Management of patients with increased risk for familial pancreatic cancer: updated recommendations from the International Cancer of the Pancreas Screening (CAPS) Consortium

Michael Goggins,1 Kasper Alexander Overbeek,2 Randall Brand,3 Sapna Syngal,4 Marco Del Chiaro,5 Detlef K Fishman,6 Claudio Bassi,7 Alfredo Carrato,8 James Farrell,9 Elliot K Fishman,10 Paul Fockens,11 Thomas M Gress,12 Jeanin E van Hooft,13 R H Hruban,14 Fay Kastrinos,15,16 Allison Klein,17 Anne Marie Lennon,18 Aimee Lucas,19 Walter Park,20 Anil Rustgi,16 Diane Simeone,20 Elena Stoffel,21 Hans F A Vasen,22 Djuna L Cahen,2 Marcia Irene Canto,18 Marco Bruno,2 International Cancer of the Pancreas Screening (CAPS) consortium

ABSTRACT

Background and aim The International Cancer of the Pancreas Screening Consortium met in 2018 to update its consensus recommendations for the management of individuals with increased risk of pancreatic cancer based on family history or germline mutation status (high-risk individuals).

Methods A modified Delphi approach was employed to reach consensus among a multidisciplinary group of experts who voted on consensus statements. Consensus was considered reached if ≥75% agreed or disagreed.

Results Consensus was reached on 55 statements. The main goals of surveillance (to identify high-grade dysplastic precursor lesions and T1N0M0 pancreatic cancer) remained unchanged. Experts agreed that for those with familial risk, surveillance should start no earlier than age 50 or 10 years earlier than the youngest relative with pancreatic cancer, but were split on whether to start at age 50 or 55. Germline ATM mutation carriers with one affected first-degree relative are now considered eligible for surveillance. Experts agreed that preferred surveillance tests are endoscopic ultrasound and MRI/magnetic retrograde cholangiopancreatography, but no consensus was reached on how to alternate these modalities. Annual surveillance is recommended in the absence of concerning lesions. Main areas of disagreement included if and how surveillance should be performed for hereditary pancreatitis, and the management of indeterminate lesions.

Conclusions Pancreatic surveillance is recommended for selected high-risk individuals to detect early pancreatic cancer and its high-grade precursors, but should be performed in a research setting by multidisciplinary teams in centres with appropriate expertise. Until more evidence supporting these recommendations is available, the benefits, risks and costs of surveillance of pancreatic surveillance need additional evaluation.

INTRODUCTION

Pancreatic cancer is a deadly disease and early detection is considered the most effective way to improve survival. The International Cancer of the Pancreas Screening (CAPS) Consortium first met in Baltimore in 2011 to establish consensus guidelines for surveillance of individuals with familial and/or inherited risk of developing pancreatic cancer. The 2013 CAPS Consortium guidelines were based on the first decade or so of experience with pancreatic surveillance.1–12 More recent evidence includes two studies showing evidence of improved outcomes for high-risk individuals in a pancreatic surveillance programme, highlighting the potential for pancreatic surveillance to affect overall survival.7,10

Individuals with a strong family history and/or genetic susceptibility have an increased risk of developing pancreatic cancer that manifests over several decades. To help ensure the benefits of pancreatic surveillance, clinicians should select those most likely to benefit, counsel patients on the risks and benefits of surveillance and optimally manage patients with lesions identified by surveillance. The International CAPS Consortium met in Baltimore in April 2018 to update its recommendations for pancreatic surveillance.

METHODS

Consensus development process

Conference chairs (Professors Canto, Goggins and Bruno) selected a multidisciplinary team of experts to participate in the guideline update. Guideline development used a modified Delphi approach.13 Delphi uses multiple iterations of a questionnaire with feedback, enabling individual reassessment of opinion to generate convergence within the panel. Participants were asked to review literature ahead of an in-person meeting to discuss areas of consensus and controversy and to reach consensus on guideline questions. After the meeting, experts
were asked to vote electronically and provide feedback on first-round questions; responses were incorporated into second-round electronic voting (figure 1).

**Literature search and development workgroup meeting**

One author (KAO) performed a systematic Medline search for relevant literature published since the 2011 meeting (online supplementary table S1). Speakers and facilitators were selected to discuss major guideline topics focusing on recent literature. Live audio-stream was available for experts not present in person, and the meeting was recorded. After the meeting, the steering committee (MG, KAO, DLC, MIC and MB) formulated voting statements based on 2013 guideline statements, new scientific insights, the meeting presentations and discussions. These statements were incorporated in an electronic survey.

**Electronic voting rounds**

International experts within the field of pancreatic cancer surveillance were invited to participate if they met the following criteria: a clinician actively involved in an institutional review board-approved pancreatic cancer surveillance programme for high-risk individuals, who attended either the 2011 or 2018 guideline development workgroup meeting or had been author on two or more scientific publications relating to pancreatic cancer surveillance since 2011. All invited experts were given the recent literature summary and the workgroup meeting video. In round 1, experts were asked to vote on statements on a seven-point Likert scale, ranging from 'strongly disagree' to 'strongly agree'. They could also opt-out from answering statements if they lacked expertise. After round 1, the steering committee revised statements deemed unclear by >5% of respondents.

In round 2, experts voted again and given (1) the original consensus statements and any revisions; (2) first-round voting for each question; and (3) their own voting. Voting was anonymous. Only the guideline coordinator (KAO) had access to voting results.

**Statistical analysis, accepting and grading of statements**

First-round group results, including distribution of answers with median and IQR, were given to voters. Statements were accepted as having reached consensus if after second-round voting ≥75% of experts disagreed (‘strongly disagree’ or ‘disagree’), or agreed (‘strongly-agree’ or ‘agree’). Non-votes were not included in consensus tabulations. All statistics were performed using SPSS v22 (IBM, Armonk, New York, USA). Strength of consensus
in online supplementary table S2. A summary of the main consensus recommendations is provided in table 3.

Who should be screened?
Age, family history and germline mutation status are the major criteria for determining eligibility for pancreatic surveillance. The number of first- and second-degree relatives with pancreatic cancer can be used to quantify pancreatic cancer risk. For example, the estimated lifetime risk of developing pancreatic cancer for an individual with two first-degree relatives with pancreatic cancer is ~8%. Family history of pancreatic cancer is also a risk factor for patients identified as having incidentally detected pancreatic cysts. Current surveillance recommendations for a family history (generally in one blood relative) are the same as for those without a family history.

Consensus on family history recommendations for pancreatic surveillance (ie, having at least one first-degree relative and one second-degree relative with pancreatic cancer) were the same as in the 2013 guidelines. Obtaining a comprehensive cancer family history from newly diagnosed patients with pancreatic cancer can help to identify family members who may benefit from surveillance. The average lifetime risk of developing pancreatic cancer (~1 in 64 in the USA) is too low for population-based screening.

Germline mutation carriers
Pancreatic surveillance is recommended for carriers of germline deleterious variants in cancer susceptibility gene. **BRCA2, ATM, BRCA1, PALB2, CDKN2A, STK11, MLH1 and MSH2.** Recommendations for age and family history vary by gene. Surveillance for CDKN2A and STK11 (Peutz-Jeghers syndrome) mutation carriers is recommended irrespective of patients' family history of pancreatic cancer, because of their high lifetime risk. Since the previous consensus, ATM mutation carriers have been added to the list recommended for surveillance. For carriers of mutations in ATM, BRCA2 and PALB2, the consensus among experts was to recommend surveillance for mutation carriers who have a blood relative with pancreatic cancer. Consensus on family history criteria for BRCA1 mutation carriers was not reached (table 1), but consensus was reached for recommending that BRCA1 mutation carriers undergo surveillance (online supplementary table S2).

Surveillance is recommended for patients with hereditary pancreatitis, with most experts recommending age 40 or 20 years after the first pancreatitis attack (online supplementary table S2), irrespective of gene status. The pancreatitis susceptibility genes, *PRSS1*, *CPA1* and *CTRC*, are associated with significantly increased risk of developing pancreatitis. Deleterious variants in *CPA1* and *CPB1* associated with pancreatic cancer risk may not always progress through a clinical syndrome of pancreatitis.

Deleterious variants in the known pancreatic cancer susceptibility genes account for ~10–20% of the familial clustering of pancreatic cancer. Deleterious variants have also been reported in ~5–10% of patients with apparently sporadic pancreatic cancer. These variants also confer risk for other cancers. Therefore, germline testing should be considered for individuals eligible for pancreatic cancer surveillance.

### Table 1 Definition of high-risk individuals eligible for pancreatic cancer surveillance.

<table>
<thead>
<tr>
<th>Gene mutation</th>
<th>PDAC family history criteria</th>
<th>Agreement</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKB1/STK11</td>
<td>Regardless of family history</td>
<td>99%</td>
<td>1</td>
</tr>
<tr>
<td>(Peutz-Jeghers syndrome)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDKN2A p16* (FAMMM)</td>
<td>With at least one affected FDR</td>
<td>99%</td>
<td>1</td>
</tr>
<tr>
<td>CDKN2A p16* (FAMMM)</td>
<td>Regardless of family history</td>
<td>77%</td>
<td>1</td>
</tr>
<tr>
<td>BRCA2</td>
<td>If at least one affected FDR, or at least two affected relatives of any degree</td>
<td>93%</td>
<td>2</td>
</tr>
<tr>
<td>PALB2</td>
<td>If at least one affected FDR</td>
<td>83%</td>
<td>2</td>
</tr>
<tr>
<td>MLH1/MSH2/MSH6 (lymph)</td>
<td>If at least one affected FDR</td>
<td>84%</td>
<td>2</td>
</tr>
<tr>
<td>ATM</td>
<td>If at least one affected FDR</td>
<td>88%</td>
<td>2</td>
</tr>
<tr>
<td>BRCA1</td>
<td>If at least one affected FDR</td>
<td>69.6%</td>
<td>3</td>
</tr>
<tr>
<td>Regardless of gene mutation status</td>
<td>If at least three affected relatives who are FDR to the individual considered for surveillance</td>
<td>97%</td>
<td>2</td>
</tr>
<tr>
<td>Regardless of gene mutation status</td>
<td>If at least two affected relatives who are FDR to each other, of whom at least one is an FDR to the individual considered for surveillance</td>
<td>93%</td>
<td>2</td>
</tr>
<tr>
<td>Regardless of gene mutation status</td>
<td>If at least two affected relatives who are FDR to each other, of whom at least one is an FDR to the individual considered for surveillance</td>
<td>88%</td>
<td>2</td>
</tr>
</tbody>
</table>

*Only encompassing CDKN2A mutations leading to changes in the p16 protein.
†Wherever relative is stated, this indicates blood relatives only.
‡An additional 20.3% somewhat agreed with surveillance (total 89.9%).
§At least two affected relatives on the same side of the family, of whom at least one is an FDR to the individual considered for surveillance.

**RESULTS**

**Participants**

Ninety-one experts met selection criteria and were invited to vote. Eighty-two completed the first round, 76 completed the second round (response rate 84%). The 76 final responders included 37 gastroenterologists, 16 surgeons, 7 pathologists, 6 radiologists, 5 geneticists, 3 oncologists, and two epidemiologists, from 11 countries and four continents; 70 (92%) worked in a university hospital setting. They had practised their profession for a median of 22 (IQR 15) years, and had been involved in a pancreatic cancer surveillance programme for a median of 10 (IQR 12) years.

**Recommendation statements**

A summary of the statements that reached consensus is provided in tables 1 and 2. All voting statements and results are provided based on Grading of Recommendations Assessment, Development and Evaluation (GRADE). definitions for quality improvement and guideline development: 1 (strong)=‘definitely do it’, 2 (weak)=‘probably do it’, 3 (no recommendation), 4 (weak)=‘probably don’t do it’, and 5 (strong)=‘definitely don’t do it’.

---

### Guidelines

#### Table 2  Statements that reached consensus

<table>
<thead>
<tr>
<th>Statement</th>
<th>Agreement grade</th>
<th>grade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At what age should pancreatic surveillance begin?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. For patients with a familial risk (no known germline mutations or PJS), screening should begin by the age of...</td>
<td>10.3%</td>
<td>4</td>
</tr>
<tr>
<td>► 45 years or 10 years younger than the youngest relative with PDAC</td>
<td>67.6%</td>
<td>2</td>
</tr>
<tr>
<td>► 50 years or 10 years younger than the youngest relative with PDAC</td>
<td>22.1%</td>
<td>2</td>
</tr>
<tr>
<td>► 55 years or 10 years younger than the youngest relative with PDAC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. For germline mutation carriers (excluding PJS), screening should begin 5 years earlier than for high-risk individuals with defined familial pancreatic cancer</td>
<td>74.7%</td>
<td>2</td>
</tr>
<tr>
<td>3. For patients with PJS, screening should begin at least by the age of...</td>
<td>14.9%</td>
<td>4</td>
</tr>
<tr>
<td>► 30 years or 10 years younger than the youngest relative with PDAC</td>
<td>17.9%</td>
<td>4</td>
</tr>
<tr>
<td>► 35 years or 10 years younger than the youngest relative with PDAC</td>
<td>67.2%</td>
<td>2</td>
</tr>
<tr>
<td>4. New-onset diabetes in a high-risk individual should lead to initiation of screening, regardless of age</td>
<td>82.4%</td>
<td>2</td>
</tr>
<tr>
<td><strong>How should high-risk individuals be screened?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Baseline pancreatic screening tests should include (multiple answers allowed)</td>
<td>86.8%</td>
<td>2</td>
</tr>
<tr>
<td>► EUS</td>
<td>92.1%</td>
<td>2</td>
</tr>
<tr>
<td>► MRI/MRCP</td>
<td>19.7%</td>
<td>4</td>
</tr>
<tr>
<td>► CT</td>
<td>2.6%</td>
<td>5</td>
</tr>
<tr>
<td>6. Follow-up pancreatic screening tests should include (multiple answers allowed)</td>
<td>89.5%</td>
<td>2</td>
</tr>
<tr>
<td>► EUS</td>
<td>89.5%</td>
<td>2</td>
</tr>
<tr>
<td>► MRI/MRCP</td>
<td>15.8%</td>
<td>4</td>
</tr>
<tr>
<td>► CT</td>
<td>1.3%</td>
<td>5</td>
</tr>
<tr>
<td>7. CA19-9 should be used as an additional surveillance test for individuals with worrisome features on imaging</td>
<td>76.5%</td>
<td>2</td>
</tr>
<tr>
<td>8. Routine testing for diabetes mellitus with fasting blood glucose and/or haemoglobin A1c should be performed.</td>
<td>76.1%</td>
<td>2</td>
</tr>
<tr>
<td><strong>Surveillance questions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. In the absence of pancreatic abnormalities, the recommended surveillance interval is 12 months</td>
<td>90.4%</td>
<td>2</td>
</tr>
<tr>
<td>10. For patients with small (&lt;1 cm), non-functioning neuroendocrine tumours, the recommended surveillance interval is 12 months</td>
<td>82.6%</td>
<td>2</td>
</tr>
<tr>
<td>11. For patients with low-risk findings (ie, pancreatic lobulation or a cyst without worrisome features), the recommended surveillance interval is 12 months</td>
<td>88.6%</td>
<td>2</td>
</tr>
<tr>
<td>12. For CDKN2A p16 mutation carriers with newly detected pancreatic abnormalities that are concerning but do not lead to surgery (mild MPD dilation, stricture without mass), repeat imaging should be performed within 3–6 months</td>
<td>98.5%</td>
<td>2</td>
</tr>
<tr>
<td>13. A diagnosis of new-onset diabetes* in an HRI under surveillance, prompts immediate investigations</td>
<td>90.3%</td>
<td>2</td>
</tr>
<tr>
<td>14. Smoking status does not affect the surveillance interval</td>
<td>76.8%</td>
<td>2</td>
</tr>
<tr>
<td>15. When a cystic lesion with worrisome features (ie, mural nodule, solid component, duct dilation, etc) is detected, EUS-FNA should be performed.</td>
<td>84.3%</td>
<td>2</td>
</tr>
<tr>
<td>16. When a solid lesion is detected, CT should be performed</td>
<td>95.7%</td>
<td>1</td>
</tr>
<tr>
<td>17. At detection of a solid lesion, EUS-FNA should be performed...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>► Always</td>
<td>70.1%</td>
<td>2</td>
</tr>
<tr>
<td>► If ≥5 mm</td>
<td>19.4%</td>
<td>1</td>
</tr>
<tr>
<td>► If ≥10 mm</td>
<td>4.5%</td>
<td>1</td>
</tr>
<tr>
<td>► Never</td>
<td>6.0%</td>
<td>5</td>
</tr>
<tr>
<td>18. When a solid lesion of uncertain significance is newly detected and the patient is not referred for surgery, imaging should be repeated after 3 months</td>
<td>91.2%</td>
<td>1</td>
</tr>
<tr>
<td>19. Standardised nomenclature should be used to define chronic pancreatitis-like abnormalities</td>
<td>98.6%</td>
<td>2</td>
</tr>
<tr>
<td>20. When an asymptomatic MPD stricture with an associated suspicious mass is detected...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>► EUS-FNA should be performed</td>
<td>75.7%</td>
<td>1</td>
</tr>
<tr>
<td>► Surgery should be performed</td>
<td>81.2%</td>
<td>2</td>
</tr>
<tr>
<td>21. When an asymptomatic MPD stricture of unknown aetiology (without a mass) is detected...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>► CT should be performed</td>
<td>86.6%</td>
<td>1</td>
</tr>
<tr>
<td>► EUS-FNA should be performed</td>
<td>77.9%</td>
<td>1</td>
</tr>
<tr>
<td>22. When a patient with an MPD stricture is not referred for surgery, repeat imaging should be performed within 3 months</td>
<td>98.5%</td>
<td>1</td>
</tr>
</tbody>
</table>

*Continued*
also consider the role of gene testing for patients with pancreatic cancer. The average lifetime risk of developing pancreatic cancer has been estimated in prospective studies for carriers of deleterious variants in BRCA2, BRCA1, CDK2NA, PRSS1, MLH1, ATM, PALB2, MSH2, and CDKN2A as high as 30%–40% for BRCA2 mutation carriers. The lifetime risk of pancreatic cancer for carriers of these genes is 8% for BRCA1 and 12% for PALB2.53,54

### Goals of surveillance

Goals of surveillance include early detection and removal of precancerous lesions, reducing the risk of pancreatic cancer, and improving long-term survival. Early detection of precancerous lesions can lead to earlier intervention and potentially reduce the risk of developing pancreatic cancer. Surveillance can also provide a better understanding of the biology of pancreatic cancer and identify genes and biomarkers that can be targeted for prevention and treatment.

#### What tests should be used for pancreatic surveillance?

Most pancreatic surveillance protocols for high-risk individuals use pancreatic imaging with MRI/magnetic retrograde cholangiopancreatography (MRCP) and/or endoscopic ultrasound (EUS), with pancreatic-protocol CT reserved for individuals unable to have MRI or EUS. The preference for EUS and MRI/
MRCP rather than CT is based on their superiority at detecting subcentimetre pancreatic cysts, and avoidance of ionising radiation. Subcentimetre pancreatic cysts are detected in up to 50% of high-risk individuals, depending on the age of the cohort. However, pancreatic cysts have low malignant potential and although the detection can help risk stratification, the primary aim is to detect and treat the following pathological lesions:

- Asymptomatic MPD strictures of unknown aetiology
- Cystic lesions with worrisome features
- Solid lesions of ≥5 mm
- Cystic lesions with worrisome features
- Asymptomatic MPD strictures (with or without mass)
- Solid lesions, regardless of size
- Asymptomatic MPD strictures of unknown aetiology (without mass)

In addition, CT can, in principle, be used to quantify changes in abdominal fat and lumbar muscle mass with the emergence of pancreatic cancer. Observation of this early wasting could help to detect early pancreatic cancers, although this approach has not been tested in prospective studies. The availability of deep learning and advanced radiomics protocols may help radiologists to identify and quantify subtle abnormalities in the pancreas by CT. MRCP and EUS should be the first-line tests for pancreatic surveillance, in part because of the cumulative radiation exposure with frequent CT, but developments in low-dose CT imaging may necessitate re-evaluation of the role of CT in surveillance. One European study examined the diagnostic yield of performing MRI/MRCP annually with EUS or limiting EUS to every third year unless there are significant changes in MRI scans. The authors found no significant difference in the diagnostic yield among the different surveillance protocols, although a larger sample size and longer follow-up would be required to definitively answer this question. Less expensive, short-protocol MRI has been evaluated for cyst mucinous neoplasms (IPMN). In addition, CT can, in principle, also be used to quantify changes in abdominal fat and lumbar muscle mass with the emergence of pancreatic cancer.
surveillance. Some Japanese centres have evaluated abdominal ultrasound as a screening modality, as detailed pancreas sonographic images are feasible in thin individuals, but there was consensus that abdominal ultrasound should not be a first-line test for pancreatic surveillance.

The experts also considered the role of CA19-9 testing. Although the role of CA19-9 testing has not been studied in high-risk individuals with familial/genetic risk, its diagnostic performance characteristics have been extensively studied. CA19-9 could have diagnostic value in individuals in whom the pre-test probability of pancreatic cancer is significant, although this question requires further investigation. For this reason, there was consensus that CA19-9 testing should be performed when there is concern about the possibility of pancreatic cancer, such as when worrisome features are found on pancreatic imaging.

Experts also reached consensus that glucose testing (fasting glucose or HbA1c) to detect new-onset diabetes was reasonable for high-risk individuals. There was also consensus that the emergence of new-onset diabetes in a high-risk individual should prompt additional investigation. Population guidelines recommend fasting glucose or HbA1c testing for individuals with risk factors for diabetes such as overweight or obesity, although there are concerns about the potential to overtreat individuals with pre-diabetes. Epidemiological studies show that 0.4% to 0.8% of patients with new-onset diabetes aged ≥50 will be diagnosed with pancreatic cancer within 3 years. A model incorporating weight loss, age and trend in glucose level can help to identify patients with new-onset diabetes more likely to have pancreatic cancer; other models incorporating additional parameters are being evaluated. One study estimated the average glucose level for a given tumour size, predicting that when glucose levels reach diabetic levels (126 mg/dL), pancreatic tumour volume is ~2–8 mL (~diameter of 1.6–2.5 cm). There is no direct evidence that glucose monitoring is of additional value for improving detection of pancreatic cancer for individuals undergoing regular pancreatic imaging. Nonetheless, given the higher risk of pancreatic cancer in high-risk individuals compared with the general population, the consensus was that new-onset diabetes in a high-risk individual should prompt further testing for the presence of pancreatic cancer.

Experts discussed circulating tumour DNA (ctDNA) and its potential to contribute to pancreatic surveillance. CtDNA testing is beginning to emerge as a clinical test; further studies are needed to define its role for patients under pancreatic surveillance. Other biomarker tests are also undergoing evaluation for their potential for early detection, but more study is needed to determine their diagnostic performance.

The experts recognised that many high-risk individuals meeting criteria for pancreatic surveillance (particularly mutation carriers) are at increased risk of developing other cancers; these individuals should undergo surveillance for other cancers tailored to their germline mutation status and cancer family history.

**Surveillance questions**

There was consensus that patients with normal pancreata, or without concerning lesions, should undergo annual pancreatic imaging surveillance. Surveillance of high-risk individuals occasionally identifies small (<1 cm) pancreatic neuroendocrine tumours (PanNEts) although it is not certain if these lesions are more common in this population. Most incidentally detected PanNEts have low malignant potential. There was consensus that patients with small (<1 cm diameter) PanNEts can undergo annual surveillance detection and that treatment of PanNEts (>1 cm) could be considered a success of surveillance. However, recent studies report small (<2 cm) PanNEts with low-risk characteristics on biopsy (eg, low Ki-67) can be safely followed up. Current neuroendocrine neoplasms guidelines recommend surveillance of asymptomatic non-functional low-risk (by grade, Ki-67 by EUS-fine-needle aspiration) PanNEts (2 cm).

Although patients in a high-risk programme commonly have pancreatic abnormalities (depending on age and other risk-factors, up to 50% will have pancreatic cysts; many also have subtle non-specific EUS parenchymal abnormalities), only a minority will develop concerning lesions. There was consensus that annual surveillance is appropriate for those with these abnormalities (figure 2). Furthermore, there was consensus that CDKN2A mutation carriers with concerning pancreatic abnormalities that do not lead to immediate surgery (eg, mild main pancreatic duct dilation, stricture without mass) should undergo additional testing such as EUS-fine-needle aspiration, and if they do not proceed to surgery after multidisciplinary review, should undergo close follow-up imaging in 3–6 months.

The predicted progression rate suggests that stage I pancreatic cancers can progress to stage IV disease within 1 year, which may explain why interval pancreatic cancers are occasionally diagnosed despite annual surveillance, even in the absence of concerning lesions (worrisome features or solid lesions) on prior scans.

Few studies have evaluated factors that influence compliance with long-term pancreatic surveillance; one such study found that many high-risk individuals drop out of regular surveillance. Factors affecting long-term compliance with surveillance require further study.

**When should surgery be performed?**

Many factors are considered when deciding if surgical resection is appropriate for patients with concerning imaging findings, including a patient’s estimated risk of pancreatic cancer based on their gene mutation status, family history, operative risk, comorbidities, life expectancy and compliance with surveillance. Decision-making is best undertaken by an experienced, expert multidisciplinary team. There was consensus that high-risk individuals should undergo pancreatic resection for broadly similar indications to individuals without known familial/genetic risk, based on established guidelines—for example, those with worrisome features. Thus, generally, surgical resection in a patient with multifocal pancreatic cysts should maintain the dominant, worrisome lesion. There was consensus that patients with solid lesions of indeterminate pathology and >5 mm should undergo pancreatic resection if additional evaluation does not yield a definitive preoperative diagnosis.

Some high-risk individuals develop multiple precursors throughout their pancreas, and those who undergo pancreatic resection for IPMN can have concomitant high-grade PanIN. This raises the question of whether resection criteria for high-risk individuals should include less concerning lesions than for those with sporadic disease, or if total pancreatectomy should be considered. There is no evidence to support this approach unless there are concerning lesions affecting multiple regions of the gland. Total pancreatectomy is a major operation, although studies have reported that morbidity and mortality are similar to those of Whipple operations, and diabetes-related mortality, is quite rare. There was also no consensus that surgical resection was indicated for less worrying lesions, such as suspected IPMN of 2 cm or with mild main pancreatic duct dilatation.

Consensus was also reached that the operative approach to a resectable pancreatic cancer should be the same for high-risk
individuals and those with sporadic pancreatic cancer. Patients with sporadic IPMN who have had partial pancreatectomy have a 5–10% risk of developing pancreatic cancer; ongoing surveillance of these individuals is needed. Studies have identified factors associated with metachronous disease. In some cases, metachronous disease represents re-emergence of a previously resected IPMN, raising the possibility that precancerous cells might spread through the main pancreatic duct. In germline mutation carriers, particularly those at highest risk of pancreatic cancer, the possibility of multiple primary cancers should be considered.

What are the goals of surveillance?
The primary goal of pancreatic surveillance is to prevent death from pancreatic cancer and prevent its emergence by identifying and treating precursor lesions. As with the first CAPS consensus guideline, there was consensus that the main pathological targets of surveillance are stage I pancreatic cancers and precursors with high-grade dysplasia either in PanIN or IPMN (online supplementary table S3). Since the last consensus meeting, the classification of pancreatic precursors has been slightly revised. Published studies of surveillance programmes reveal evidence of downstaging of pancreatic cancers, with most pancreatic cancers diagnosed as stage IIB or stage I. The detection and management of high-grade dysplasia in PanIN and IPMN remains a significant goal of surveillance; these lesions are not only more commonly detected by pancreatic imaging, they are more likely to have pancreatic precursor lesions than in patients without such a family history. The imaging characteristics of IPMN can be useful in identifying evidence of high-grade dysplasia within IPMN, but this is not the case for PanIN, most of which are microscopic lesions that cannot be identified with available technologies. Most pancreatic ductal adenocarcinomas are thought to arise from PanIN. This is thought to be true for patients with sporadic pancreatic cancers and also for those with a familial/ inherited susceptibility to develop pancreatic cancer. Most pancreatic cancers from such individuals have genetic signatures consistent with PanIN origin, and pancreatic cancers detected during surveillance often arise in areas of the gland separate from pancreatic cysts. Indeed, many pancreatic cancers associated with IPMN are genetically distinct from the IPMN. Since PanIN generally do not cause specific imaging abnormalities, high-grade PanIN (previously known as PanIN-3) is diagnosed only by surgical pathology review of pancreatic resections undertaken for other concerning imaging findings. In some cases, evidence of pancreatic neoplasia can be inferred by the presence of mutations detected in secretin-stimulated pancreatic fluid samples, and multifocal PanIN lesions by imaging findings of lobulocentric atrophy, but further investigation is needed to determine the value of these tests for patients under pancreatic surveillance.

Areas for future research
Emerging technologies such as CT detection of muscle and fat wasting as well as subtle changes in the pancreas using deep learning have yet to be applied to the high-risk setting. Similarly, the value of glucose monitoring in detecting new-onset diabetes for patients

Figure 2  Decision flow-chart for the management of pancreatic abnormalities found during surveillance. EUS, endoscopic ultrasound; FNA, fine-needle aspiration; MPD, main pancreatic duct; MRCP, magnetic retrograde cholangiopancreatography.
already undergoing routine pancreatic imaging is not known. The development of non-invasive blood tests, such as tests for ctDNA, provides hope that these will eventually improve the early detection of pancreatic cancer. The emergence of interval (ie, presenting before their annual surveillance) advanced-stage pancreatic cancers in some patients under regular pancreatic imaging suggests that biological characteristics, such as early lymph node metastases and venous invasion even with small cancers, make early detection efforts particularly challenging. The main factors used in clinical practice to assess the risk of pancreatic cancer in high-risk individuals remain family history, gene mutation status, age and pancreatic imaging abnormalities. Other known factors, such as diabetes and metabolic syndrome markers, smoking status, other cancer family history, gene variants identified through genome-wide meta-analysis, and circulating biomarkers that predict future risk, could help to improve risk stratification, particularly if models could be developed and validated.

Cost-effectiveness models of pancreatic surveillance have been reported. One recent paper estimated that MRI is more cost-effective for highest-risk individuals (relative risk >20); cost-effectiveness model results depend on cost estimates and MRI and EUS costs vary considerably. Ultimately, pancreatic surveillance programmes need to demonstrate better evidence that survival from pancreatic cancer can be improved by surveillance or even that the detection and treatment of high-grade dysplasia can lower the incidence of pancreatic cancer. Indeed, the US Preventive Services Task Force recommended that pancreatic screening should not be carried out, although it excluded the study by Vasan et al, because it focused on mutation carriers and completed its literature review before the recent CAPS study was published. These two studies show that pancreatic surveillance of high-risk individuals can lead to downstaging of pancreatic cancers diagnosed. Such downstaging is associated with better survival compared with historical controls, particularly when surveillance detects stage I cancers. The need to evaluate long-term outcomes necessitates pancreatic surveillance be undertaken in academic settings. Efforts to implement a pancreatic surveillance programme need to be balanced with its costs. This is a difficult balance to achieve since the harms of overdiagnosis can take many years to become evident, as is the case for other cancers. The evaluation of long-term outcomes of high-risk individuals participating in pancreatic surveillance programmes, including the potential for harm, should continue.

Author affiliations
1Pathology, Medicine Oncology, Johns Hopkins University, Baltimore, Maryland, USA
2Gastroenterology and Hepatology, Erasmus University Medical Center, Rotterdam, The Netherlands
3Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA
4GI Cancer Genetics and Prevention Program, Medical Oncology, Dana Farber Cancer Institute, Boston, Massachusetts, USA
5Department of Surgery, Division of Surgical Oncology, Denver, Colorado, USA
6Department of Surgery, University of Verona, Verona, Italy
7Medical Oncology, Hospital Ramón y Cajal, Madrid, Spain
8Medicine, Yale University School of Medicine, New Haven, Connecticut, USA
9The Russell H Morgan Department of Radiology and Radiological Science, Baltimore, Maryland, USA
10Department of Gastroenterology & Hepatology, Amsterdam Gastroenterology & Metabolism, Amsterdam, The Netherlands
11Gastroenterology, Endocrinology, Metabolism and Infectiology, University of Marburg, Marburg, Germany
12Gastroenterology and Hepatology, Amsterdam University Medical Centres, Amsterdam, The Netherlands
13Department of Pathology, Johns Hopkins University, Baltimore, Maryland, USA
14Division of Digestive and Liver Diseases, Columbia University Medical Center, New York City, New York, USA
15Oncology, Johns Hopkins University, Baltimore, Maryland, USA
16Medicine, Johns Hopkins University, Baltimore, Maryland, USA
17Gastroenterology, Ichilov School of Medicine at Mount Sinai, New York City, New York, USA
18New York University Medical Center, New York City, New York, USA
19University of Michigan, Ann Arbor, Michigan, USA
20Gastroenterology and Hepatology, Leiden University, Leiden, The Netherlands

Correction notice This article has been corrected since it was published Online First. The author names and affiliations have been updated.


Contributors The consensus meeting was initiated and organised by MG, MIC, and DLC. The consensus study design was developed by KAO and revised and approved by MB, DLC, MG, and MIC. Relevant literature was collected and summarised by KAO. Presentations during the development workshop meeting were given by MB, RB, MDC, EF, TMG, SS, MIC, and MB, and the discussions facilitated by JF and JEiV. All authors except KAO, and all previously mentioned study collaborators provided the data (votes) for this study. Data were collected and analysed by KAO. The results were critically reviewed by MB, DLC, MG, and MIC. The final manuscript was drafted by KAO, DLC, MIC, and MB. All authors approved the final manuscript.

Funding The consensus meeting was supported by NIH grant U01CA210170 and by a donation of “Kom in beweging tgen alveeldkikkertekken”, “Living With Hope Foundation”, and Hugh and Rachel Victor. MG is the Sol Goldman Professor of Pancreatic Cancer Research. AML is the Benjamin Baker Scholar.

Disclaimer JEiV received research funding from Abbott and Cook Medical; she is a consultant to Boston Scientific, Cook Medical, and Medtronics. DLC is a consultant to Tramedico. MB received research funding from Boston Scientific, Cook Medical, Pentax Medical, 3M; he is a consultant to Boston Scientific, Cook Medical, Pentax Medical, Mylan, MedRisk, and Medicom. PF is a consultant to Olympus, Cook Medical, Ethicon Endosurgery and received research funding from Boston Scientific. RB has received research funding from Immunovia and Freenome. MIC received research funding from Pentax C2 Crysobalon and Endogastro Solutions. DS received research funding from Immunovia, Sanofi and Tempus; she is on the Scientific Advisory Board for Nybo Therapeutics, Interpace and Tyne.

Competing interests The authors disclose the following: JEiV received research funding from Abbott and Cook Medical; she is a consultant to Boston Scientific, Cook Medical, and Medtronics. DLC is a consultant to Tramedico. MB received research funding from Boston Scientific, Cook Medical, Pentax Medical, 3M; he is a consultant to Boston Scientific, Cook Medical, Pentax Medical, Mylan, MedRisk, and Medicom. PF is a consultant to Olympus, Cook Medical, Ethicon Endosurgery and received research funding from Boston Scientific. RB received research funding from Immunovia and Freenome. MIC received research funding from Pentax C2 Crysobalon and Endogastro Solutions. DS received research funding from Immunovia, Sanofi and Tempus; she is on the Scientific Advisory Board for Nybo Therapeutics, Interpace and Tyne.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article.

ORCID iDs
Michael Goggins http://orcid.org/0000-0002-4286-2296
Kasper Alexander Overbeek http://orcid.org/0000-0003-1829-9963
Thomas M Gress http://orcid.org/0000-0002-9333-5461
Walter Park http://orcid.org/0000-0001-8187-4188
REFERENCES


Correction: Management of patients with increased risk for familial pancreatic cancer: updated recommendations for the international cancer of the pancreas screening (CAPS) Consortium


The affiliation for 2 and 23 should be the same and should be Gastroenterology and Hepatology, Erasmus University Medical Center, Rotterdam, The Netherlands. They are cited differently as below.

Gastroenterology and Hepatology, Erasmus Medical Centre, Rotterdam, The Netherlands

Gastroenterology and Hepatology, Erasmus University Rotterdam, Rotterdam, The Netherlands

Also the affiliation of the Johns Hopkins University authors should also include The Sol Goldman Pancreatic Cancer Research Centre.

Figure one has been added for clarity: