Short Report

Pancreatic Morphological Patterns on MRI in Individuals With Suspected Type 5 Diabetes: An Exploratory Case Series From Mzuzu Central hospital, Malawi

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Abstract

Purpose

Type 5 diabetes mellitus (T5DM), recently proposed as a diabetes phenotype associated with chronic undernutrition, remains poorly characterized regarding pancreatic structural changes. This study aimed to describe pancreatic MRI morphological features in individuals with clinically suspected T5DM from a resource-limited African setting.

Methods

This retrospective case series included four individuals with clinically suspected T5DM from Mzuzu Central Hospital, Malawi. Clinical characteristics, nutritional history, and routine abdominal MRI findings were reviewed. Pancreatic morphology was assessed using manual segmentation of axial T2-weighted PROPELLER images, with segmentation-derived pancreatic area and volume obtained.

Results

Four individuals (two females and two males; age range, 10–35 years) were included. All patients had a lean body habitus (BMI range, 16.4-18.3 kg/m^2), childhood nutritional deprivation history, and no documented diabetic ketoacidosis or recurrent ketosis. MRI demonstrated a consistent morphological pattern characterized by relative preservation of the pancreatic head and uncinate process with reduction of the distal pancreas. Three patients showed thinning of the pancreatic body and tail, while the youngest patient demonstrated a shortened pancreatic tail not reaching the splenic hilum. Pancreatic body diameter ranged from 7.6 to 11.6 mm, with segmentation-derived pancreatic volume ranging from 16.9 to 27.3 cm^3.

Conclusion

Individuals with clinically suspected T5DM demonstrated a recurrent pancreatic MRI pattern of preserved head morphology with reduced body and tail structures. These preliminary findings suggest that MRI-based pancreatic morphological assessment may provide additional structural information for malnutrition-associated diabetes phenotyping, particularly in settings with limited metabolic characterization.

Keywords: Type 5 diabetes mellitus; pancreas MRI; pancreatic morphology; malnutrition-related diabetes; pancreatic volume

Introduction

Type 5 diabetes mellitus (T5DM), previously referred to as malnutrition-related diabetes mellitus, was recently reintroduced into the international diabetes classification framework following growing recognition that chronic undernutrition-associated diabetes represents a distinct clinical entity[1-5]. Historically, T5DM was primarily described in low- and middle-income countries and was characterized by young-onset diabetes, low body mass index (BMI), relative insulin deficiency, and atypical ketosis resistance[2,3]. However, its classification has remained controversial because of overlap with other forms of diabetes and the absence of universally accepted diagnostic criteria[2,3,6,7].

Emerging evidence suggests that chronic undernutrition during fetal development or early childhood may impair pancreatic development and endocrine reserve, potentially resulting in reduced insulin secretory capacity and altered pancreatic morphology[1,3]. Experimental and clinical observations have supported the hypothesis that nutritional deprivation may influence pancreatic growth and long-term metabolic function[3]. Nevertheless, the structural pancreatic phenotype of suspected T5DM remains poorly characterized, particularly using imaging-based approaches.

Pancreatic morphological abnormalities have increasingly been recognized in several forms of diabetes[8-14]. MRI studies in type 1 diabetes mellitus (T1DM), for example, have demonstrated reduced pancreatic size, progressive pancreatic atrophy, and altered pancreatic morphology compared with non-diabetic individuals[9-13]. These findings suggest that pancreatic imaging may provide clinically relevant phenotypic information beyond conventional biochemical assessment.

Despite growing international interest in T5DM, imaging data from sub-Saharan Africa remain extremely limited[1-3,5,15,16]. Malawi, a resource-limited country in

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southern Africa, advanced diagnostic investigations such as C-peptide measurement, pancreatic autoantibody testing, exocrine pancreatic function assessment, or genetic testing are frequently unavailable[17]. Consequently, clinicians often rely primarily on clinical phenotype and basic laboratory evaluation when assessing atypical diabetes presentations. Under such conditions, routine MRI may offer a practical opportunity for exploratory pancreatic phenotypic assessment. Regrettably, there are no published local data describing pancreatic MRI findings in patients with suspected T5DM in Malawi. The lack of regional radiological data hinders accurate differential diagnosis and standardized clinical management of T5DM locally.

Against this background, this case series aims to describe exploratory pancreatic MRI findings and quantitative pancreatic morphological measurements in patients clinically suspected of type 5 diabetes in Mzuzu, Malawi. The preliminary results presented herein may provide baseline imaging evidence for future large-scale research and help improve the diagnostic workflow for T5DM in resource-limited African settings.

Materials and Methods

Study participants

This retrospective, single-center, exploratory case series was conducted at Mzuzu Central Hospital, Malawi. Individuals with clinically suspected T5DM who underwent abdominal MRI between 1 February 2026 and 31 May 2026 were consecutively identified.

Clinical suspicion of T5DM was based on a combination of clinical characteristics suggestive of malnutrition-associated diabetes, including young-onset diabetes, a lean body habitus, a history of childhood nutritional deprivation or chronic undernutrition, and absence of a typical obesity-associated type 2 diabetes mellitus phenotype. A history of diabetic ketoacidosis (DKA) or recurrent ketosis was assessed where available. Because advanced metabolic, immunological, and genetic evaluations, including C-peptide measurement and pancreatic autoantibody testing, were not routinely available, cases were classified as clinically suspected T5DM rather than confirmed T5DM. Inclusion criteria were: (1) clinical suspicion of T5DM based on available clinical information; (2) available demographic and clinical records; and (3) completion of abdominal MRI examination with adequate pancreatic visualization. Exclusion criteria included a history of known pancreatic disease, severe chronic liver or renal disease, or contraindications to MRI.

Clinical data collection

Demographic and clinical data were retrospectively extracted from medical records, including age, sex, body mass index (BMI), history of childhood nutritional deprivation, history of DKA or ketosis, current diabetes treatment status, and available laboratory data. Fasting plasma glucose values were recorded when available; because all included individuals were receiving insulin therapy at the time of evaluation, these measurements were interpreted as current glycaemic status under treatment rather than baseline disease severity.

MRI protocol

MRI examinations were performed using a locally available 1.5T clinical MRI scanner. Routine abdominal MRI protocols were acquired without intravenous contrast administration, including axial T1-weighted and T2-weighted sequences. Because the study was performed in a resource-limited clinical setting, dedicated pancreatic MRI protocols and advanced quantitative sequences were not routinely available. Axial T2-weighted PROPELLER images provided the most consistent visualization of pancreatic parenchyma and were therefore selected for morphological assessment. MRI datasets were reviewed independently by two radiologists with abdominal imaging experience, who were blinded to the clinical details during image evaluation.

Pancreatic Morphological Measurement and Evaluation

Pancreatic morphology was assessed using axial T2-weighted PROPELLER images, which were selected because of their improved robustness to respiratory motion and consistent visualization of pancreatic margins[11,18,19]. The assessed morphological parameters included pancreatic body anterior-posterior diameter, approximate pancreatic area, and segmentation-derived pancreatic volume. For segmentation analysis, axial T2-weighted PROPELLER images were imported into ITK-SNAP (version 4.4.0)[20]. The pancreas was manually delineated slice-by-slice by a radiologist with abdominal imaging experience. The segmentation included visible pancreatic parenchyma while excluding adjacent vessels, bowel structures, and surrounding fat tissue. The resulting segmentation masks were subsequently imported into 3D Slicer (version 5.10.0) for calculation of segmentation-derived pancreatic volume and pancreatic area[21]. Pancreatic body anterior-posterior diameter was measured on axial images at the level of the superior mesenteric vein whenever this anatomical landmark was clearly visualized.

Results

Demographic and clinical characteristics

A total of four individuals with clinically suspected T5DM were included in this case series. Detailed demographic, clinical and laboratory data are summarized in Table 1. The patients were aged 10-35 years, including two females and two males. All patients had a lean body habitus, with BMI ranging from 16.4 to 18.3 kg/m^2. A history suggestive of childhood nutritional deprivation was documented in all cases. None of the patients reported previous diabetic ketoacidosis (DKA) or recurrent ketosis episodes. All patients were receiving insulin therapy at the time of evaluation. Available fasting plasma glucose measurements, obtained during routine follow-up under treatment, ranged from 78 to 383 mg/dL and were therefore interpreted as reflecting treated glycaemic status rather than baseline disease severity.

MRI-based pancreatic morphological assessment

Across the four cases, a consistent pattern of pancreatic morphological alteration was observed. The pancreatic head and uncinate process appeared relatively preserved, while the distal pancreas demonstrated variable degrees of morphological reduction, including thinning of the body and shortening of the tail. Three patients (cases 1–3) showed a slender pancreatic body and tail with relatively preserved pancreatic head morphology. The youngest patient (case 4, 10-year-old male) also demonstrated preservation of the pancreatic head and uncinate process, with a relatively short pancreatic tail that did not extend fully to the splenic hilum. No focal pancreatic mass, large cystic lesion, or imaging features of advanced chronic calcific pancreatitis were identified.

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Table 1. Demographic and clinical characteristics of individuals with clinically suspected type 5 diabetes mellitus

Case	Age (years)	Sex	BMI (kg/m²)	Childhood nutritional deprivation	Current fasting plasma glucose (mg/dL)	Urine Ketones	Ketoacidosis History
1	22	Female	18.3	Present	383	Absent	Absent
2	35	Female	18.1	Present	275	Absent	Absent
3	17	Male	17.9	Present	224	Absent	Absent
4	10	Male	16.4	Present	78	Absent	Absent

Table 2. MRI-derived pancreatic morphological parameters of individuals with clinically suspected type 5 diabetes mellitus

Case	Age (years)	Sex	Pancreatic body diameter (mm)	Segmentation-derived pancreatic area (cm²)	Segmentation-derived pancreatic volume (cm³)
1	22	Female	7.6	58.4	22.9
2	35	Female	9.6	63.4	23.1
3	17	Male	11.6	69.9	27.3
4	10	Male	8.9	48.6	16.9

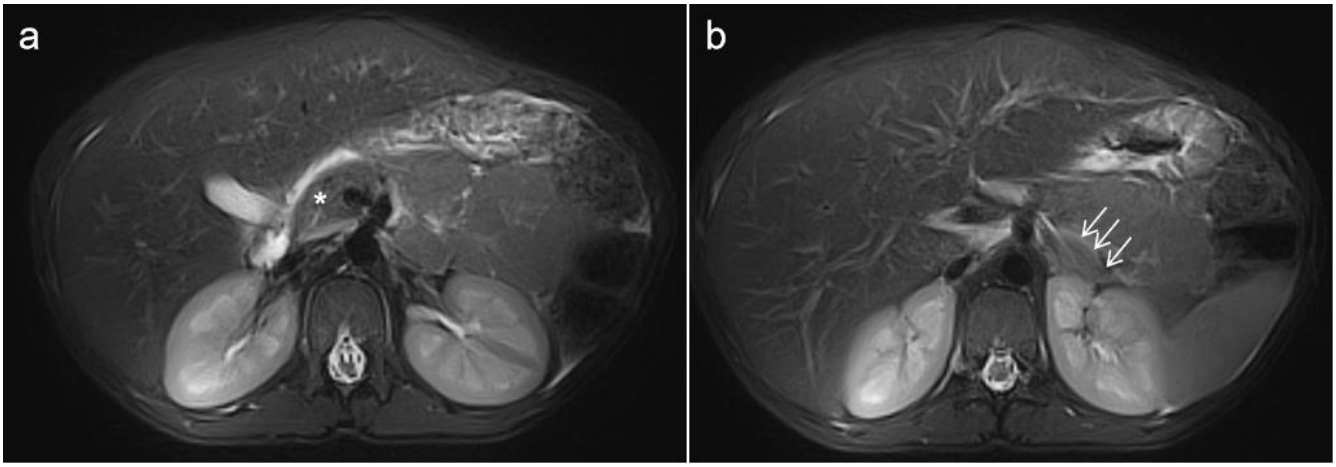

Figure 1. Representative T2-weighted PROPELLER MRI findings in a 10-year-old boy with clinically suspected type 5 diabetes mellitus. (a) Relative preservation of the pancreatic head (asterisk). (b) Shortened distal pancreas with reduced extension of the pancreatic tail toward the splenic hilum (white arrows)

Mild bilateral pleural effusion was observed on MRI in all included patients.

Quantitative results of pancreatic body anterior-posterior diameter, pancreatic area and pancfreatic volume are listed in Table 2. The pancreatic body anterior-posterior diameter ranged from 7.6 to 11.6 mm. Segmentation-derived pancreatic area ranged from 48.6 to 69.9 cm², and segmentation-derived pancreatic volume ranged from 16.9 to 27.3 cm³. The lowest pancreatic volume was observed in case 4 (16.9 cm³), whereas the largest volume was observed in case 3 (27.3 cm³). Figure 1 shows one representative case of suspected T5DM.

Discussion

In this case series from Mzuzu Central Hospital, Malawi, pancreatic MRI demonstrated a consistent morphological pattern among four individuals with clinically suspected T5DM based on clinical characteristics including lean phenotype, childhood nutritional deprivation history, and absence of ketosis-prone presentation. The pancreatic head and uncinate process were relatively preserved in all cases, whereas the pancreatic body and tail showed varying degrees of reduction, including parenchymal thinning and shortening of the distal pancreas. Although based on a small number of patients, the reproducibility of this distributional pattern across cases raises the possibility that distal pancreatic morphological changes may represent a relevant imaging feature in individuals with malnutrition-associated diabetes.

These findings should be interpreted within the context of an exploratory imaging study. In the absence of comprehensive pancreatic endocrine assessment, including C-peptide measurement, pancreatic autoantibody testing, and genetic evaluation, the observed MRI features cannot be considered specific diagnostic markers for T5DM. Rather, this study provides preliminary radiological observations that may contribute to the characterization of pancreatic structural changes in populations where detailed diabetes phenotyping remains challenging.

The relative preservation of the pancreatic head and uncinate process with reduction of the pancreatic body and tail was a notable observation in this series. The anatomical

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basis underlying this distribution remains uncertain; however, regional differences in pancreatic development, tissue reserve, vascular supply, or susceptibility to chronic nutritional stress may contribute. Previous studies have demonstrated that pancreatic morphology is influenced by multiple factors, including age, sex, body size, adiposity, and metabolic status, highlighting the importance of interpreting pancreatic measurements within an appropriate clinical context[22,23].

Pancreatic structural alterations have been described in several diabetes phenotypes, although the mechanisms are likely heterogeneous. In type 1 diabetes mellitus (T1DM), reduced pancreatic volume has been consistently reported using MRI, including in individuals with recently diagnosed disease[8-10,13,24,25]. These observations suggest that autoimmune diabetes may be associated with structural changes extending beyond pancreatic β-cell destruction alone. Proposed mechanisms include immune-mediated injury, reduced trophic effects of insulin and other β-cell-derived factors, and alterations in pancreatic tissue composition[26-28]. In contrast, pancreatic morphology in type 2 diabetes mellitus (T2DM) is strongly influenced by metabolic factors, particularly obesity, insulin resistance, and ectopic fat accumulation. Although some studies have reported reduced pancreatic volume in T2DM, other studies have emphasized increased pancreatic fat deposition and metabolic remodeling rather than uniform pancreatic atrophy[8,12,27-29]. The individuals described in this series had a distinct lean phenotype with low BMI and a history of childhood nutritional deprivation, which differs from the typical metabolic context associated with common T2DM. Pancreatic changes are also well recognized in pancreatogenic diabetes (type 3c diabetes mellitus), where chronic pancreatitis, fibrosis, and exocrine tissue destruction may lead to pancreatic atrophy and impaired endocrine function[26,30]. However, none of the patients in this series demonstrated imaging features of advanced chronic pancreatitis, such as calcification, ductal abnormalities, or focal pancreatic destruction. Therefore, the observed distal pancreatic reduction may not represent classical pancreatitis-associated pancreatic loss.

The biological basis of the morphological pattern observed in this series remains uncertain. Chronic undernutrition provides a plausible mechanism, as early-life nutritional deprivation has been associated with impaired pancreatic development, altered β-cell mass, and long-term metabolic consequences[31]. Malnutrition-related diabetes, historically described in populations exposed to chronic nutritional stress, may represent a distinct pathway of diabetes development compared with autoimmune or metabolic forms of diabetes[6,16]. Recent discussions surrounding T5DM have emphasized the need to better define the relationship between nutritional deprivation, pancreatic structural changes, and endocrine dysfunction[1,3,16].

The relative preservation of the pancreatic head with involvement of the distal pancreas raises additional questions regarding regional susceptibility. The pancreas develops from distinct embryological components, and regional differences in developmental regulation and tissue composition may theoretically influence the response to chronic nutritional stress[23]. However, whether this distributional pattern represents a characteristic feature of T5DM or reflects individual variation cannot be determined from the current sample and requires validation in larger imaging cohorts.

In this study, pancreatic morphology was assessed using routine abdominal MRI rather than a dedicated pancreatic imaging protocol. Despite the absence of isotropic high-resolution sequences, T2WI PROPELLER images provided sufficient pancreatic visualization for morphological assessment. Previous studies have demonstrated that MRI-based pancreatic volume measurement is feasible and reproducible, supporting the use of imaging-derived pancreatic morphology as a potential approach for phenotyping pancreatic structural changes[18,19]. In settings where advanced metabolic and immunological testing is unavailable, routine MRI may provide complementary information to clinical assessment. The presence of mild bilateral pleural effusion in all four patients was an additional imaging observation. In the context of low BMI and childhood nutritional deprivation, pleural effusion may reflect altered nutritional status, low protein states, or other systemic physiological changes. However, because biochemical nutritional markers such as serum albumin were unavailable, this finding should be interpreted cautiously.

Several limitations should be acknowledged. First, this was a small, single-centre case series and the findings require confirmation in larger cohorts. Second, classification of T5DM could not be be definitively confirmed because C-peptide, pancreatic autoantibodies, pancreatic exocrine function testing, and genetic evaluation were unavailable. Third, the lack of age-, sex-, and body-size-matched controls prevented determination of whether the observed pancreatic morphology differs from expected variation related to nutritional status. Finally, because MRI acquisition was not optimized for quantitative pancreatic volumetry, segmentation-derived volumes should be considered morphological estimates rather than definitive reference measurements. Despite these limitations, this study provides preliminary radiological observations of pancreatic morphology in individuals with suspected T5DM from an underrepresented population. The consistent finding of relative preservation of the pancreatic head with reduction of the body and tail suggests a potential imaging pattern that warrants further investigation. Future studies incorporating standardized MRI protocols, nutritional assessment, and pancreatic functional biomarkers are needed to determine whether these morphological features are associated with T5DM-specific pathophysiological processes.

Conclusion

Routine pancreatic MRI demonstrated a consistent morphological pattern in individuals with clinically suspected T5DM, characterized by relative preservation of the pancreatic head and uncinate process with reduction of the pancreatic body and tail. Although these findings are preliminary and not diagnostic, they suggest that MRI may provide useful structural phenotyping information in suspected malnutrition-associated diabetes, particularly in settings where comprehensive metabolic evaluation is limited. Further studies with larger cohorts and appropriate control groups are needed to clarify the clinical significance of these imaging features.

Author contributions

All authors contributed to the study conception and design. Conceptualization: Yingpu Zhu and Jingping Zhang; Data curation: Yingpu Zhu, Arnold Kayira, Blessed Kondowe and Patrick Manda; Methodology and formal analysis: Yingpu

Zhu and Jingping Zhang; Investigation: Yingpu Zhu, Blessed Kondowe and Jingping Zhang; Writing - original draft preparation: Yingpu Zhu and Jingping Zhang; Writing-review & editing: Yingpu Zhu, Blessed Kondowe, Junyi Ren and Jingping Zhang; Supervision: Jingping Zhang. All authors read and approved the final manuscript.

Data Availability

All data supporting the findings of this study are available within the paper.

Declarations

Ethics approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of the Mzuzu University (Approval No. MZUNIERC/DOR/26/39).

Disclosures: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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References

1. Chen S, Lu M. Type 5 diabetes mellitus: nutritional-imprinted β-cell insufficiency, diagnostic gaps, and emerging therapeutic strategies. Front. Endocrinol. (Lausanne) 2026; 17: 1739521.

2. Misra A, Joshi S, Mithal A. Malnutrition-related diabetes mellitus: Rushing toward “type 5” amid unresolved questions and limited evidence. Diabetes Metab. Syndr. 2025; 19: 103250.

3. Taneera J, Saeed R, Mahgoub E, Farhan Z, Alobeidli A, Shoukat M, Shaat N. Type 5 diabetes: A comprehensive review to understand the basis of diabetes of poverty. Biochim Biophys Acta Mol Basis Dis 2026; 1872: 168147.

4. Goundan P, Junqueira A, Kelleher-Yassen D, Steenkamp D. Fibrocalculous pancreatic diabetes. Minerva Endocrinol. 2016; 41: 70-7.

5. Gupta L, Misra A. From malnutrition-related diabetes mellitus to ‘type 5 diabetes’: phenotypic variation, not reclassification. Diabetologia 2026; 69: 249-50.

6. Unnikrishnan R, Mohan V. Fibrocalculous Pancreatic Diabetes. Curr. Diab. Rep. 2020; 20: 19.

7. Kumaran S, Unnikrishnan AG. Fibrocalculous pancreatic diabetes. J. Diabetes Complications 2021; 35: 107627.

8. Virostko J. Quantitative Magnetic Resonance Imaging of the Pancreas of Individuals With Diabetes. Front. Endocrinol. (Lausanne) 2020; 11: 592349.

9. Campbell-Thompson ML, Filipp SL, Grajo JR, Nambam B, Beegle R, Middlebrooks EH, Gurka MJ, Atkinson MA, Schatz DA, Haller MJ. Relative Pancreas Volume Is Reduced in First-Degree Relatives of Patients With Type 1 Diabetes. Diabetes Care 2019; 42: 281-7.

10. Williams AJ, Thrower SL, Sequeiros IM, Ward A, Bickerton AS, Triay JM, Callaway MP, Dayan CM. Pancreatic volume is reduced in adult patients with recently diagnosed type 1 diabetes. J. Clin. Endocrinol. Metab. 2012; 97: E2109-13.

11.Williams AJ, Chau W, Callaway MP, Dayan CM. Magnetic resonance imaging: a reliable method for measuring pancreatic volume in Type 1 diabetes. Diabet. Med. 2007; 24: 35-40.

12.Higashi M, Tanabe M, Tanabe K, Okuya S, Takeda K, Nagao Y, Ito K. Multiparametric Magnetic Resonance Imaging Findings of the Pancreas: A Comparison in Patients with Type 1 and 2 Diabetes. Tomography 2025; 11 .

13.Virostko J, Williams J, Hilmes M, Bowman C, Wright JJ, Du L, Kang H, Russell WE, Powers AC, Moore DJ. Pancreas Volume Declines During the First Year After Diagnosis of Type 1 Diabetes and Exhibits Altered Diffusion at Disease Onset. Diabetes Care 2019; 42: 248-57.

14.Virostko J, Tirkes T. Cross-sectional imaging of the pancreas in diabetes. Abdominal radiology (New York) 2024; 49: 2116-24.

15.Trimble ER, Phillips D, Balcha SA. Phenotype of insulin-dependent diabetes in chronic undernutrition: beta cell stress and immune dysfunction-a rural sub-Saharan perspective on type 5 diabetes. Diabetologia 2025; 68: 2643-51.

16.Jebasingh F, Thomas N. Type 5 Diabetes- The Rejuvenated Spirit from a Ghost of the Past. Indian journal of endocrinology and metabolism 2025; 29: 249-52.

17.Ahuja MM, Sharma GP. Serum C-peptide content in nutritional diabetes. Hormone and metabolic research = Hormon- und Stoffwechselforschung = Hormones et metabolisme 1985; 17: 267-8.

18Heyn C, Sue-Chue-Lam D, Jhaveri K, Haider MA. MRI of the pancreas: problem solving tool. J Magn Reson Imaging 2012; 36: 1037-51.

19.Williams JM, Hilmes MA, Archer B, Dulaney A, Du L, Kang H, Russell WE, Powers AC, Moore DJ, Virostko J. Repeatability and Reproducibility of Pancreas Volume Measurements Using MRI. Sci. Rep. 2020; 10: 4767.

20Yushkevich PA, Piven J, Hazlett HC, Smith RG, Ho S, Gee JC, Gerig G. User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. Neuroimage 2006; 31: 1116-28.

21. Fedorov A, Beichel R, Kalpathy-Cramer J, Finet J, Fillion-Robin JC, Pujol S, Bauer C, Jennings D, Fennessy F, Sonka M et al. 3D Slicer as an image computing platform for the Quantitative Imaging Network. Magn. Reson. Imaging 2012; 30: 1323-41.

22. Szczepaniak EW, Malliaras K, Nelson MD, Szczepaniak LS. Measurement of pancreatic volume by abdominal MRI: a validation study. PLoS. ONE 2013; 8: e55991.

23. Saisho Y, Butler AE, Meier JJ, Monchamp T, Allen-Auerbach M, Rizza RA, Butler PC. Pancreas volumes in humans from birth to age one hundred taking into account sex, obesity, and presence of type-2 diabetes. Clinical anatomy (New York, N.Y.) 2007; 20: 933-42.

24. Regnell SE, Peterson P, Trinh L, Broberg P, Leander P, Lernmark Å, Månsson S, Elding Larsson H. Pancreas volume and fat fraction in children with Type 1 diabetes. Diabet. Med. 2016; 33: 1374-9.

25. Missima NG, Hill H, Aioanei CS, Liss P, Espes D. Alterations of the pancreas in type 1 diabetes - from prior to diagnosis to long-standing disease. Endocrine 2025; 90: 140-8.

26. Hart PA, Bellin MD, Andersen DK, Bradley D, Cruz-Monserrate Z, Forsmark CE, Goodarzi MO, Habtezion A, Korc M, Kudva YC et al. Type 3c (pancreatogenic) diabetes mellitus secondary to chronic pancreatitis and pancreatic cancer. Lancet Gastroenterology & Hepatology 2016; 1: 226-37.

27. Spilseth B, Fogel EL, Toledo F, Campbell-Thompson M. Imaging abnormalities of the pancreas in diabetes: implications for diagnosis and treatment. Curr. Opin. Gastroenterol. 2024; 40: 381-8.

28. Saisho Y. Pancreas Volume and Fat Deposition in Diabetes and Normal Physiology: Consideration of the Interplay Between Endocrine and Exocrine Pancreas. The review of diabetic studies : RDS 2016; 13: 132-47.

29. Garcia TS, Rech TH, Leitão CB. Pancreatic size and fat content in diabetes: A systematic review and meta-analysis of imaging studies. PLoS. ONE 2017; 12: e0180911.

30. Rasheed A, Galande S, Farheen S, Mitnala S, Nageshwar Reddy D, Talukdar R. Type 3c diabetes associated with chronic pancreatitis: A narrative review. Pancreatology 2025; 25: 1003-12.

31. Vaag AA, Grunnet LG, Arora GP, Brøns C. The thrifty phenotype hypothesis revisited. Diabetologia 2012; 55: 2085-8.