THE PANCREAS: FUNCTIONS, DISORDERS, AND ITS PHYSIOLOGICAL ROLE IN MAMMALIAN ORGANISMS

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Abstract

This review explores the scientific literature on pancreatic diseases, with a focus on exocrine pancreatic insufficiency (EPI). It highlights the relationship between pancreatic health and obesity and examines the influence of pancreatic exocrine function on the development of adults and adolescents. Studies on piglets, a widely used model for optimizing treatments for human pancreatic diseases, are also referenced. The pancreas, a critical organ with both exocrine and hormonal functions, plays a central role in the health of animals and humans. Pancreatic disorders are often severe and challenging to manage. A balanced diet and appropriate dietary supplements can significantly improve patient outcomes and the progression of these diseases. Thus, a healthy lifestyle and diet are essential for maintaining the pancreas's optimal physiological function.

Keywords: pancreas, pancreatic disorders, exocrine pancreatic insufficiency (EPI), obesity, diabetes.

Introduction

The pancreas is a glandular organ critical to the proper functioning of the entire body. Pancreatic insufficiency refers to the organ's inability to produce or secrete sufficient digestive enzymes for the proper digestion and absorption of nutrients. This condition typically arises from damage to the pancreas due to various clinical causes, including recurrent acute or chronic pancreatitis, diabetes, autoimmune disorders, gastrointestinal cancers, or post-pancreatectomy complications. In children, pancreatic insufficiency is most commonly associated with cystic fibrosis or rare genetic disorders like Shwachman-Diamond syndrome. Manifestations include malabsorption, malnutrition, vitamin deficiencies, and weight loss (or growth failure in children). Treatment focuses on addressing the underlying cause, preventing further pancreatic damage, and alleviating symptoms.

Structure of the Pancreas

Anatomically, the pancreas is divided into three regions: the head, body, and tail. The organ's parenchyma has a lobular structure, comprising numerous secretory vesicles that account for 80–85% of its mass. The discharge ducts play a vital role in pancreatic function. Each lobule connects via ducts that merge into the main pancreatic duct, which extends from the pancreas's tail to its opening in the duodenum at the greater papilla. An accessory pancreatic duct, present in about 70% of individuals, may also connect to the main duct, facilitating secretion delivery.

The histological structure of the pancreas includes two primary components:

1. **Pancreatic Islets (Langerhans Islets):** These clusters of endocrine cells, numbering up to 2 million, are responsible for producing pancreatic hormones.
2. **Secretory Cells:** Constituting the majority of the pancreas, these cells secrete pancreatic juice and enzymes essential for digestion.

This dual functionality—hormonal and exocrine—positions the pancreas as a vital organ for maintaining metabolic and digestive health.

Physiological Functions of the Pancreas

The pancreas serves two primary functions: endocrine and exocrine. The endocrine function involves the production of hormones that regulate blood sugar levels, such as insulin, proinsulin, glucagon, amylin, C-peptide, somatostatin, and pancreatic polypeptide (PP). Insulin decreases blood sugar levels, while glucagon raises them. These hormones are produced in the pancreatic islets (Langerhans islets).

The exocrine function, performed by secretory cells, involves the production of digestive enzymes that are part of an iso-osmotic, alkaline pancreatic juice. These enzymes, which digest proteins, fats, carbohydrates, and nucleic acids, are secreted into the duodenum via the pancreatic ducts. Goblet cells within the ducts also secrete mucus. The pancreatic juice composition includes proteolytic enzymes (e.g., trypsin, chymotrypsin, carboxypeptidase, elastase), lipolytic enzymes (e.g., lipase, phospholipase, esterase), glycolytic enzymes (e.g., amylase), and nucleolytic enzymes (e.g., ribonuclease, deoxyribonuclease).

Advancements in EPI Management

Efforts to improve the quality of life for EPI patients have included exploring microbial pancreatic enzymes for supplementation. Studies show that these enzymes enhance fat and nitrogen absorption, as well as lipase and amylase activity, though values remain lower than in healthy individuals. This research underscores the potential for dietary interventions to mitigate the effects of pancreatic insufficiency and improve patient outcomes.

Pancreatic Exocrine Insufficiency (EPI)

Exocrine pancreatic insufficiency (EPI) is a condition that impairs the digestion of food due to insufficient production of pancreatic enzymes. This deficiency prevents the body from effectively breaking down and absorbing essential nutrients such as fats, proteins, carbohydrates, vitamins, and minerals.

EPI can result from various underlying causes, including chronic pancreatitis, surgeries involving the pancreas, stomach, or intestines, and genetic disorders like cystic fibrosis or Shwachman-Diamond syndrome. Conditions such as Crohn’s disease and celiac disease can also lead to EPI in some individuals. Excessive alcohol consumption is a major contributor to chronic pancreatitis, with long-term heavy drinking (more than 80 grams of ethanol daily for 6–12 years) being a significant risk factor. Additionally, individuals with diabetes are particularly vulnerable to developing EPI, as confirmed by clinical studies.

Initially, EPI may be asymptomatic. However, as the pancreas's ability to absorb fats diminishes, symptoms such as abdominal pain, diarrhea, gas, bloating, and a sensation of fullness may appear. Weight loss and deficiencies in fat-soluble vitamins (e.g., vitamin D and K) can lead to complications such as bone pain and bleeding disorders.

Diagnosis

EPI diagnosis involves evaluating blood vitamin levels and pancreatic enzyme production. Patients are also assessed for underlying conditions that might contribute to EPI, such as celiac disease. A “3-day stool test” may be performed to measure fat content in bowel movements. Imaging techniques like CT scans, MRIs, and endoscopic ultrasounds are often used to detect signs of pancreatic inflammation or damage.

By identifying and addressing EPI early, appropriate management can improve nutrient absorption and overall health.

Inflammatory Diseases

Chronic and Acute Pancreatitis

Chronic pancreatitis (CP) is the leading cause of EPI in adults and the most prevalent pancreatic disorder. Inflammation in the pancreas disrupts normal cellular function, causing digestive enzymes to activate prematurely, potentially leading to self-digestion of pancreatic tissue and surrounding organs. Chronic inflammation can impair insulin production, disrupt digestion, and, if untreated, become life-threatening.

CP is categorized into various subtypes, including autoimmune pancreatitis, paraduodenal pancreatitis, and pancreatitis associated with genetic mutations. The condition can result from numerous factors, such as alcohol abuse, smoking, immune system malfunctions, high blood lipid levels, certain medications, and chronic stress. Over time, chronic inflammation causes irreversible damage to pancreatic tissue, impairing digestion and increasing the risk of diabetes. Additionally, malnutrition caused by CP can lead to complications in the cardiovascular system, bones, and immune system.

Acute pancreatitis, in contrast, occurs suddenly without prior symptoms and is more common in men aged 30 to 40. Symptoms include severe abdominal and back pain, vomiting, dizziness, and excessive sweating. Severe cases may lead to complications such as pseudocysts, abscesses, sepsis, kidney failure, respiratory distress, and shock.

Treatment and Management

Treatment for pancreatitis depends on the type and severity. Acute pancreatitis may require medications, intravenous fluids, and pain management, while chronic pancreatitis often involves enzyme supplements, steroids, or diabetes management. A balanced diet is critical in both cases to support immune function and maintain gut microbiome health. Emerging research suggests that angiotensin-converting enzyme (ACE) inhibitors may offer therapeutic benefits for CP.

Genetic and Hereditary Factors

In some cases, pancreatitis results from inherited conditions such as cystic fibrosis or hereditary pancreatitis. These progressive disorders are often marked by recurrent acute episodes that develop into chronic disease, leading to symptoms like pain, diarrhea, malnutrition, and diabetes. Surgery may be the only diagnostic or treatment option in certain instances.

Prognosis and Mortality

While studies on long-term survival rates for CP patients are limited, available data indicate that 60–75% of deaths are due to complications outside the pancreas. These include alcohol- and smoking-related conditions such as lung or esophageal cancer, liver cirrhosis, and cardiovascular diseases. Other common causes of death include tuberculosis, gastrointestinal disorders, and malignant tumors.

Understanding the complexities of pancreatic disorders, their causes, and their systemic impacts is essential for effective management and improving patient outcomes.

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