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The role of ultrasonography in the diagnosis and management of chronic pancreatitis: Opportunities, limitations and prospects for development – a literature review

Authors:
1. Jakub Jan Pokrzepa [JP]
5th Military Hospital with Polyclinic in Cracow
Wrocławska 1-3 Street, 30-901 Krakow; Cracow, Malopolska,
https://orcid.org/0009-0000-7907-1511
E-mail: jakub.pokrzepa@onet.pl

2. Karolina Baran [KB]
Independent Public Health Care Facility of the Ministry of Internal Affairs and Administration in Krakow, Kronikarza Galla 25 Street, 30-053 Krakow: Cracow, Małopolska,
https://orcid.org/0009-0004-1627-5065
E-mail: 99barankarolina@gmail.com

3. Katarzyna Bartnik [KBA]
5th Military Hospital with Polyclinic in Cracow: Cracow, Wrocławska 1-3 Street 30-901 Kraków, Małopolska, Poland, PL
https://orcid.org/0009-0005-9095-5875
E-mail: kasiabartnik08@gmail.com

4. Gabriela Blecharz [GB]
5 Military Clinical Hospital SPZOZ in Cracow
Wrocławska 1-3 Street, 30-901 Krakow; Cracow, Malopolska,
https://orcid.org/0009-0007-9275-3913
E-mail: blecharzgabriela@gmail.com

5. Marlena Jankowska [MJ]
Stefan Zeromski Specialised Hospital (SP ZOZ) in Cracow: Cracow, os. Na Skarpie 66 Street 31-913 Kraków, Małopolska, Poland, PL
https://orcid.org/0009-0005-2240-8853
E-mail: marlena.rosol@wp.pl

6. Natalia Jańczyk [NJ]
Stefan Zeromski Specialised Hospital (SP ZOZ) in Cracow: Cracow, os. Na Skarpie 66 Street 31-913 Kraków, Małopolska, Poland, PL
https://orcid.org/0009-0000-1862-9681
E-mail: nataliajanczyk34@gmail.com

7. Karolina Mędrysa [KM]
Voivodeship Hospital in Bielsko-Biała,
Armii Krajowej Street 101, 43-316 Bielsko-Biała
https://orcid.org/0009-0002-1557-0244
E-mail: karolinamedrysa@gmail.com

8. Michał Presak [MP]
5 Military Clinical Hospital SPZOZ in Cracow
Wrocławska 1-3 Street, 30-901 Krakow; Cracow, Malopolska,
https://orcid.org/0009-0006-0335-5917
E-mail: michal.presak@gmail.com

9. Julia Szwech [JS]
5 Military Clinical Hospital SPZOZ in Cracow
Wrocławska 1-3 Street, 30-901 Krakow; Cracow, Malopolska,
https://orcid.org/0009-0006-3792-0101
E-mail: julia.szwech@op.pl

10. Jakub Michal Adamski [JA]
Jagiellonian University in Cracow
Sw. Anny 12 Street, 33-332 Krakow; Cracow, Malopolska
https://orcid.org/0009-0000-2773-9495
E-mail: jakub.michal.adamski@gmail.com

Corresponding author: Jakub Jan Pokrzepa
5th Military Hospital with Polyclinic in Cracow
Wrocławska 1-3 Street, 30-901 Krakow; Cracow, Malopolska,
E-mail: jakub.pokrzepa@onet.pl

Abstract

Introduction and purpose

Chronic pancreatitis is a progressive disorder of the pancreas that may be caused by numerous factors. It leads to impaired nutrient absorption, diabetes development, chronic pain and an increased risk of pancreatic cancer development over the long term. Ultrasonography, both transabdominal and endoscopic, is a valuable diagnostic modality for CP, that provides good visualization of pathologic changes.

A brief description of the state of knowledge

The most common etiologies of chronic pancreatitis are alcohol consumption, smoking and genetic mutations. Ultrasound diagnostics, due to recent improvements in technology, enables early detection of the disease, making it possible to initiate treatment early enough, enhance the likelihood of its success and decrease the risk of complications, which include pseudocysts, duodenal stricture, splanchnic vein thrombosis and pancreatic cancer. The most common ultrasonographic findings in CP include dilatation of the main pancreatic duct, parenchymal calcifications, increased pancreatic volume, uneven contours, enlarged lymph nodes and the presence of free fluid in the abdominal cavity.

Conclusions

The findings above can be visualized using ultrasound techniques, including the least invasive and most accessible transabdominal ultrasound, endoscopic ultrasound, which enables the detection of pathologies at early disease stages, and emerging techniques such as elastography, which allows for the assessment of pancreatic fibrosis. Although there has been considerable improvement in ultrasound technology over the past few years, further development in the imaging modalities and the introduction of new, more precise guidelines and scoring systems is still required.

Keywords: Chronic pancreatitis; ultrasonography; transabdominal ultrasonography; endoscopic ultrasonography; elastography

Introduction

Chronic pancreatitis is a progressive fibroinflammatory condition of the pancreas.[1] Recently a shift in defining chronic pancreatitis has emerged. Historically, definitions started with identifying advanced stages and working backwards. In contrast, international consensus groups-including the International Association of Pancreatology, American Pancreatic Association, Japan Pancreas Society, and European Pancreatic Club - proposed criteria for early, possible, and definitive chronic pancreatitis.[2]

The literature identifies several causes of chronic pancreatitis (including most recently recognized form - autoimmune pancreatitis). Interpretation of causes requires caution, as data heavily depend on local guidelines and may be subject to reporting biases. Patients in most cases exhibit similar clinical features.

Hallmark signs of chronic pancreatitis include calcifications within the pancreatic tissue or ducts, ductal dilatation, fibrosis, parenchymal atrophy and the impairment of both exocrine and endocrine function of pancreas.
These lead to malabsorption of nutritional factors, diabetes, chronic pain, and an elevated risk of pancreatic cancer. Interestingly, a significant subset of patients with chronic pancreatitis neither experiences pain (approximately 30%) nor has a history of acute pancreatitis (around 50%). [3,4] In clinical settings, "chronic pancreatitis" is sometimes used as a broader term to encompass various chronic pancreatic inflammatory diseases that share some, but not all, characteristics of the classic form.[5] In 28% of cases the cause of the disease remains idiopathic.[6] Effective management requires addressing both the physical and psychosocial dimensions of the disease, alongside mitigating complications and nutritional deficiencies.

Epidemiology

Reliable data on the population burden of chronic pancreatitis are scarce. Between 2001 and 2013, the prevalence among insured adult Americans (48.67 million individuals) ranged from 25.4 to 98.7 cases per 100,000, depending on diagnostic criteria.[7] The annual incidence is estimated at 4–5 new cases per 100,000, consistent with findings from a smaller but comprehensive population-based study in Minnesota.[8]
Similar prevalence and incidence rates have been observed in data from international studies, including an Italian primary care survey, analyses from eight pancreatic units in Spain, 22 hospitals in China, and a nationwide survey from Japan, reporting prevalence rates of 13.5 to 52.4 cases per 100,000 and an incidence of 5 new cases per 100,000 annually.[9–12] Approximately 3–35% of patients experiencing an initial acute pancreatitis episode will progress to chronic pancreatitis within 3–8 years.[13,14] Men account for two-thirds of cases, and prevalence is higher among Black individuals compared to White individuals.[6]

Pathogenesis and risk factors

The classic type, often linked to alcohol consumption (in 42 to 77% of patients), smoking (in >60%), or genetic mutations (in 10%), typically begins with recurring painful episodes of pancreatitis, which over a period of 3 to 5 years evolve into persistent, debilitating upper abdominal pain often accompanied by nausea and vomiting. Pain results from peripheral and central neural sensitization, leading to increased visceral sensitivity, allodynia and hyperalgesia.[15–17] Severe pain disrupts patients' lives, often exacerbated by alcohol abuse and psychosocial factors such as poor resilience and insufficient social support.[18] It ultimately leads to the irreversible damage of the pancreatic tissue.[18] Alcohol consumption exceeding 80 g per day for over 6–12 years and smoking histories of over 35 pack-years significantly increase the risk of developing chronic pancreatitis.[19–21] Genetic mutations, particularly in CFTR, SPINK1, or CTRC genes, are linked to over 90% of early-onset cases (<35 years of age).[5] Hereditary pancreatitis, resulting from mutations in the PRSS1 gene, is uncommon and represents about 1% of all cases.[6] Regardless of etiology, chronic pancreatitis significantly elevates the risk of pancreatic cancer, with cumulative risks of 1.8% at 10 years and 4% at 20 years for sporadic cases, and up to 7.2% by age 70 in hereditary cases.[6,22]

As we now know, chronic pancreatitis rarely has a single cause. It is usually caused by a combination of factors, including genetic, environmental and lifestyle factors. A proposed model of disease progression describes chronic pancreatitis as a gradually worsening condition in which those at-risk experience recurrent episodes of inflammation, eventually leading to irreversible damage. Chronic pancreatitis negatively impacts both quality of life and life expectancy.[23]

Complications

Complications include pseudocysts, bile duct or duodenal strictures, splanchnic venous thrombosis, and pancreatic cancer. Endocrine dysfunction leads to glucose intolerance and type 3c diabetes, characterized by unstable blood glucose levels.[24] Exocrine insufficiency manifests with steatorrhea, malnutrition, and deficiencies in fat-soluble vitamins (A, D, E, K), vitamin B12, zinc, and magnesium, often resulting in osteopenia or osteoporosis, which in turn can result in low-impact fractures.[18,25–28]

Role of imaging in the diagnosis of chronic pancreatitis

Imaging plays a crucial role in the diagnosis of chronic pancreatitis (CP), facilitating the identification of characteristic morphological changes and guiding clinical management. Various imaging techniques, including computed tomography (CT), magnetic resonance imaging (MRI), transabdominal and endoscopic ultrasonography (EUS), are used to assess the extent of pancreatic damage and differentiate CP from other conditions.

Ultrasonography as a tool in the diagnosis of chronic pancreatitis

Transabdominal ultrasonography (US) is a non-invasive imaging modality used to diagnose chronic pancreatitis (CP). Recent innovations in ultrasound technology have enhanced its diagnostic precision, making it a competitive alternative to more invasive techniques. While endoscopic ultrasound (EUS) remains the gold standard, transabdominal US provides comparable diagnostic accuracy, making it a viable alternative in clinical contexts.

Comparison of ultrasound with other imaging modalities

A study comparing transabdominal US and computed tomography (CT) revealed similar sensitivities (64% for US) and specificities (85% for US) in the diagnosis of CP, indicating that US can effectively detect the condition.[29] However, neither method is adequate as an autonomous diagnostic instrument.[29] Despite its limitations, US continues to be a primary imaging technique due to its non-invasive nature and accessibility.[30] Regardless of its invasive character endoscopic ultrasound (EUS) remains the most accurate technique in the detection of early-stage chronic pancreatitis changes. While MRI has limited application in diagnosing early-stage CP it offers a fine standard of calcifications and parenchymal changes detection, without exposing the Patient to the radiation consequences.[6] Selected parameters characterizing aforementioned imaging methods are summarized in the **Table 1.**

Table 1. *Selected parameters characterizing imaging methods used in the diagnosis and management of CP*

Modality	**Computed Tomography (CT)**	**Magnetic Resonance Imaging (MRI)**	**Endoscopic Ultrasound (EUS)**	**Transabdominal Ultrasonography (TUS)**
Imaging technique	X-ray-based cross-sectional imaging	Magnetic field and radio waves	High-frequency ultrasound via endoscope	External ultrasound waves
Parenchymal changes	Limited	Good	Excellent	Poor to moderate
Detection of calcifications	Excellent	Good	Limited	Limited
Contrast requirement	Often required	Often required	Not required	Not required
Early-stage CP detection	Poor	Moderate	Excellent	Poor
Radiation Exposure	Yes	No	No	No

The following **Fig. 1** presents a comparison of images showing large inflammatory masses (green arrows) with calcifications and dilated main pancreatic duct (blue arrows) in a patient with chronic pancreatitis on ultrasound and CT scan.

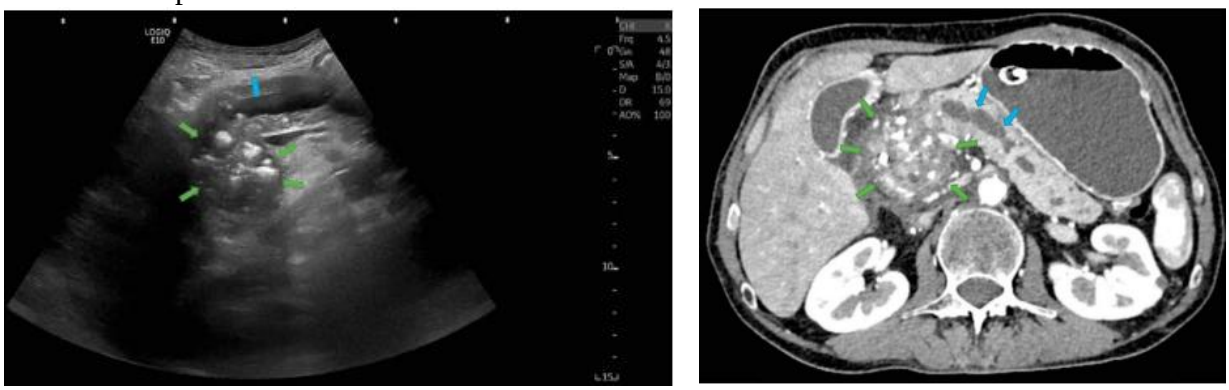

Figure 1. *Left US image, right CT scan* [29]

Key changes seen on ultrasound in CP

The most common finding is the dilation of the main pancreatic duct, often accompanied by calculi and variations in duct caliber. The pancreatic parenchyma may appear heterogeneous, with areas of different echogenicity, calcifications, cysts, and hyperechoic foci. Structurally, the pancreas may be enlarged with uneven contours and show signs of fibrosis or lobulation. Hyperechoic inclusions are frequently observed within the pancreas, sometimes with acoustic shadowing, indicating calcifications or fibrotic changes. Additionally, enlarged lymph nodes and a medium amount of free fluid in the abdominal cavity may be found.

Modern transabdominal ultrasound has demonstrated good diagnostic accuracy, with sensitivity and specificity varying depending on the scoring system used, such as the Rosemont criteria, a classification system employed to standardize the assessment of chronic pancreatitis features.[31,32]

More invasive technique - endoscopic ultrasonography (EUS) can detect echogenic foci, which suggest calcification, prominent interlobular septae pointing to fibrosis, small cystic cavities due to edema, lobulated outer gland margins indicating fibrosis or atrophy, and heterogeneous parenchyma. EUS identifies ductal dilation, irregularity, echogenic walls due to fibrosis, side-branch ectasia, and echogenic foci indicating stones.[33] Distinct structural changes such as pseudocysts, calcifications and fibrosis are detectable, helping in the diagnosis of various forms of chronic pancreatitis. The following **Fig. 2** presents typical signs usually seen in early chronic pancreatitis.

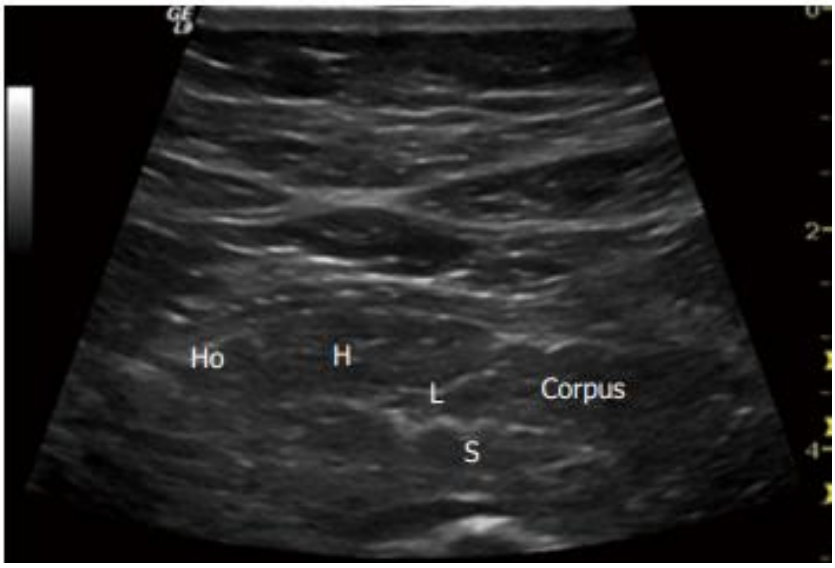

Figure 2. *Lobularity (L), stranding (S), hyperechoic foci (H) in early chronic pancreatitis seen on US* [34]

Endoscopic ultrasonography (EUS) in the assessment of structural changes and microcalcifications

EUS plays a significant role in the diagnosis and management of chronic pancreatitis (CP), particularly in the initial stages when it facilitates the distinction between CP and other pancreatic pathologies, thus enabling more effective therapeutic interventions.[35,36] It remains superior in certain aspects, particularly in detailed visualization of pancreatic structures. EUS allows to identify specific characteristics such as hyperechoic foci, lobularity, cysts, and ductal changes, which are essential for diagnosing CP with high sensitivity and specificity.[37] It provides high-resolution images of the pancreatic parenchyma and duct, which are crucial for evaluating and managing CP and its complications.[36,38] Endoscopic ultrasound is especially useful in diagnosing groove pancreatitis, a rare type of chronic pancreatitis, as it offers high-resolution imaging that helps in differentiating it from other disorders.[39]

The use of EUS-guided fine-needle aspiration (FNA) and biopsy can be challenging in CP patients due to the heterogeneous nature of the lesions, however it remains a useful technique for obtaining tissue samples.[35,40] EUS-elastography, which quantifies pancreatic fibrosis, and the endoscopic pancreatic function test (ePFT) are advanced techniques that enhance the diagnostic accuracy of EUS by providing both morphological and functional assessments.[38,41] Although EUS offers several benefits, it also possesses limitations, such as operator dependency and difficulties in correlating EUS images with histopathological findings due to the often heterogeneous nature of lesions found in CP.[35]

Furthermore, while EUS is a valuable tool for diagnosing CP, it frequently needs to be complemented by other diagnostic modalities to achieve a thorough assessment and precise diagnosis.[39] The integration of artificial intelligence (AI) with EUS is a promising development, potentially increasing the specificity and precision of CP diagnosis by augmenting image interpretation and differentiation between CP and pancreatic cancer.[42]

The following Fig. 3 presents a comparison of images showing dilated main pancreatic duct (arrowheads; A) with intraductal calcifications (asterisk; A) and hyperechoic features with shadowing (arrow; B) and dilated branch ducts (arrowheads; B) on endoscopic ultrasound and dilated main pancreatic duct (arrowheads; C) and side branches as well as parenchymal calcifications (arrows; C) on CT imaging in a patient with a history of chronic pancreatitis.

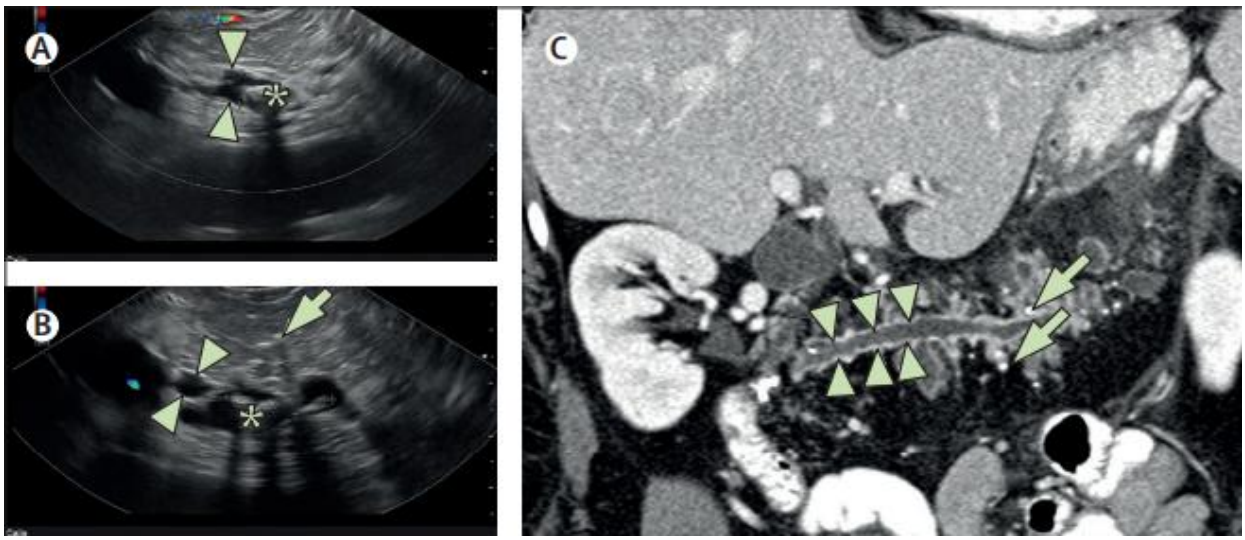

Figure 3. *A),B) endoscopic ultrasound imaging; C) CT scan* [18]

Elastography in the assessment of pancreatic fibrosis

Recent advancements in ultrasound technology, such as elastography, have enhanced its diagnostic capabilities. Elastography allows for the evaluation of tissue characteristics, helping in the diagnosis and grading of chronic pancreatitis by assessing fibroinflammatory status.[41,43–45] Transabdominal elastography, including shear wave elastography, has shown promise in assessing pancreatic stiffness, which correlates with CP severity.[46] The ability to measure tissue hardness can enhance diagnostic accuracy, especially in early-stage CP where traditional imaging may be less effective.[47] Other publications mention the application of EUS-elastography, which has proven its ability to diagnose CP at early stages thus allowing for more effective treatment.[35,38]

The following **Fig. 4** presents an image of elastography with endoscopic ultrasonographic (EUS) shear wave measurement.

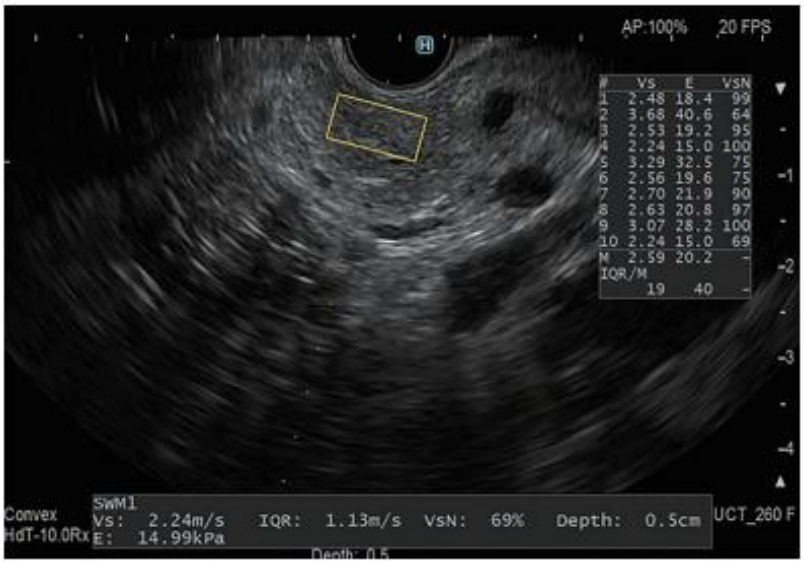

Figure 4. *EUS elastography with shear wave measurement* [47]

Use of ultrasonography in monitoring disease progression

The creation of specialized scoring systems, like the Gemelli USCP score, is intended to facilitate the staging and monitoring of chronic pancreatitis by ultrasound. This score has demonstrated a strong correlation with conventional imaging modalities and laboratory markers of pancreatic exocrine insufficiency, indicating its potential as a non-invasive tool for patient follow-up.[48] Transabdominal ultrasonography is also a valuable tool in the evaluation of fibrosis progression in chronic pancreatitis as it can assess both ductal and parenchymal features of the pancreas. One of the most helpful techniques employed in quantifying fibrosis progression is shear wave elastography, a form of transabdominal US which quantifies tissue elasticity, providing an objective measure of fibrosis.[44,49] While EUS is often considered more reliable due to its great spatial resolution, transabdominal US remains a reasonable practical alternative, especially if combined with elastography techniques. It offers a less invasive option compared to methods like ERCP, which may have adverse effects.[50] Another method applicable in monitoring the progression of CP is secretin-stimulated ultrasonography, a technique which measures pancreatic fluid flow and can be used to evaluate exocrine pancreatic function, which is often impaired in CP. It provides a feasible method for assessing pancreatic secretion and correlates well with other methods like MRI.[51,52] The best modality in monitoring complications is Contrast Enhanced Ultrasound (CEUS). It can significantly simplify the differentiation between pancreatic ductal adenocarcinoma and inflammatory masses in CP by analyzing perfusion patterns, which aids in identifying potential malignant transformations within the pancreas.[53,54] While CT is superior in visualizing extrapancreatic and vascular complications, ultrasonography is helpful in evaluating gallstones and characterizing peripancreatic collections, which are common complications of CP.[55,56]

Limitations of ultrasonography in CP

Despite its advantages, transabdominal US has limitations, such as operator dependence and potential interference from conditions such as obesity or ascites, which can affect measurement accuracy.[46] It is less effective than MRI and EUS in identifying changes in pancreatic duct width and the architectural details of cysts.[57] The deep localization of the pancreas poses technical challenge in accurate measurement of pancreatic stiffness, although recent software developments show promise.[45] Due to the limited sensitivity for CP of the ultrasonography findings often need to be confirmed by CT or MRI to enhance diagnostic accuracy and provide comprehensive evaluation in cases of inconclusive results, suspected complications, early disease stages, or when malignancy needs to be ruled out.[50,58,59]

The future of ultrasonography in CP

Although EUS offers several benefits, it is confronted with challenges like variability between operators and the difficulty of correlating ultrasound images with histopathological results.[35,37] Technological advancement in EUS, both in terms of more sophisticated imaging methods and the creation of newer diagnostic equipment, are expected to improve the accuracy and consistency of diagnosing chronic pancreatitis.[35,36] The development of portable ultrasound technology has immense potential in the propagation of community medicine, particularly in the management of chronic pancreatitis. Portable ultrasound devices, such as point-of-care ultrasound (POCUS), are being increasingly utilized in rural and underserved areas due to their accessibility and cost-effectiveness. These devices can improve diagnostic capabilities and patient management in settings with limited resources.[60,61] The use of portable ultrasound in connection with other technologies, such as AI, can improve disease monitoring and management, potentially reducing the need for more expensive and time-consuming diagnostic procedures.[62]

Conclusion

Chronic pancreatitis frequently causes persistent abdominal discomfort. It is predominantly caused by excessive alcohol consumption, tobacco use or genetic mutations.[6] In summary, though transabdominal ultrasound offers moderate diagnostic accuracy for chronic pancreatitis, advancements in technology and the introduction of new scoring systems could improve its utility in clinical practice. Nevertheless, it should be supplemented by other imaging modalities to ensure a detailed assessment and accurate diagnosis. Ultrasound, especially endoscopic ultrasound (EUS) and its advanced techniques such as elastography, plays a central role in diagnosing and managing chronic pancreatitis. Despite offering significant benefits, ongoing research and advancements in technology are necessary to overcome existing limitations and enhance diagnostic precision. Although recent advancements in ultrasound imaging techniques have enhanced its usefulness in diagnosing pancreatic conditions there is still a need for specific guidelines for its use in chronic pancreatitis.[44]

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Authors' Contributions Statement:

Conceptualization: [JP][KB]
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Check: [KM][KBA]
Formal analysis: [GB][JS]
Investigation: [JP][KB][GB]
Resources: [JP][NJ][MJ][[JA]
Data curation: [MP][KM][JA][KBA]
Writing – rough preparation: [JP][KB]
Writing – review and editing: [NJ][MJ]
Visualization: [JA][JS][KBA]
Supervision: [MP][KM][GB]
Project administration: [JP]

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