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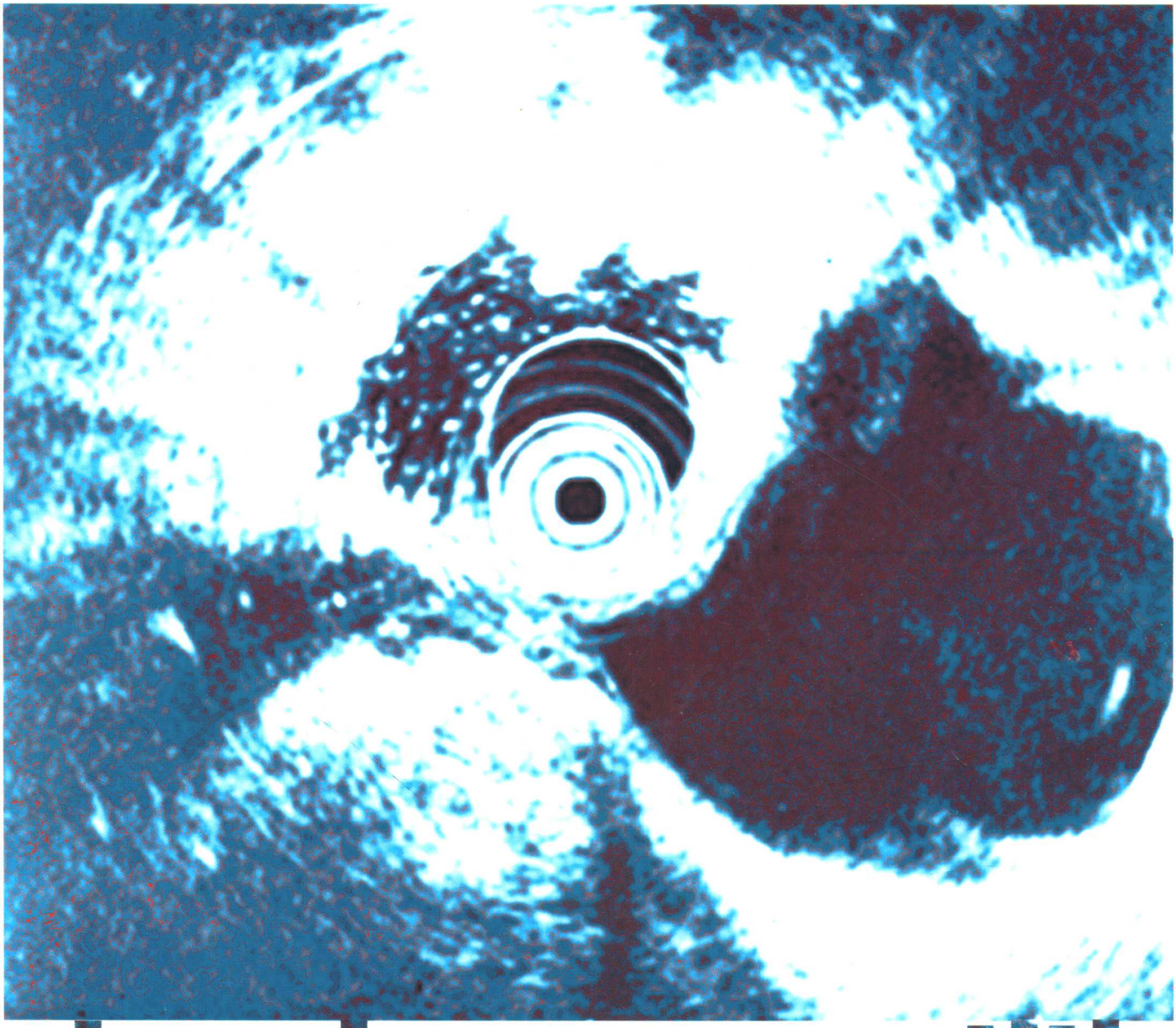

# chronic pancreatitis

*Guido N. J. Tytgat MD PhD and Marco J. Bruno MD PhD*

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*1105 AZ Amsterdam The Netherlands*

**Revised and updated from *Management of Gastrointestinal Diseases,***
**Edited by Sidney J. Winawer, MD**

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Chronic pancreatitis is a continuing inflammatory process that typically causes pain and results in irreversible damage to the pancreas with permanent loss of exocrine and endocrine function. Previously, subdivisions of acute, relapsing acute (with clinical and biologic restitution of the gland after each attack), chronic relapsing (chronic pancreatitis with acute exacerbations), and chronic pancreatitis were made. The distinction between relapsing acute pancreatitis and chronic relapsing pancreatitis, however, is arbitrary and has no functional or pathologic foundation; these 'relapsing' categories should therefore be omitted. It should be noted that although younger patients often present themselves with severe pain as a key symptom, older patients frequently do not have pain, particularly in idiopathic chronic pancreatitis (1).

## Epidemiology

The prevalence of chronic pancreatitis is not well known, but estimates range from 0.04 to 5% (2). Its prevalence seems to be rising, particularly in women (3–5). Not only is the male:female ratio steadily decreasing, but so is the average age of onset for the disease (**Fig. 1**). To what extent this is a true change or the result of improved diagnosis is unclear. Although few reliable studies have been performed, incidence rates seem to vary geographically from 0.3 to 10 cases per 100 000 per year. The main etiologic agent of chronic pancreatitis in Western countries is alcohol. The changes in prevalence, age of onset, and male:female ratio, therefore, seem to be due largely to changes in drinking habits in Western countries during the past 40 years; alcohol consumption has not only increased for females and the overall population, but there is also a tendency to start drinking at an earlier age. However, although alcohol is by far the most important etiologic agent, other factors must be considered as well. The incidence rate of chronic pancreatitis in Switzerland, for example, is lower than that in Denmark, despite the fact that per capita alcohol consumption is much higher in Switzerland (**Fig. 2**). Moreover, there is often a discrepancy between the incidence of chronic pancreatitis and the incidence of cirrhosis of the liver in distinct communities where alcohol intake is high. Gallstone-induced chronic pancreatitis seems to be disappearing.

## Pathophysiology

Morphologically, chronic pancreatitis is characterized by an irregular sclerosis with destruction and permanent loss of parenchymal tissue that may be either focal, segmental, or diffuse and may also be associated with varying degrees of dilatation of duct-system segments (**Fig. 3**). Adequate pancreatic histology is rarely obtained and hence histologic methods of grading cannot be routinely applied. With modern imaging techniques, however, one can visualize the pancreatic duct caliber, size of the gland, presence or absence of cavities, intraductal filling defects, calculi, duct strictures, and fascial thickening. The extent of organ involvement can also be ascertained (*see* Fig. 3).

Pathophysiologically, there have long been two conflicting theories on the development of chronic pancreatitis: the intraductal disease—lithiasis or secretory abnormality—theory and the enzyme activation–oxidative stress—primary cellular damage—theory (**Fig. 4**). Sarles is a proponent of the primary secretory abnormality theory (6). Abnormal pancreatic juice has a high viscosity, a high protein and lactoferrin content, and contains abnormal proteins as well as a decreased concentration of lithostathine, previously called pancreatic stone protein (7). Intraductal precipitations—protein plugs—in this abnormal pancreatic juice, consisting of multiple proteins, including digestive enzymes, glycoproteins, and acidic mucopolysaccharides, lead to duct and ductule obstruction with subsequent clogging of acini, epithelial lesions, and acinar damage which cause inflammation, fibrosis, and ultimately calcification of the intraductal protein plugs (8, 9). Some findings, however, do not support this hypothesis. The center of the plugs usually consists of desquamated cells; the nidus of the stone is often free of calcium, and acini are not blind-ending but rather tubular structures.

Other researchers, however, postulate a direct effect on the pancreatic exocrine cell (10). This primary cellular lesion leads to induction of intracellular lysosomal enzymatic activity, decreased activity of scavenger enzymes, elevated amounts of free oxygen radicals, and lipid peroxidation. There is evidence that pancreatic zymogens may become prematurely activated in patients with chronic pancreatitis; α1-proteinase inhibitor has been found to be complexed with chymotrypsin in pancreatic juice obtained from patients with chronic pancreatitis, suggesting partial

**Characteristics of chronic pancreatitis in the Western World**

| | 1970–1974 | 1985 |
|---|---|---|
| Mean age at onset (yr) | 46 | 37 |
| Mean age at diagnosis (yr) | 49.9 | 39.5 |
| Alcoholic pancreatitis (%) | 42 | 75 |

Fig. 1 Characteristics of chronic pancreatitis in the Western World.

*in situ* activation (11). The activity of lysosomal enzymes is increased in the juice of patients with chronic pancreatitis (12). The so-called stone protein that precipitates in chronic pancreatitis may be partially degraded trypsinogen (13), suggesting that premature activation of trypsinogen might occur, but this has been rebutted by Sarles (14). It is therefore tempting to speculate that digestive enzyme activation in chronic pancreatitis may result from admixture of zymogens with lysosomal hydrolases capable of activating the digestive enzymes. The subsequent cell death is thought to lead to fibrosis, with duct obstruction occurring secondarily to focal fibrosis (15). Current opinion favors the primary cellular damage–oxidative stress theory over the primary secretory abnormality theory, but both concepts remain controversial, at least in part.

## Etiology

There are several etiologic factors to be considered **(Fig. 5)**, but in Western countries chronic alcoholism is undoubtedly the major cause of chronic pancreatitis; it represents 70–90% of cases (3, 16, 17). Alcohol-induced chronic pancreatitis develops after 10–15 years of alcohol abuse. It is most frequent in men and the mean age at the onset of the disease is between 35 and 40 years. There is a linear relation between the level of alcohol consumption and the logarithmic risk for development of the disease. There does not appear to be a threshold level below which alcohol is non-toxic to the pancreas (18). The type of alcoholic beverage and the pattern of alcohol consumption (paroxysmally or continuously) seems to have no significant influence on the risk of developing chronic pancreatitis (19).

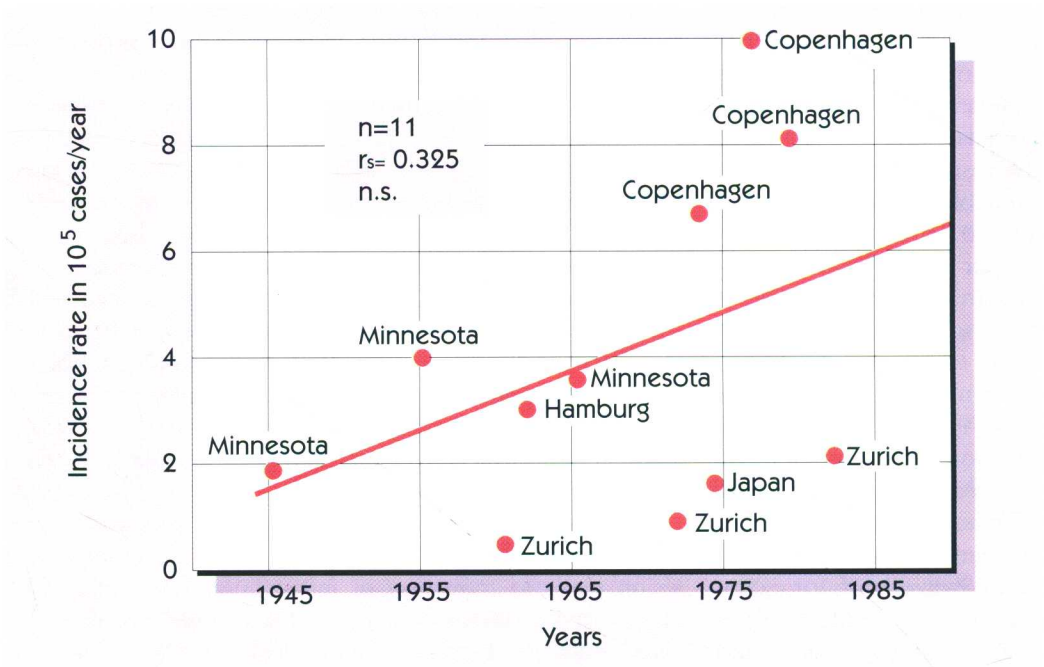



**Fig. 2 Incidence rates of chronic pancreatitis for the years 1945–1982 in the five locations studied. (Adapted from reference 4.)**

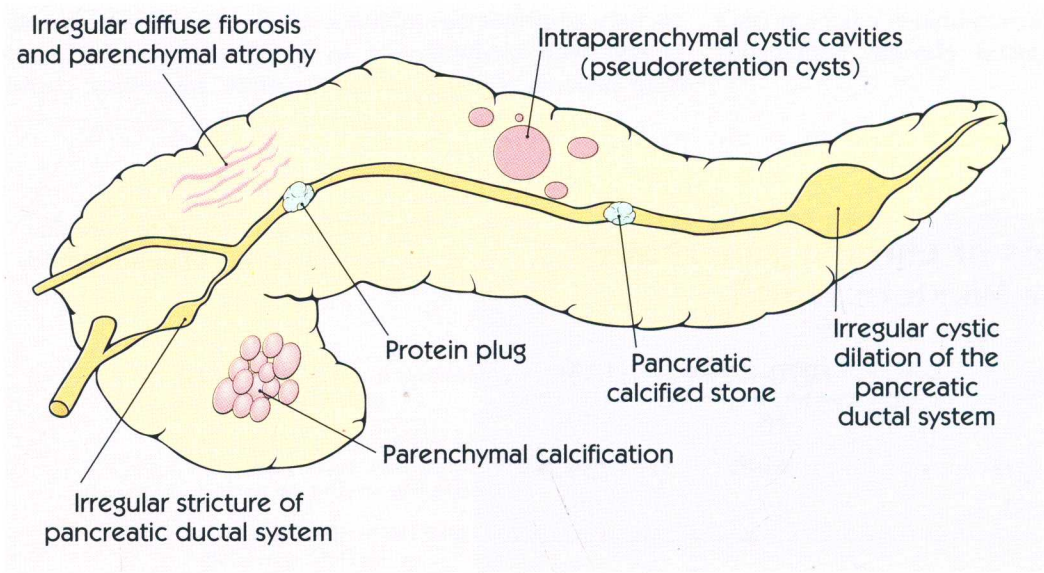



**Fig. 3 Characteristic pathologic changes in chronic pancreatitis.**

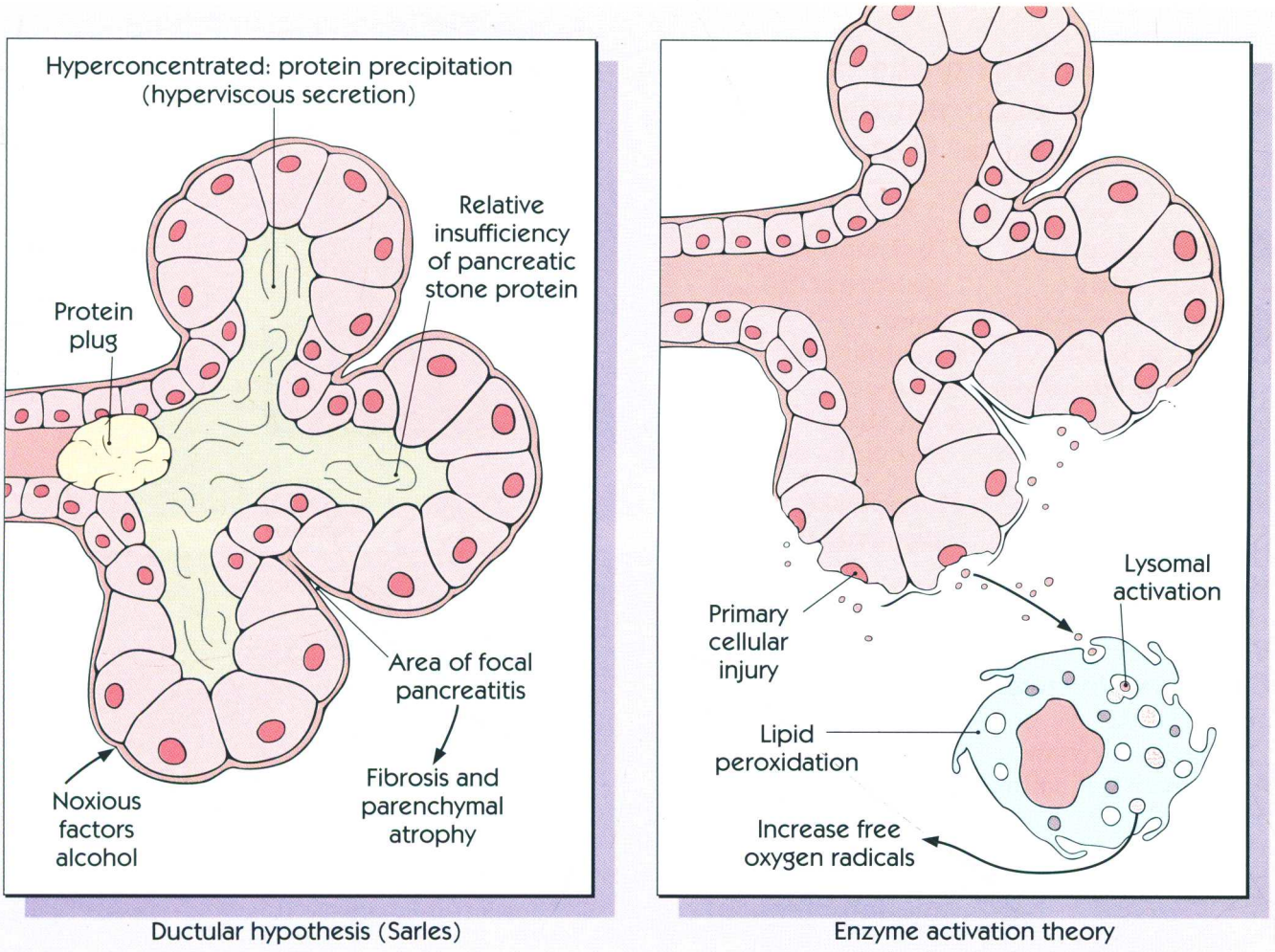



**Fig. 4 Etiology and pathogenesis of chronic pancreatitis.**

Other causes, such as hyperparathyroidism and hereditary familial forms, represent fewer than 1% of cases. In 10–30% of cases the etiology is unknown.

## Different Types of Chronic Pancreatitis

Non-calcified and calcified forms of chronic pancreatitis are, for many patients, almost certainly different stages of the same disease (7, 11). Chronic calcifying pancreatitis represents 95% of cases of chronic pancreatitis (**Figs 6 & 7**). Regardless of the etiology (*see* Fig. 5), the lesions are similar. The lobular appearance, however, may vary from normal to completely destroyed. Ducts are irregular, often focally strictured or beaded, and lined with atrophic epithelium. In addition, the ducts carry proteinaceous plugs, either with or without calcification. Calculi contain mostly insoluble calcium carbonate in the form of calcite and protein, of which a substantial fraction is low molecular weight pancreatic stone protein (20). The latter, a glycosylated small acinar protein, is probably a stabilizer of pancreatic juice, which is normally saturated in calcium (21); it acts by blocking the growth sites of calcium crystals. In pancreatic juice, the native stone protein is hydrolyzed to a smaller insoluble form (22). The pancreatic stone protein concentration in pancreatic juice is increased in chronic pancreatitis (9).

Obstructive pancreatitis is due to severe narrowing or occlusion of the main pancreatic duct or of its side branches because of tumor, (post-traumatic) scarring, pseudocysts, or congenital anomalies (**Fig. 8**). An example of the latter is the type of chronic pancreatitis that can be seen in some patients with pancreas divisum. Pancreatic calculi and proteinaceous precipitates are almost always absent in obstructive chronic pancreatitis.

Among other categories, hereditary pancreatitis and tropical pancreatitis resemble chronic calcifying pancreatitis histologically, but the clinical picture is somewhat different with less acute exacerbations and development of pseudocysts and more frequent pancreatic insufficiency. Sclerosing pancreatitis is an uncommon form due either to cystic fibrosis or to some unknown agent. Pancreatic atrophy without inflammation has been described in connection with long-standing gluten enteropathy.

## Different types of chronic pancreatitis and etiological factors

**Chronic calcific pancreatitis**
Ethanol
Organic solvents and other chemicals
Drugs
Analgesics
Thiazides
Prednisone
Hyperlipidemia
Hypercalcemia/ hyperparathyroidism
Viral infections
Congenital structural abnormalities: pancreas divisum
Antioxidant deficiency

**Obstructive pancreatitis**
Tumor
Post-traumatic
Pseudocyst
Congenital (pancreas divisum)

**Hereditary pancreatitis**

**Tropical pancreatitis**

**Sclerosing pancreatitis**

**Cystic fibrosis (mucoviscidosis)**

**Pancreatic atrophy (e.g. as seen in celiac disease)**

Fig. 5 Different types of chronic pancreatitis and etiologic factors.

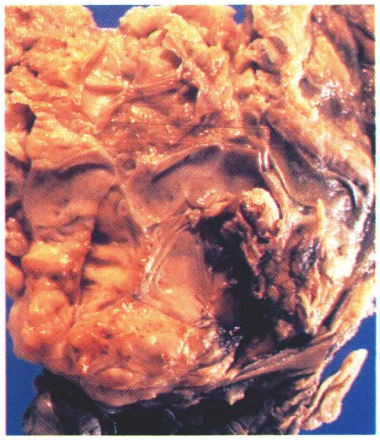
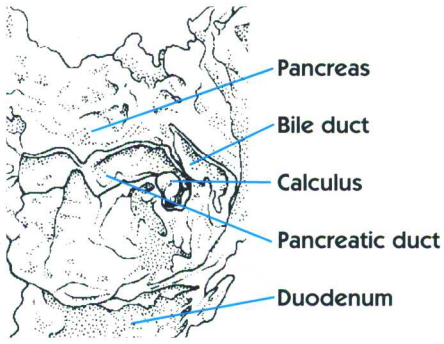


Fig. 6 Characteristic macroscopic appearance in chronic pancreatitis, showing a calculus in the pancreatic duct.




## Clinical Presentation and Course

In the majority of patients, chronic pancreatitis is clinically characterized by recurrent or persisting upper abdominal pain. However, although pain is often a key symptom it should be noted that 16% of patients with alcoholic pancreatitis and 23% of non-alcoholic patients did not feature pain in their history (23). There may be occasional episodes of acute exacerbation of pain, suggesting or compatible with acute pancreatitis; for these, the grading scheme for acute pancreatitis is appropriate. Such attacks are usually associated with pancreatic edema, although in a small number of patients it may indicate development of pancreatic necrosis. The attacks usually occur early in the natural history of chronic pancreatitis and their incidence decreases in time as the disease progresses (24, 25). Although the classic description of chronic pancreatitis is that of epigastric pain radiating through the back, the pain pattern is often atypical. The pain may be maximal in the right or left upper quadrants, in the back, or diffuse throughout the upper abdomen; it may even be located in the anterior chest or flank. Characteristically, it is persistent and deep-seated. The pain is often increased by alcohol and heavy fatty meals; it is often eased by bending forward. Usually there is a disparity between the severity of the abdominal pain and the paucity of physical signs. The mechanism of the chronic abdominal pain in chronic pancreatitis is poorly understood (3). A relationship between intraductal pressure and the severity of abdominal pain has been postulated but remains controversial (26, 27).

Evidence of pancreatic insufficiency (e.g. steatorrhea and diabetes) may also be present. Weight loss, abnormal stools, and other signs and symptoms suggesting malabsorption are common, especially when the disease is more advanced. During a painful period, weight loss may occur due to voluntary diet restriction intended to prevent postprandial pain. Clinically apparent deficiencies of fat-soluble vitamins are rare in this condition.

There is no grading system for clinical symptoms and signs of chronic pancreatitis. The main reasons for this are the inability to quantify pain, the difficulty in determining the onset of irreversible change, the different modes of progression (which may be by relapse and remission or insidious and constant), and the response to treatments (which may be variable and unpredictable).

## Prognosis

Several studies indicate that chronic pancreatitis is a severe disease. Factors that influence disease evolution and survival are not clear (**Fig. 9**). The exact role of continuing alcohol consumption is not fully known, although discrepancies in survival may reflect differences in the patterns of consumption. It may prevent painful relapses in chronic pancreatitis, but it does not arrest progressive gland destruction.

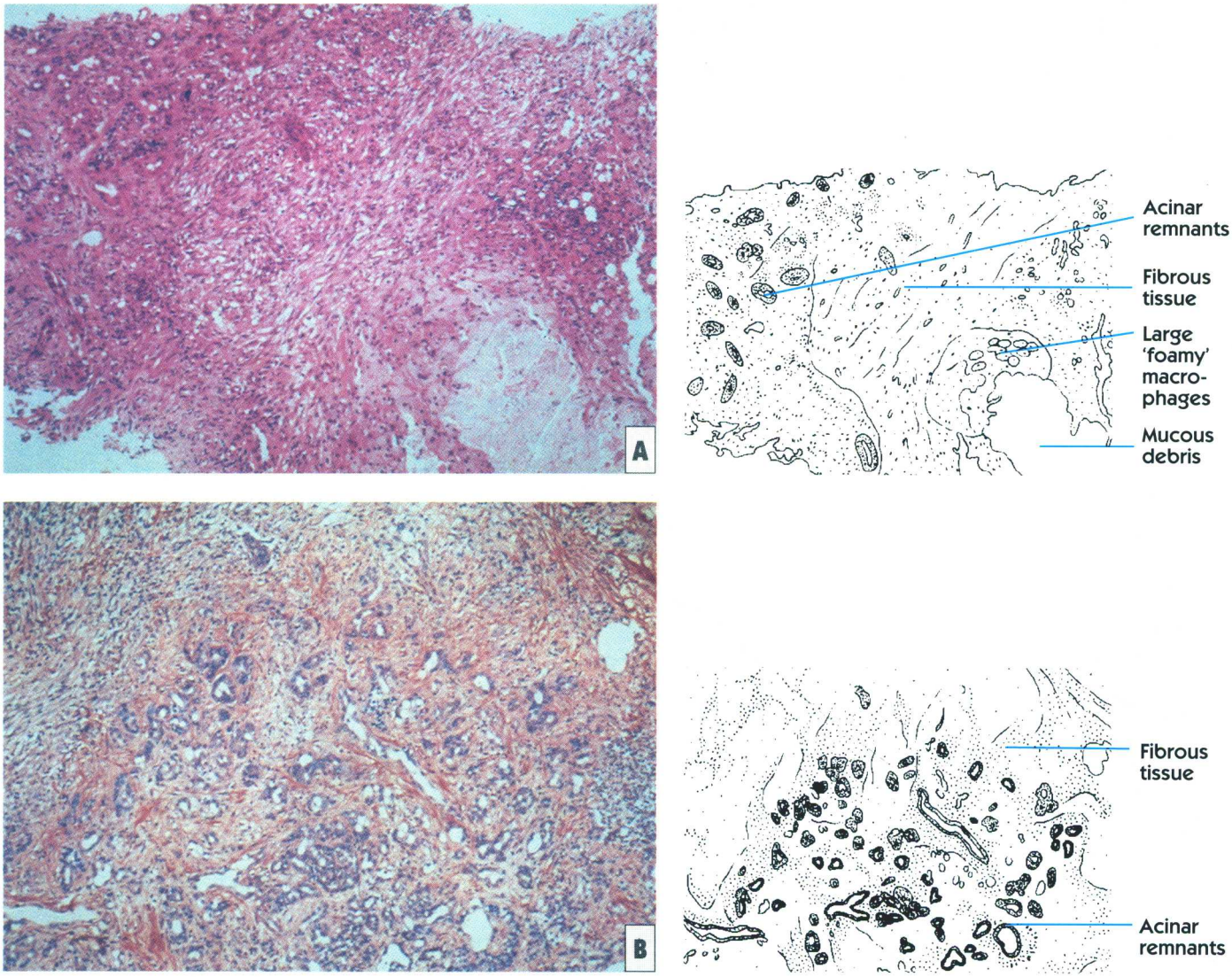



Fig. 7 Histologic appearance in chronic pancreatitis. (A) Bands of fibrous tissue have replaced the acini, the ducts have been destroyed, and macrophages have collected. (B) Phosphotungstic acid–hematoxylin (PTAH) stain emphasizes the fibrous tissue (rust-colored); only scattered pancreatic acini survive (×75).

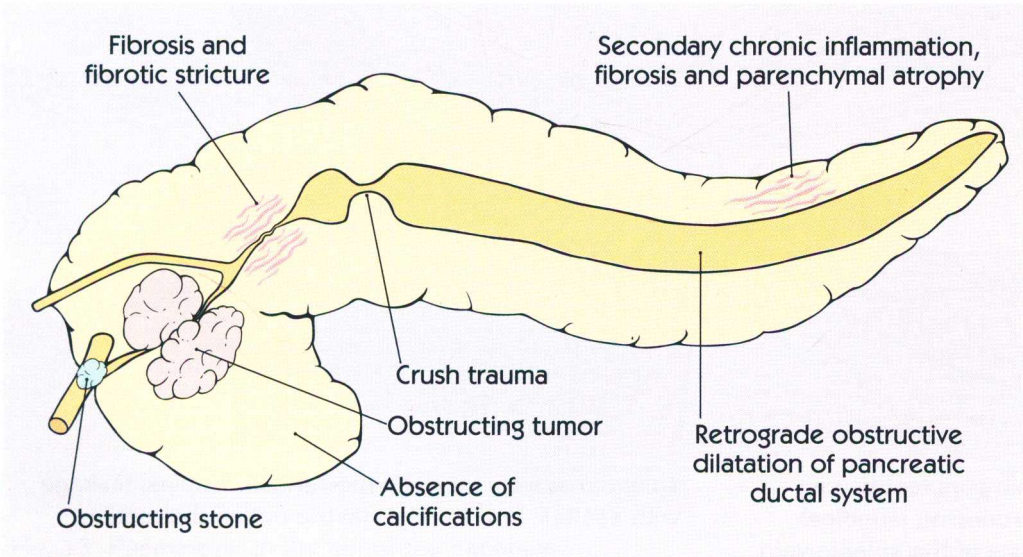



Fig. 8 Chronic obstructive pancreatitis results from occlusion of the main pancreatic duct or its branches by any of a variety of causes.

The most critical period for a patient with chronic pancreatitis seems to be the first 5 years after the clinical onset of the disease. All the most important complications (attacks of acute pancreatitis, pseudocysts, jaundice, etc.) tend to occur during this period, and the probability that surgical treatment will be necessary is at its highest. From 5 to 10 years after the onset, attacks of acute pancreatitis become rare, and pseudocyst formation or jaundice occurs less often. After 10 years, surgical complications are very unusual. Both frequency and severity of pain tend to decrease over time (25). The incidence of pancreatic calcification, exocrine pancreatic insufficiency, and diabetes progressively increases after the onset of the disease.

The mortality rate is about 50% 20–25 years after the initial diagnosis; 15–20% of patients die of complications associated with complications of the disease itself (28, 29). The

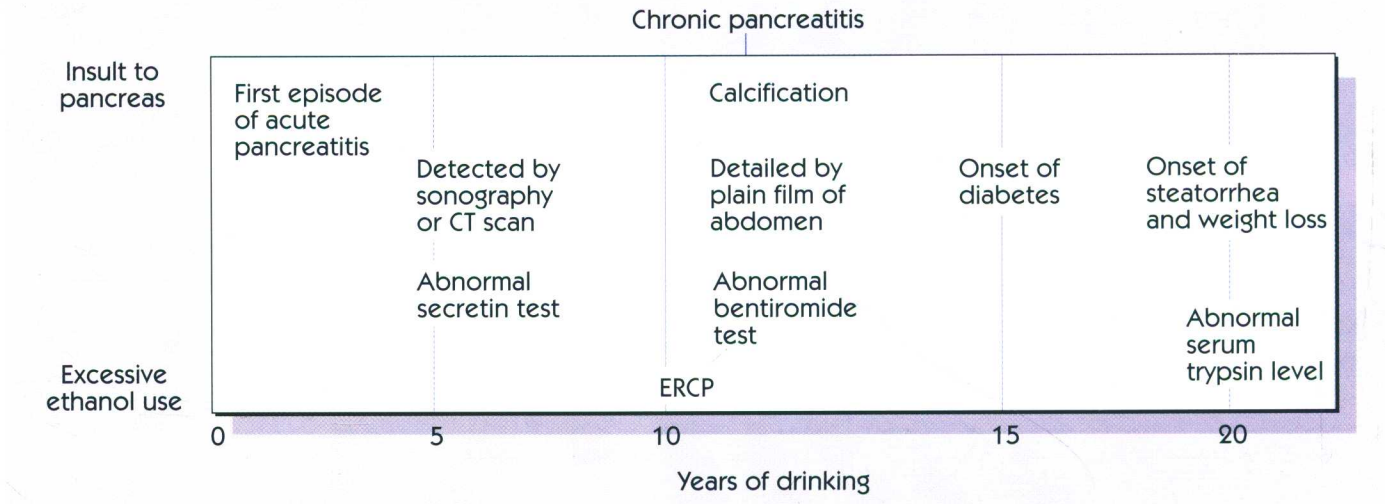



**Fig. 9 Natural history of chronic pancreatitis and pancreatic exocrine insufficiency.**

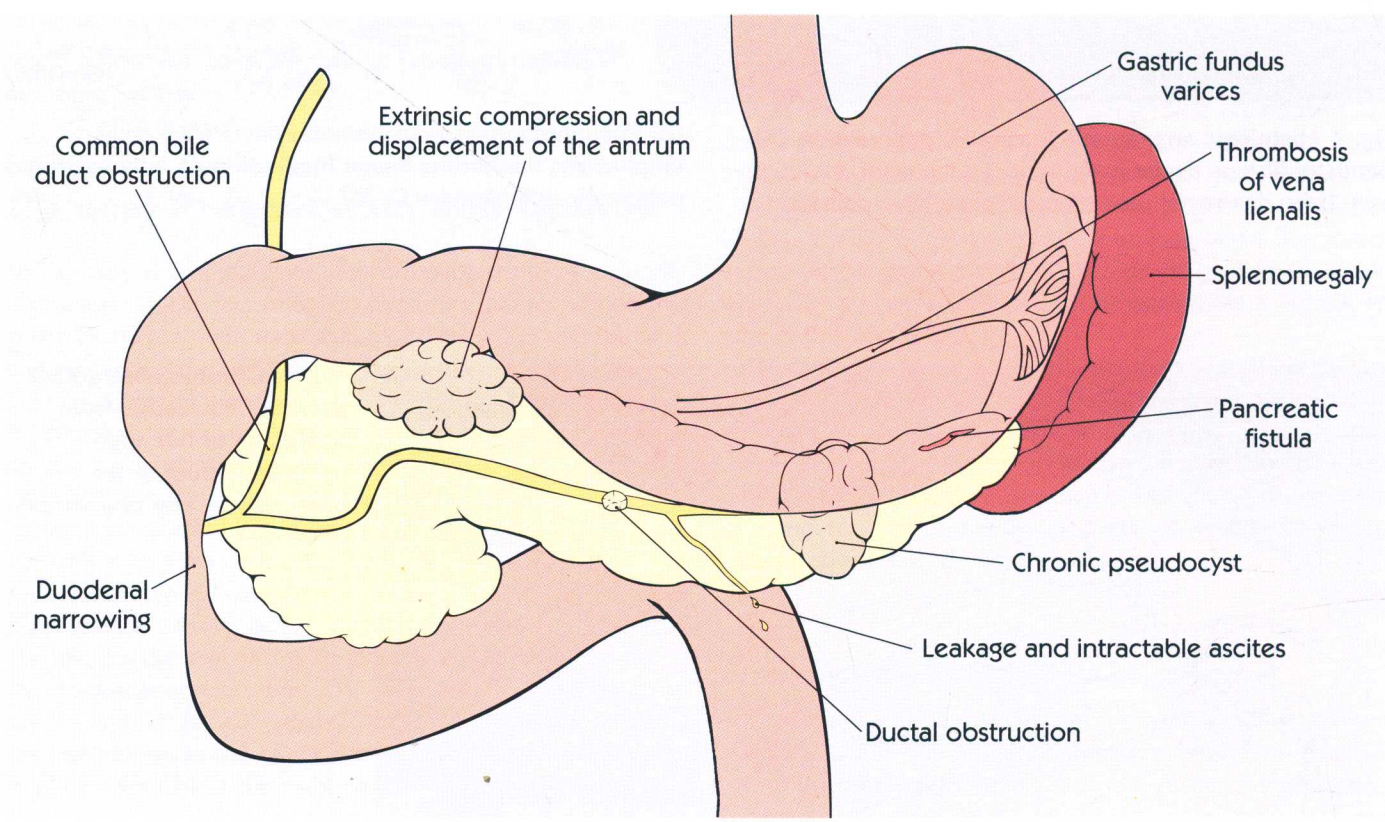



**Fig. 10 Complications of chronic pancreatitis can include bile duct obstruction (producing jaundice), pseudocyst formation, thrombosis of the splenic vein, splenomegaly, gastric fundic varices, fistulas, leakage with ascites, and (rarely) gastric outlet obstruction.**

remaining deaths are due to factors often associated with alcoholism such as trauma, malnutrition, alcoholic liver disease, infection, or tobacco use. In about 4% of patients, pancreatic cancer develops within 20 years of a diagnosis of chronic pancreatitis (30).

## Complications

Metabolic consequences of chronic pancreatitis include a disturbed phosphate metabolism (31) and a significant increase of duodenal ionized calcium secretion (32). Gastrointestinal bleeding may occur from a peptic ulcer, gastritis, a pseudocyst eroding into the duodenum, or ruptured varices, secondary to splenic vein thrombosis due to inflammation in the body and tail of the pancreas (**Fig. 10**). Rare complications are subcutaneous fat necrosis (appearing as tender red nodules on the lower extremities), bone pain secondary to intramedullary fat necrosis, and inflammation of the joints of the upper and lower extremities. Such migratory polyarthritis is often associated with fever and eosinophilia.

The prevalence of associated liver disease is variously reported in the literature (3). Histologically proven alcoholic cirrhosis may be found in up to 43% of patients (33). Alcohol-related liver disease is the cause of death in 15% of patients with chronic pancreatitis (3).

A common complication of chronic pancreatitis is bile duct stenosis with cholestasis or even jaundice. The reported prevalence of stenosis of the intrapancreatic part of the common bile duct ranges from 10% (34) to 46% (35). Chronic biliary obstruction may lead to cholangitis and ultimately to biliary cirrhosis (36). All patients with chronic pancreatitis and raised alkaline phosphatase should undergo endoscopic retrograde cholangiopancreatography (ERCP). Those with significant chronic biliary obstruction should receive surgical decompression or endoscopic stenting (**Fig. 11**).

Gastric outlet obstruction because of pancreatic inflammation is uncommon in chronic pancreatitis (37) (**Fig. 12**).

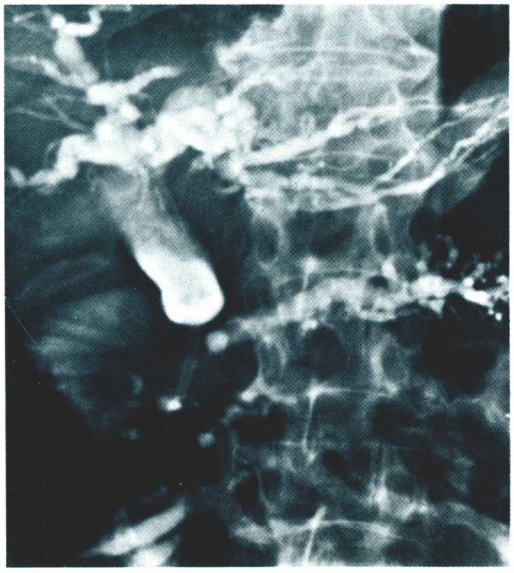


**Fig. 11 Advanced chronic pancreatitis with distal stricture and severe narrowing of the intrapancreatic segment of the common bile duct, bypassed with a prosthesis.**

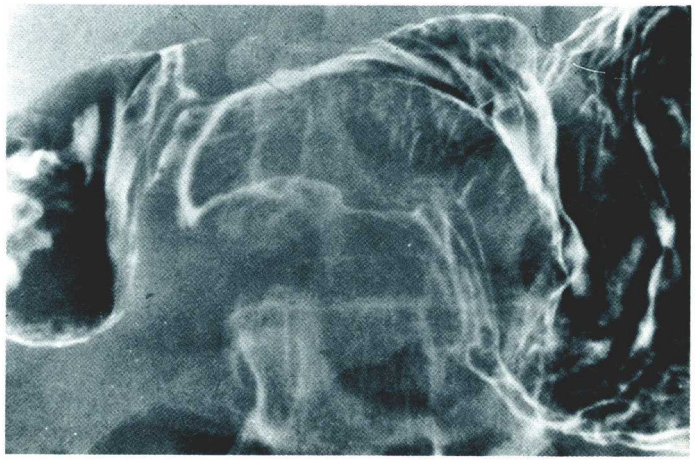


**Fig. 12 Compression, distortion, and obstruction of the antrum due to a large pancreatic inflammatory mass and a cyst in a patient with chronic pancreatitis.**

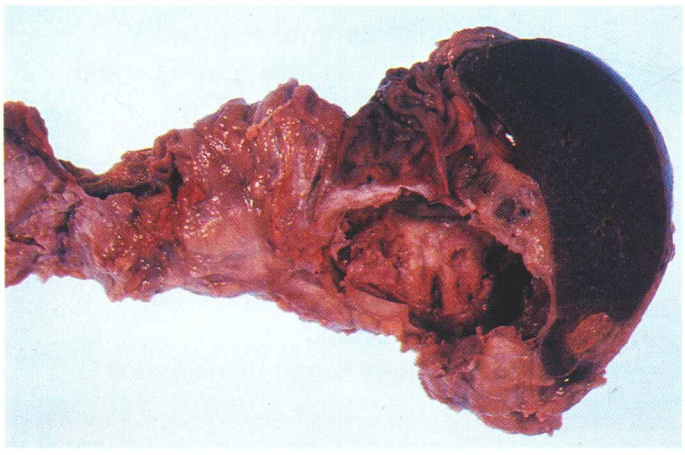
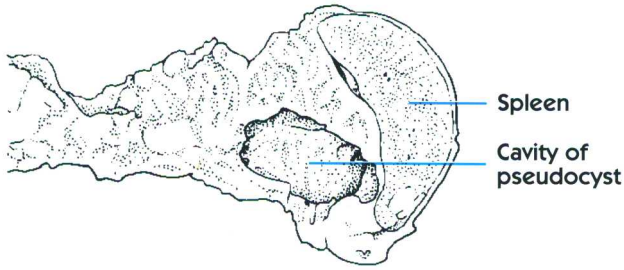


**Fig. 13 Pseudocyst in the tail of the pancreas.**



The development of superimposed pancreatic necrosis is a possible though uncommon complication (24). Less frequent but of crucial importance is the development of a pleuropancreatic fistula or high amylase-containing effusion within the pleura, pericardium, or peritoneum.

Fluid collections occur frequently in chronic pancreatitis (**Fig. 13**). Pseudocysts are of two types: those containing pancreatic debris after attacks of necrotizing pancreatitis and those containing pure pancreatic juice, probably because of ductular obstruction. The most feared complications of pseudocysts are hemorrhage, rupture, and infection. They may also cause jaundice, stenosis of the intestinal tract, or fistula. Many of these complications require therapy. Pseudocysts can be treated by surgical resection or drainage, percutaneous drainage, or endoscopic drainage. Alternatively, many pseudocysts regress spontaneously (38).

## Diagnosis

### Morphologic Diagnosis

The most commonly used modalities in the diagnosis of chronic pancreatitis, in addition to a plain abdominal X-ray of the abdomen, are ultrasonography, computed tomography (CT), and ERCP. New techniques, such as magnetic resonance (MR) imaging, pancreatic Trucut biopsy, and endoscopic ultrasound, can be useful in certain circumstances but are not yet widely available. Different imaging techniques vary in the way they represent the underlying pathology. No single technique yields enough morphologic data to stand entirely alone.

The vast majority of cases can be adequately diagnosed with ultrasonography, CT, and ERCP. In general, there is a good correlation between ERCP and ultrasonography,

**Revised Marseille–Cambridge classification of chronic pancreatitis: image grading**

| Severity | ERCP | | Ultrasound/CT |
|---|---|---|---|
| Normal | Visualization of entire duct system with uniform filling of side branches without acinar opacification and without abnormal features | | Visualization of entire gland and demonstration and measurement of main pancreatic duct |
| Equivocal | <3 abnormal branches | *1 abnormal sign only | Main duct enlarged (<4 mm)<br>Gland enlarged (up to 2x normal)<br>Cavities (<10 mm)<br>Irregular ducts<br>Focal reduction in parenchymal echogenicity<br>Echogenic foci in parenchyma<br>Increased or irregular echogenicity of wall of main duct<br>Irregular contour to gland, particularly focal enlargement |
| Mild | >3 abnormal branches | ≥2 abnormal signs | |
| Moderate | Abnormal main duct and branches | | |
| Marked | Large cavities (>10 mm)<br>Intraduct calculi<br>Duct obstruction with stricture<br>Gross irregularity of main pancreatic duct | | Large cavities (>10 mm)<br>Calculi or intraduct filling detects<br>Duct obstruction (>4 mm)<br>Major duct irregularity<br>Gross gland enlargements (>2x normal)<br>Contigous organ involvement |

*1 abnormal sign = main pancreatic duct 2–4 mm; gland 1–2x normal

Fig. 14 Revised Marseille–Cambridge classification of chronic pancreatitis: image grading.

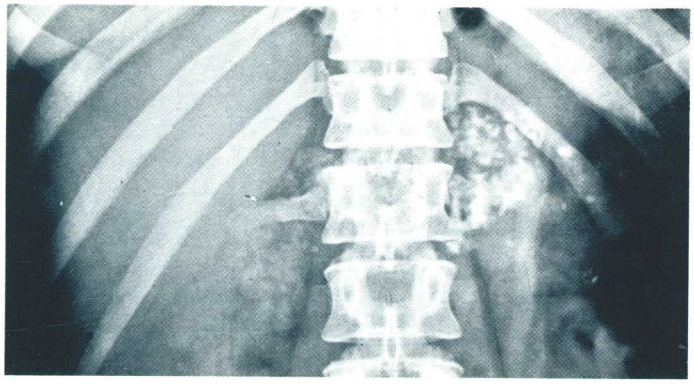


Fig. 15 Diffuse calcification of the pancreas as seen on abdominal plain film.

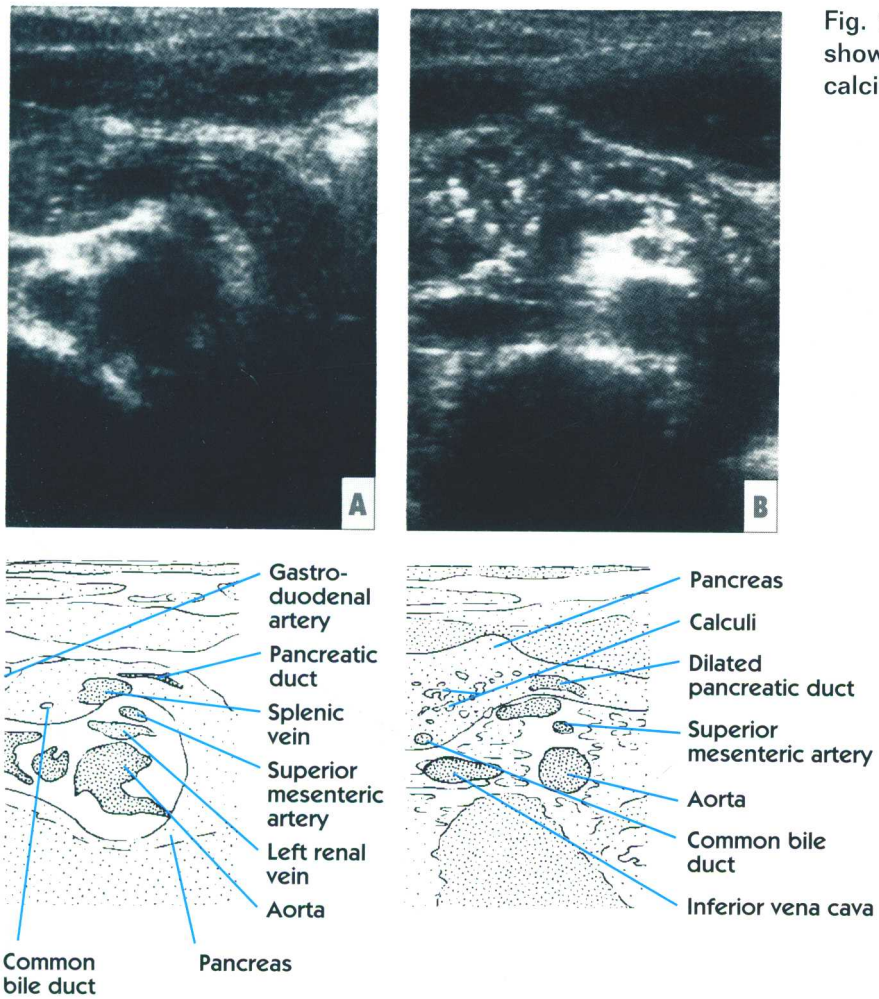



Fig. 16 Ultrasound scans (horizontal sections) showing (A) the normal pancreas and (B) calcifying pancreatitis. Note the bright echoes.

which implies that both techniques independently are reliable but may be even more reliable when combined (*see* Fig. 35). Currently, the Marseille–Cambridge classification (39, 40) is most often used (**Fig. 14**). Large cavities (greater than 10 mm) or calculi are in their own right always indicative of advanced pancreatitis. Intraductal filling defects, usually due to protein plugs, are often transitory and can be seen at any stage of chronic pancreatitis.

### Abdominal Plain Film

The radiographic hallmark of chronic pancreatitis is the presence of scattered calcification throughout the pancreas **(Fig. 15)**. Pancreatic calcification indicates that significant damage has occurred. Overall, this technique, although highly specific (>95%), has a rather moderate sensitivity for the diagnosis of chronic pancreatitis. At initial presentation about 30% of patients have pancreatic calcifications (41). Although alcohol is by far the most common cause, pancreatic calcification may also be seen in severe protein–calorie malnutrition, hyperparathyroidism, hereditary pancreatitis, and sometimes post-traumatic pancreatitis.

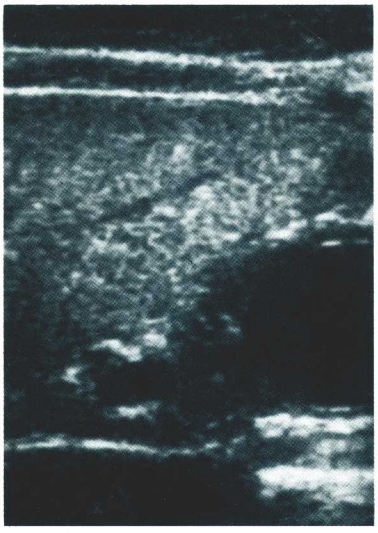
### Ultrasound

In current clinical practice, ultrasound is usually the first diagnostic step when pancreatic disease is suspected. Many cases of chronic pancreatitis can be rapidly detected by

ultrasound and a reliable differentiation from pancreatic cancer is often possible. Still, the criteria for ultrasound diagnosis of chronic pancreatitis are rather poorly defined. At least two abnormal features should be identified to establish a reliable diagnosis of chronic pancreatitis. Ultrasound allows accurate measurement of pancreatic size. The pancreas is often enlarged in the presence of active inflammation and may remain so for some time after the inflammation has resolved. As the atrophy of the organ progresses, the size may become normal and finally even smaller than normal (42). The contours of the pancreas are often asymmetric and irregular but may also appear normal. Abnormalities of the parenchymal texture are common but are non-specific for the diagnosis of chronic pancreatitis. The usual pattern is that of heterogenicity and increased echogenicity (**Fig. 16**). Occasionally, the gland is indistinguishable from the retroperitoneal tissue. Pancreatic calculi usually produce bright echoes. Visualization of the pancreatic duct system is possible with high-quality equipment. Dilated pancreatic ducts are common in chronic pancreatitis but may be absent in mild forms. Although duct caliber and duct-wall echogenicity can be appreciated to some extent, overall information about the ducts is less precise with ultrasound than with ERCP. Ultrasound is helpful in the detection of concomitant hepatic and biliary diseases, peripancreatic fluid collections (**Fig. 17**), and retroperitoneal masses. Almost all cysts, pseudocysts, and abscesses are easily detected by ultrasound. The reported sensitivities of ultrasound for chronic pancreatitis range from 48 to 83%, with most studies reporting values of 60–70%. The specificity may reach 80–90% (42,43).

### Endoscopic Ultrasound

Endoscopic ultrasound (**Figs 18 & 19**) seems to be a promising technique in the diagnosis of pancreatic disease (44). It avoids problems of intervening bowel gas and adipose tissue during imaging. It also allows the use of higher ultrasound frequencies than can be used with transabdominal ultrasonography, which results in enhanced spatial resolution. To obtain reliable and interpretable images of the head, body, and tail of the pancreas, it is necessary to view the gland from both an intragastric and an intraduodenal position. As compared to a control group of healthy individuals, endoscopic ultrasound showed various abnormalities in parenchymal and/or ductular features in patients with chronic pancreatitis (45). When three or more of these abnormal features were found in a group of patients presenting with abdominal pain of suspected pancreatic origin, its sensitivity for patients with early or mild chronic pancreatitis was 86%. Other investigators found that endoscopic ultrasound showed inflammatory changes in almost all patients in whom ERCP suggested chronic pancreatitis (100% in Cambridge classification stages 2 and 3 and 88% in stage 1), but also in a considerable number of patients with normal ERCP during a clinical period of pancreatic inflammation (46). Intraductal ultrasound of the pancreas may be useful in patients with a localized stenosis of



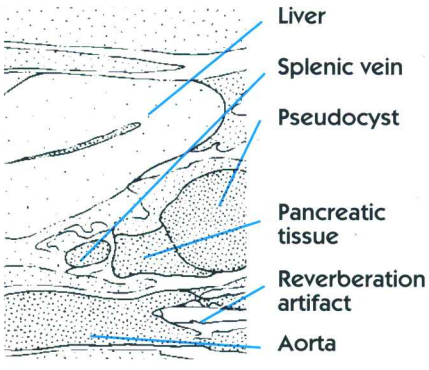



**Fig. 17 Pancreatic pseudocyst, seen as an echolucent structure on ultrasound scan (longitudinal section).**

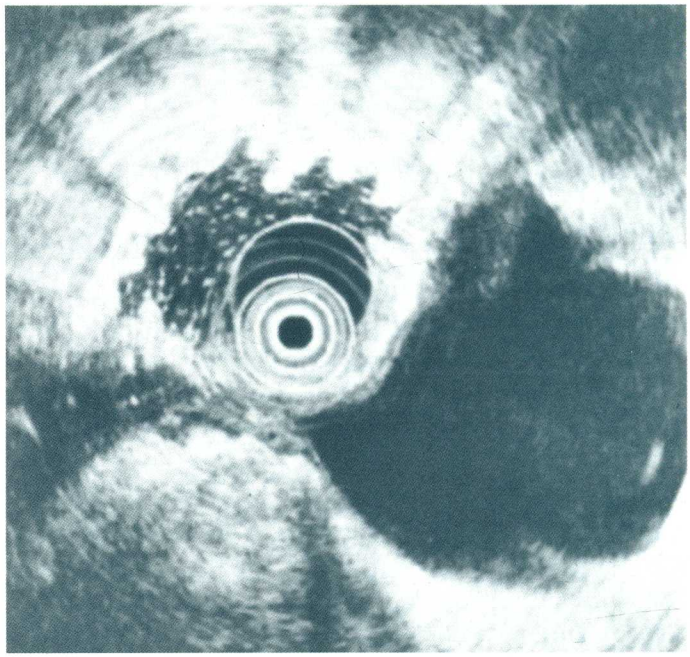


**Fig. 18 Endosonographic image from the gastric corpus showing a large, almost completely anechoic pseudocyst (between 2 and 5 o'clock). The cyst can be endoscopically drained as the distance to the stomach is small and no vessels are visible in between.**

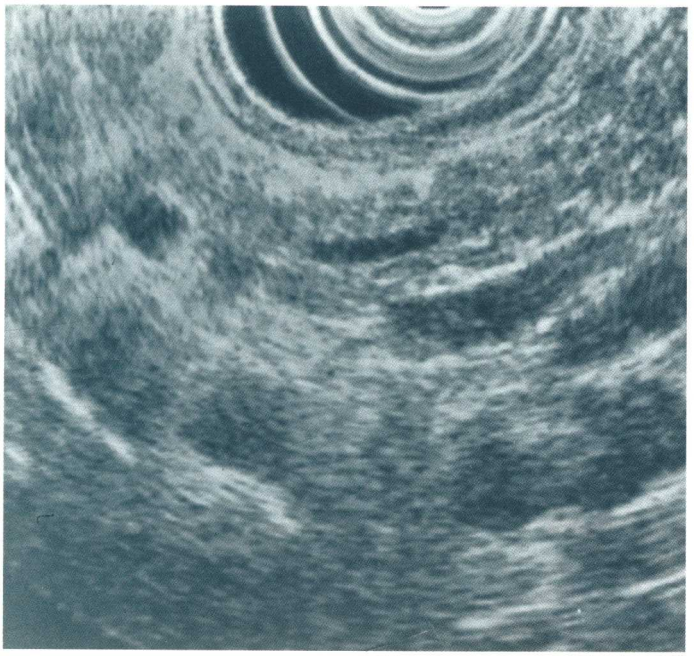


Fig. 19 Endosonographic image of the body of the pancreas, taken from the stomach. The pancreatic duct wall is slightly hyperechoic and the parenchyma is lobulated. These are early changes that occur in chronic pancreatitis. The splenic vein is visible below the pancreas.

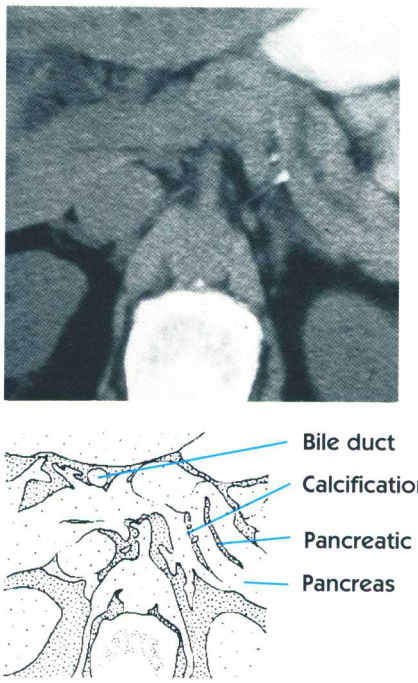



Fig. 20 Chronic pancreatitis. The pancreas is swollen on this CT scan, and the dilated pancreatic duct can be seen clearly in the body and tail. Some calcification is present in the body and the bile duct is also dilated.

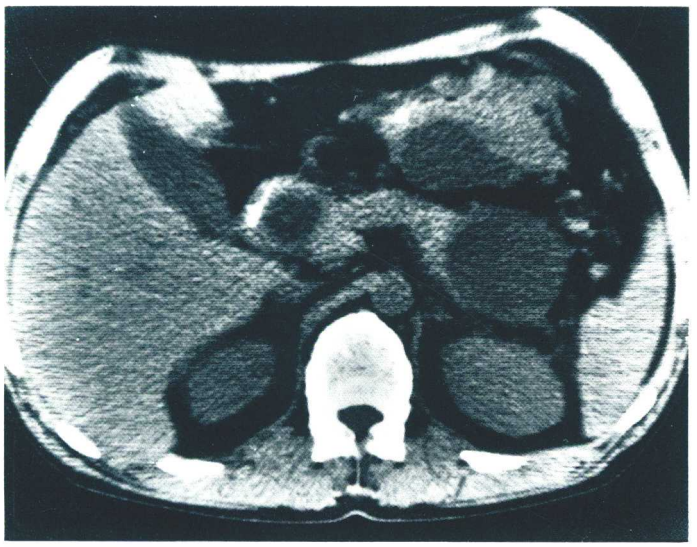


Fig. 21 CT scan showing large pseudocysts in the (peri)pancreatic region in a patient with chronic pancreatitis.

the pancreatic duct to differentiate between pancreatic cancer and chronic pancreatitis (47).

The initial results of the use of endoscopic ultrasound techniques in the diagnosis of pancreatic disease are encouraging. Additional investigation, however, is required to establish its final role.

### Computed Tomography

The CT diagnostic criteria for chronic pancreatitis are reasonably well established (48). The size of the pancreatic gland can usually be readily assessed. Diffuse enlargement, normal size, or a small atrophic gland may be found (**Fig. 20**). The outlines are often irregular, and the density is usually heterogeneous or increased. Alterations of the duct system are best detected on images after intravenous infusion of contrast material. CT is superior to the other imaging techniques for the detection of calculi and calcifications. Irregular, calcified ducts are characteristic of chronic pancreatitis. Nearly all cystic lesions are detected by CT (**Fig. 21**). CT may provide useful information about other intra-abdominal organs and may readily visualize the spread of inflammation beyond the gland in the more severe forms

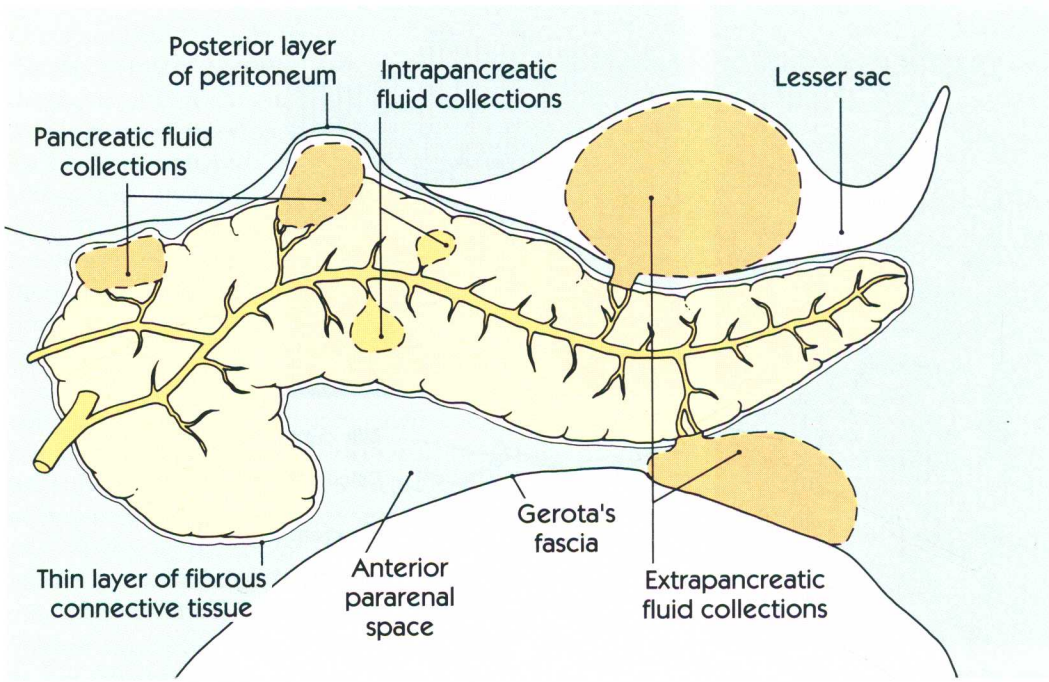



**Fig. 22** Pancreatic and extrapancreatic fluid collections. Extrapancreatic fluid collections occur in the lesser sac (the most common location) and the anterior perirenal space (the second most common location). Intrapancreatic fluid collections represent focal accumulations of pancreatic juice at the site of duct rupture.

of chronic pancreatitis (**Fig. 22**). The reported sensitivities of CT for the diagnosis of chronic pancreatitis range from 74 to 90%, and the specificities range from 84 to 100%. Studies comparing the diagnostic accuracy of CT and ultrasound show that CT detects 10–20% more cases. CT, however, is more expensive; it also exposes the patient to ionizing radiation and thus should not be used as the initial screening method.

### Magnetic Resonance Imaging

The role for magnetic resonance (MR) in the investigation of pancreatic disease is steadily increasing. MR-imaging techniques that are used in the investigation of the pancreas are T1- and T2-weighted spin-echo-pulse sequences, fat-suppressed T1 images, and fast spin-echo or breath-hold gradient-echo images with contrast enhancement using gadolinium-DTPA or manganese-DTPA. The loss of signal intensity on T1-weighted fat-suppressed MR images reflects the loss of aqueous protein in the acini of the pancreas secondary to fibrosis (49). The sensitivity for the detection of fibrosis seems to make this technique more sensitive than CT in the identification of the early fibrotic changes of chronic pancreatitis that precede calcifications and morphologic changes (41). MR is much less sensitive than CT in the detection of calcifications. Because of its sensitivity for these early fibrotic changes, however, this does not seem to have a deleterious effect on the detection of the disease. Pseudocysts appear as signal-void structures on contrast-enhanced MR images. Because of its superior ability to depict lack of contrast enhancement, MR seems superior compared to CT in distinguishing focal enlargement of the gland due to chronic pancreatitis from that due to pancreatic carcinoma.

Presently, CT remains the first-line imaging modality in the evaluation of pancreatic disease. This is mainly because in the majority of cases it is more readily available. However, as more MR imagers are installed and experience increases, a larger role can be expected for MR in the investigation of pancreatic disease.

### Endoscopic Retrograde Cholangiopancreatography

The role of ERCP is threefold: to diagnose chronic pancreatitis, to differentiate it from pancreatic cancer, and to help select patients who are candidates for therapeutic endoscopic or surgical therapy.

ERCP is the most precise technique to obtain images of the main pancreatic duct and its side branches. An adequate pancreatogram requires a control film, adequate duct filling to the second-generation side branches without parenchymal opacification, and avoidance of air-bubble injection or movement blur (50, 51). Avoiding overdistention or repeated injections is important for safe pancreatography. Continued injection of contrast beyond a tight stricture is hazardous if endoscopic drainage or surgical intervention within 24 hours is impossible. Filling and distending a communicating pseudocyst is hazardous and to be avoided if endoscopic or urgent surgical drainage is impossible.

Accurate interpretation of the pancreatogram requires detailed evaluation of all ductal changes, of collections of contrast material into cavities or cysts, and of intraparenchymal or intraductular calcifications and protein plugs. Films should be taken during the filling phase to detect small filling defects and also during emptying, with the patient in the supine position. The characteristic findings in chronic pancreatitis are dilatation and tortuosity of the major pancreatic duct as well as dilatation and beading of the side branches (**Figs 23–26**). Segments of narrowing, usually with prestenotic dilatation in the main duct, are often seen; the upper limit of normal for the main pancreatic duct is 6.5 mm in the head, 5 mm in the body, and 3 mm in the tail (**Figs 27 & 28**). When the duct terminates prematurely, the type of obstruction may be abrupt, tapering, or irregular. Both calcification in the gland and calculi in the duct may be present. A calcification larger than 5 mm in diameter is always associated with