ID: 101745081

International Journal of Medical Science and Advanced Clinical Research (IJMACR)

Available Online at:www.ijmacr.com

Volume – 7, Issue – 6, November - 2024, Page No. : 57 – 63

Evaluation of Pancreatic Diseases Using Dual Energy Computed Tomography and Iodine Mapping

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How to citation this article: Dr. Shraavan Shankar, Dr. Praveen Kumar John, "Evaluation of Pancreatic Diseases Using Dual Energy Computed Tomography and Iodine Mapping", IJMACR- November - 2024, Volume – 7, Issue - 6, P. No. 57 – 63.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Introduction: Pancreatic pathologies particularly chronic pancreatitis and pancreatic cancer, pose a significant cost to healthcare systems globally. Due to subtle nature of pancreatic illness Traditional CT imaging frequently lacks the accuracy required for early detection. With its better contrast-to-noise ratio (CNR) and capacity for iodine mapping, dual-energy computed tomography (DECT) presents a promising avenue for increased diagnostic precision and early detection of pancreatic disorders.

Materials and Methods: Cross-sectional observational study of 42 patients were done with known or suspected pancreatic lesions referred to Department of Radiodiagnosis, A.J. Institute of Medical Sciences, Mangalore. Patients underwent DECT scans using the Siemens SOMATOM go Top system. Post processing iodine images were acquired and parameters such as iodine density, mixed density, and virtual non-contrast (VNC) were calculated. Receiver operating characteristic (ROC) curve analysis was used to determine optimal iodine density thresholds for distinguishing between normal and pathological pancreas.

Results: Out of 42 patients, 79% had abnormal pancreatic findings, with chronic calcific pancreatitis being the most prevalent (23.8%). The optimal iodine density threshold for differentiating normal from abnormal pancreas was 2.2 mg/mL. DECT exhibited high sensitivity (90.9%) and specificity (88.8%) for detecting pancreatic lesions.

Conclusion: DECT provides enhanced diagnostic accuracy compared to conventional CT, particularly through iodine mapping, aiding in the early detection

and assessment of pancreatic pathologies. This improvement has the potential to reduce morbidity and mortality associated with pancreatic diseases.

Keywords: Chronic pancreatitis, Virtual non contrast, dual-energy CT, iodine mapping, pancreatic lesions, ROC analysis.

Introduction

The pancreas, a retroperitoneal gland with both endocrine and exocrine functions, is vital in digestion and metabolic regulation. Due to its deep location in the upper abdomen, physical examination of the pancreas is challenging, often allowing disorders such as diabetes, cystic fibrosis, pancreatitis, and pancreatic cancer to progress unnoticed over long periods of time [1]. Pancreatic diseases, particularly acute pancreatitis (AP), chronic pancreatitis (CP), and pancreatic cancer, have a significant global health impact. The incidence rates of AP, CP, and pancreatic cancer are 33.7, 9.6, and 8.1 per 100,000 person-years, respectively [2]. In the United States, the financial burden of AP alone is substantial, with the average cost of an AP hospital admission around $9,870, and the total annual healthcare cost exceeding $2.2 billion. These diseases also dramatically reduce the quality of life, with AP, CP, and pancreatic cancer contributing to a loss of 11%, 23%, and 98%, respectively [3]. Additionally, many patients with these conditions develop metabolic complications such as diabetes of the exocrine pancreas (DEP) and exocrine pancreatic dysfunction (EPD), further complicating disease management.

Despite advancements in imaging technologies, diagnosing pancreatic pathologies early remains challenging due to their subtle and complex pathophysiological development [4]. Traditional imaging methods, including computed tomography (CT), primarily provide qualitative or semi-quantitative information, making precise diagnosis difficult. Dual-energy computed tomography (DECT), which was first conceptualized in the 1970s, has become clinically viable due to technological advancements that have overcome earlier limitations like scan duration and image resolution [5, 6]. DECT employs two distinct energy levels (low: 80-100 kVp, high: 140 kVp) to provide enhanced imaging capabilities, allowing for the quantification of iodine concentration (IC) and other parameters, which helps in better tissue characterization and lesion detection [4, 7]. The ability of DECT to generate iodine overlay maps and virtual non-contrast (VNC) images without additional radiation exposure offers advantages over conventional CT [8].

Numerous studies have shown that DECT offers improved signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) compared to traditional 120 kVp images, especially in detecting pancreatic adenocarcinoma, where it also enhances reader confidence [7]. Despite its promising potential, there is still a need for further research to fully establish DECT's utility in routine clinical practice, particularly for pancreatic diseases. This study aims to assess the diagnostic value of DECT in pancreatic pathologies by comparing its effectiveness with conventional CT in lesion detection and evaluating its role in iodine mapping.

Materials and Methods

This cross-sectional observational study was carried out at the A.J. Institute of Medical Sciences, Mangalore, in the Department of Radiodiagnosis. Based on a sample size calculation from a prior study by Bhosale et al. [9], 42 individuals with known or suspected pancreatic lesions were included. Assuming a 95% confidence interval and 90% power with a pooled standard deviation of 3, the required sample size was determined to be 42.

Sampling Technique and Study Population

Patients referred to the department of radiodiagnosis for computed tomography (CT) scan because of suspected or confirmed pancreatic lesions were chosen for the study using a purposive sample technique. Individuals who underwent CT scans for pancreatic pathology and satisfied the inclusion requirements were recruited. However, the study did not include patients who did not give their consent, had a known pregnancy, or were contraindicated for contrast agents.

Data Collection and Imaging Protocol

Detailed informed consent was obtained from all participants. Clinical data were gathered and examined, including age, gender, symptoms, and pertinent blood test results, such as serum lipase and amylase levels. Pancreatic pathologies were confirmed using ultrasound and histopathological evaluation in cases of malignancy. Subjects underwent dual-energy computed tomography (DECT) scans of the abdomen, utilizing the Siemens SOMATOM go Top twin beam dual-energy system. This system allows simultaneous acquisition of high and low kilovolt (kV) datasets in a single scan by splitting the X-ray beam with two filters. A triphasic abdominal scan with dual-energy images taken during the late arterial phase was the imaging protocol that was used.

Post-processing of the images was conducted using Syngo. via workstation software. A region of interest (ROI) measuring 1 cm² was placed in the affected pancreatic area and in the normal pancreatic parenchyma. Virtual non-contrast (VNC) liver mode was used to calculate iodine density, mixed density, iodine overlay, and VNC values. To prevent false positives, care was taken to avoid blood vessels, necrotic regions, and calcifications. Iodine mapping was carried out in order to identify regions of elevated or decreased iodine uptake and aid in the detection of pancreatic diseases.

Imaging Parameters

The DECT scans were performed with the following parameters:

- kV: AuSn 120
- mAs: 117
- Acquisition: 640 x 0.6 mm
- Pitch: 0.3
- Rotation time: 0.33 seconds
- Scan duration: 10-11 seconds
- Slice width: 5 mm
- Reconstruction: 1.5 mm
- Scan direction: Cranial-Caudal

Statistical Analysis

Data were entered into Excel and analyzed using SPSS version 24.0. While qualitative data were displayed as numbers and percentages, quantitative data were displayed as the mean and standard deviation. To determine the significance of differences between two groups, unpaired t-tests or Mann-Whitney U tests were applied. A p-value of less than 0.05 was considered statistically significant.

Results

In this study, patients with suspected pancreatic lesions were 44.5 ± 17.59 (Mean ± SD) years old on average. The age group of 35–54 years old accounted for 47.6% of patients with probable pancreatic lesions, followed by 19–34 years old (21.4%). Males made up the majority of study participants (90.5%), compared to females (9.5%). Compared to patients with normal pancreas (21%), 79% of the 42 research participants had some form of pancreatic lesion.

The average VNC of patients with suspected pancreatic lesions in this study found to be 31.33 ± 11.88 (Mean ± SD) HU. The average iodine overlay of patients with suspected pancreatic lesions in this study found to be 33.21 ± 15.04 (Mean ± SD) HU. The average mixed density of patients with suspected pancreatic lesions in this study found to be 65.5 ± 21.80 (Mean ± SD) HU. The average iodine density of patients with suspected pancreatic lesions in this study found to be 1.63 ± 0.74 (Mean ± SD) mg/MI

As shown in the Figure 1 & Table 1, there is significant AUC for DECT prediction of pancreatic lesions with a AUC value of 0.943 ± 0.037 (Standard Error) with a p value <0.001 & with a 95% confidence interval (0.871-1.00). DECT has sensitivity and specificity rates of 90.9% and 88.8% respectively for the prediction of pancreatic pathological lesions.

Graph 1: ROC curve for DECT prediction of pancreatic lesions

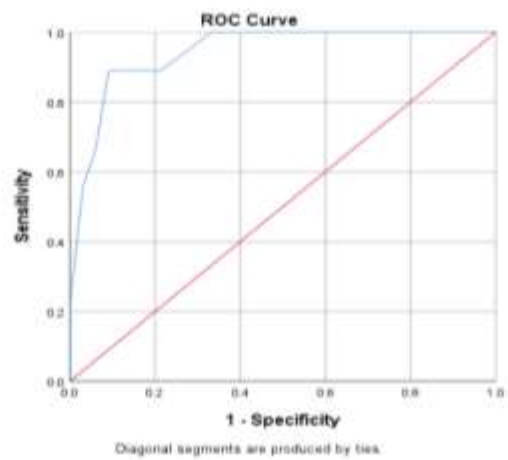

Table 1: Area under the curve for DECT prediction of pancreatic lesions

AUC	Std. Error	P value	95% Confidence Interval	
			(Lower Bound)	(Upper Bound)
0.943	0.037	<0.001	0.871	1.000

Table 2 presents the sensitivity and specificity of DECT (Dual-Energy Computed Tomography) in predicting pancreatic pathology. The DECT model demonstrated a high sensitivity of 90.9%, indicating its ability to correctly identify patients with pancreatic lesions. Additionally, it showed a specificity of 88.8%, reflecting its accuracy in ruling out those without the pathology. The positive predictive value (PPV) was 96.77%, meaning that 96.77% of patients who tested positive using DECT indeed had pancreatic pathology. The negative predictive value (NPV) was 72.72%, indicating that 72.72% of patients who tested negative were truly free of pancreatic pathology. Overall, these metrics highlight the strong diagnostic capability of DECT in detecting pancreatic lesions.

Table 2: Sensitivity & Specificity of DECT Prediction for pancreatic pathology

DECT Prediction for Pancreatic Pathology	Percentage (%)
Sensitivity	90.9
Specificity	88.8
Positive Predictive Value (PPV)	96.77
Negative Predictive Value (NPV)	72.72

Table 3 compares four key DECT parameters—VNC (Virtual Non-Contrast), iodine overlay, mixed density, and iodine density—between patients with abnormal and normal pancreatic tissue. The results show that the iodine density shows a highly significant difference ($p < 0.001$), with lower values in the abnormal pancreas (1.4 ± 0.63) compared to the normal pancreas (2.51 ± 0.36).

VNC, iodine overlay, and mixed density values are higher in the abnormal pancreas, the differences between the abnormal and normal pancreas are not statistically significant ($p > 0.05$). This indicates that iodine density is a key distinguishing parameter in detecting pancreatic abnormalities.

Table 3: Comparison of DECT Parameters Between Abnormal and Normal Pancreas

Parameter	Abnormal Pancreas (Mean ± SD)	Normal Pancreas (Mean ± SD)	P value
VNC	31.9 ± 12.83	29.22 ± 7.66	0.554
Iodine Overlay	33.12 ± 15.52	33.55 ± 13.97	0.939
Mixed Density	66.75 ± 21.45	60.88 ± 23.79	0.481
Iodine Density	1.4 ± 0.63	2.51 ± 0.36	<0.001*

*Significant at 95% CI

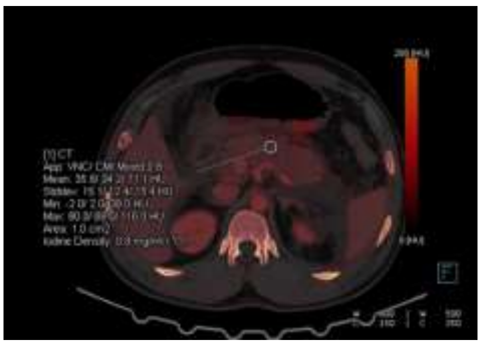

Figure 1: 27 year old male came with complaints of epigastric pain, vomiting. Ultrasound showed bulky pancreas with peripancreatic fat stranding and fluid. Serum amylase was elevated [799 U/L]. Patient was referred for CECT. Axial iodine overlay image showing low iodine density of 0.8mg/ml within the pancreatic parenchyma. Subsequently a diagnosis of acute pancreatitis was made.

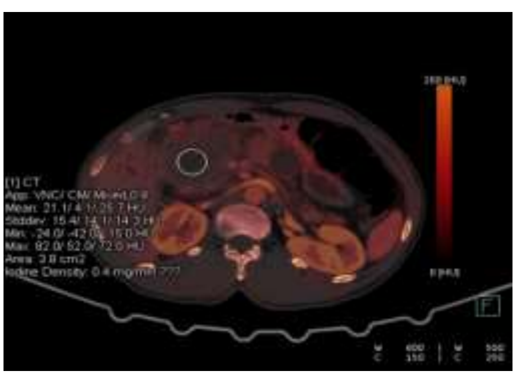

Figure 2: 41 year old male came was referred for CECT with complaints of pain abdomen loss of appetite and weight. CA 19-9 was elevated [425 U/mL]. Ultrasound done showed hypodense lesion in the head of pancreas. Axial iodine overlay images showing very low iodine density of 0.4 mg/mL. Histopathology and immunohistochemistry came out to be pancreatic adenocarcinoma.

Discussion

The principle of dual energy CT (DECT), though conceived in the 1970s, was limited by technical issues such as scan time and slice thickness, requiring separate acquisitions which led to motion artifacts and increased dose. Advances in CT technology have made DECT clinically viable. Increasing literature, especially in abdominopelvic imaging, highlights DECT's advantages, such as improved lesion visibility, better tissue characterization, reduced metallic artifacts, fewer acquisition phases, less contrast volume, and reduced need for follow-up imaging [10-16]. Pancreatic pathologies are particularly challenging to detect with conventional CT, often requiring additional imaging for full characterization, making DECT a promising tool in this area [17, 18].

Despite DECT's excellent detection of benign and malignant lesions, limitations exist that prevent its routine clinical application. More studies are needed, especially focused on pancreatic pathologies, as there is limited data available in this area. This study aims to assess the role of iodine mapping.

The study included 42 patients with a mean age of 44.5 ± 17.59 years, predominantly males (90.5%). The majority of patients had abnormal pancreatic findings (79%), with chronic calcific pancreatitis (23.8%) being the most common, followed by acute-on-chronic pancreatitis (16.7%) and pancreatic adenocarcinoma (9.5%). The average VNC was 31.33 ± 11.88 HU, iodine overlay was 33.21 ± 15.04 HU, mixed density was 65.5 ± 21.80 HU, and iodine density was 1.63 ± 0.74 mg/mL.

The area under the curve (AUC) for DECT prediction of pancreatic lesions was 0.943 ± 0.037 ($p < 0.001$), with a 95% confidence interval of 0.871-1.00. Iodine quantification analysis also yielded an AUC of 0.834 in a study by Simon et al. [19]. The ROC curve analysis in this study found that 2.2 mg/mL was the optimal threshold to differentiate normal from abnormal pancreas, similar to Simon et al. , which found 2.1 mg/mL as the threshold for differentiating inflammatory from normal pancreatic tissue. Sensitivity and specificity of iodine density in this study were 90.9% and 88.8%, respectively, while Simon et al. reported 95.5% and 76.9% [19].

The mean VNC for abnormal and normal pancreas was 31.9 ± 12.83 and 29.22 ± 7.66, respectively ($p = 0.554$). Mean iodine overlay values were 33.12 ± 15.52 (abnormal) and 33.55 ± 13.97 (normal) with no significant difference ($p = 0.939$). Mixed density values were 66.75 ± 21.45 (abnormal) and 60.88 ± 23.79 (normal) ($p = 0.481$). Iodine density values were significantly different: 1.4 ± 0.63 (abnormal) vs. 2.51 ± 0.36 (normal) ($p < 0.001$), consistent with Simon et al., who found significant differences between inflammatory and normal pancreatic parenchyma [19].

Conclusion

In this study, DECT demonstrated significant advantages over conventional CT in diagnosing pancreatic diseases, particularly iodine density images as it were more effective in identifying pancreatic pathologies. Chronic calcific pancreatitis was the most common finding (23.8%), and ROC analysis indicated that 2.2 mg/mL was the optimal iodine density threshold for differentiating between normal and abnormal pancreas. DECT showed high sensitivity (90.9%) and specificity (88.8%) for detecting pancreatic lesions, highlighting its utility in improving diagnostic accuracy and reducing morbidity and mortality in pancreatic diseases.

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