Quantitative Sensory Testing in Painful Chronic Pancreatitis

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Conflicts of Interest

• No conflicts of interest to disclose.

Support

• Anna Evans Phillips has been supported by the American Pancreatic Association Young Investigator in Pancreatitis Award.
Objectives

• Describe derivation of normal thresholds of pancreatic quantitative sensory testing
• Describe the use of pancreatic quantitative sensory testing in a population of CP patients
Pain in Chronic Pancreatitis (CP)

- Most disabling symptom
- Affects ~90% of patients
- Invasive therapy is offered to patients whose pain is thought to be due to obstructive disease (Pancreatic duct stones, strictures)
- Pain response to therapies is unpredictable
- Correlates poorly with morphologic features on imaging

-Wilcox CM et al, Clin Gastro and Hep, March 2015
-Olesen SS et al, Pancreapedia, Feb 2015
## Pain Assessment Tools in CP

Aspects of pain included in general multidimensional tools, specific pain assessment tools for chronic pancreatitis (CP), and impact of pain assessment tools (adapted from the criteria for evaluation of pain by the American Gastroenterological Association [14] with 8 additional pain aspects from the literature [4,18–20]).

<table>
<thead>
<tr>
<th>Aspects of Pain</th>
<th>General multidimensional tools</th>
<th>CP-specific tools</th>
<th>Impact of pain tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MPQ(^a)</td>
<td>PDQ(^b)</td>
<td>Izbricki(^c)</td>
</tr>
<tr>
<td>Key reference</td>
<td>[37]</td>
<td>[18]</td>
<td>[48]</td>
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<tr>
<td>Duration of pain</td>
<td></td>
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<tr>
<td>Location of pain</td>
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<td>Radiation of pain</td>
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<tr>
<td>Triggers/exacerbators of pain</td>
<td>F</td>
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<tr>
<td>Pain pattern (Continuous/Intermittent)</td>
<td>F</td>
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<tr>
<td>Objective measure of pain intensity(^c)</td>
<td>S</td>
<td></td>
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<tr>
<td>Subjective estimate of intensity of pain</td>
<td>F</td>
<td></td>
<td></td>
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<tr>
<td>Frequency of pain attacks</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Description of pain</td>
<td>B</td>
<td></td>
<td></td>
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<tr>
<td>Associated symptoms with pain</td>
<td>B</td>
<td></td>
<td></td>
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<tr>
<td>Postprandial pain</td>
<td></td>
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<td>Analgesic use</td>
<td></td>
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<tr>
<td>Relieving factors of pain</td>
<td>F</td>
<td></td>
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</tr>
<tr>
<td>Ability to work/occupation status</td>
<td></td>
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<tr>
<td>Effect on daily activities/function</td>
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<tr>
<td>Effect on mental health</td>
<td></td>
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</tbody>
</table>

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Teo et al. Pancreatology 2016;16(6):931-939
Pain versus Nociception

- Tools to date: cannot differentiate pain versus nociception
- Cannot predict outcomes of treatment
- Lack objectivity
- Pain: Subjective and emotional experience associated with actual or potential damage

- Nociception: Response of sensory nervous system to harmful or potential harmful stimuli

- Due to the subjective nature and emotional aspect of pain, it is unlikely that there will ever be a biomarker for pain but it is more likely that there will be biomarker(s) to assess nociceptive activity
Suboptimal Pain Response to Existing Therapies

- CP pain results from multiple mechanisms
- Central sensitization: hyper-exitability in the central nervous system
  - functional reorganization of cerebral cortex
  - Neuroplastic and neuropathic changes occur in response to persistent visceral and somatic pain stimuli
  - Incomplete pain response to local CP therapies is thought to be due to central sensitization

-Drewes AM et al, Pancreatology, Sep 2017
Quantitative Sensory Testing

Central Sensitization

Segmental Sensitization

Figure 1.

1. different fibers & pathways
2. central convergence
3. central excitability
4. descending modulation
5. neuroplastic changes

-Drewes et al., unpublished
Pancreatic QST (P-QST)

• New and simplified testing protocol
• Developed in collaboration with Danish colleagues
• Tailored specifically for use in patients with CP
• Utilizes convergence of visceral nerves and somatic nerves in the spinal cord root
• Facilitates surface testing of the pancreatic viscerotome (T10)
P-QST
Central sensitization

None (normal)  Segmental sensitization  Widespread sensitization

QST
Values Used in Diagnostic Thresholds

Central Sensitization

- Temporal Summation Index Forearm (*TS Index Forearm*)
- Pressure Detection Sum (*pPDT sum*)
- Cold Pressor Test Area Under Curve (*AUC*)
- Conditioned Pain Modulation Index (*CPM Index*)

Segmental Sensitization

- Pressure Detection Index (*pPDT Index*)
- Temporal Summation Index Abdomen (*TS Index Abdomen*)
Temporal Summation

- Wind-up phenomenon from repeated stimuli
-Measured on forearm and abdomen (T10)

$TS\ Index = 10stim - 1stim$
Pressure Detection/Tolerance

- Measured in 6 different locations over surface of body
- Pain Detection Threshold: $p_{PDT}$
- Pain Tolerance Threshold: $p_{PTT}$

$p_{PDT}$ or $p_{PTT}$ Index = \[ \frac{\text{mean}(T10^{ABD} + T10^{BACK})}{\text{mean}(C5 + L1 + L4)} \]
Conditioned Pain Modulation

- Detection of altered descending inhibition
- Hand is exposed to ice water for 2 minutes
- Patient’s discomfort is rated every 10 seconds (scale 1-10)
- If hand is removed, score of 10 is assigned for that timepoint
- Pressure tolerance test before and after

\[
CPM = \frac{pPTT_{AFT} - pPTT_{BEF}}{pPTT_{BEF}}
\]
Hypothesis

• This protocol will help to identify specific phenotypes in patients with CP.
• These phenotypes will associate with patient and disease characteristics.

Significance

• If QST is able to identify specific phenotypes, it can be used as a predictive tool to identify patients who will respond to specific therapies.
Aims: Normogram Study

1) Use P-QST protocol to develop a normogram
2) Use newly developed normogram to phenotype patients with chronic pancreatitis
Study Sites

• Institutional Review Board approval was obtained at each site individually

  – University of Pittsburgh Medical Center (Pittsburgh, PA, USA)
  – The Johns Hopkins University Medical Center (Baltimore, MD, USA)
  – Aalborg University Hospital (Aalborg, Denmark).
Study Subjects

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;40 yrs</td>
<td>20</td>
<td>21</td>
<td>41</td>
</tr>
<tr>
<td>40-59 yrs</td>
<td>21</td>
<td>20</td>
<td>41</td>
</tr>
<tr>
<td>≥ 60</td>
<td>20</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Totals</td>
<td>61</td>
<td>61</td>
<td>122</td>
</tr>
</tbody>
</table>

Exclusion Criteria:

- Medical or Surgical disease that would affect QST testing
- Chronic Abdominal Pain (daily abdominal pain, or more than 6 episodes of abdominal pain per year)
- Chronic Narcotic Use (prescription or otherwise)
- Chronic Pain Syndrome
- Pregnancy
TS Index

- Non-parametric evaluation
- No age or gender effects were observed
- Median TS Index: 1.0 (IQR 0.0-2.0)
- 75th percentile = 2.0
- Correlation between TS Forearm and TS Abdomen
- TS Forearm: widespread hyperalgesia
- TS Abd: segmental hyperalgesia

Threshold: TS Index > 2
pPDT Index, pPTT Index

- Mixed effects models
- Differences seen in absolute thresholds (lower with increasing age, female)
- pPDT Index: Median 1.0, lower 25th percentile 0.87
- Correlation of pPDT and pPTT Indices (rho 0.66, p<0.001)

Threshold pPDT Index ≤ 0.85
pPDT Sum Scores

- Sum of pPDT and pPTT absolute thresholds across all dermatomes (C5 + T10 back + T10 abd+ L1 + L4)
- Gender differences seen
- Correlation of pPDT and pPTT sum scores (rho 0.75, p<0.001)
- pPDT Sum score female: Median 520 kPa (lower 25\textsuperscript{th} percentile 403kPa)
  - Threshold pPDT Sum (female) = <400kPa
- pPDT Sum score male: Median 786 kPa (lower 25\textsuperscript{th} percentile626kPa)
  - Threshold pPDT Sum (male) = <600kPa
Cold Pressor Test: Area Under Curve (AUC)

- No age or gender effects seen
- Median: 7.3 VAS per sec
- Upper 75\textsuperscript{th} percentile 8.8 VAS per sec

Threshold AUC >9 VAS per sec
CPM Index

- Suboptimal increase in pain tolerance threshold after ice water exposure
- Normality: based on within-subject coefficient of variation in CPM test stimulus (pPTT non-dominant L4 dermatome)
- Impaired: CPM response ≤ normal within-subject variation in CPM test stimulus between two repeated assessments without the conditioning stimulus
- Percentage variation in reference population: 13.0% (95% CI 10.9% - 15.2%)

Threshold Impaired CPM: ≤ increase of 15% from baseline pPTT
Diagnostic Thresholds

2 of 4 criteria for widespread hyperalgesia met?
- CPM < 15%
- Cold pressor AUC > 9 VAS/sec
- pPDT sum: women < 400 kPa, men < 600 kPa
- TS index forearm > 2 VAS

1 of 2 criteria for segmental hyperalgesia met?
- pPDT index < 0.85
- TS index pancreas > 2 VAS

Normal QST

Central sensitization
Segmental sensitization
Normal central processing of pain
Distribution Across QST Phenotypes

Controls

- Normal Pain Processing (n=71, 58%)
- Widespread Hyperalgesia (n=27, 22%)
- Segmental Hyperalgesia (n=24, 20%)

CP Patients

- Normal Pain Processing (n=20, 40%)
- Widespread Hyperalgesia (n=18, 36%)
- Segmental Hyperalgesia (n=12, 24%)

N=122
M/F Equal gender groups
3 age groups: <40, 40-60, > 60

N=50.
Mean age 54.4±12.3 years. 30 (60%) male.
32 (64%) EtOH etiology.
Aims: P-QST in CP Patients

1) Phenotype pain in patients with chronic pancreatitis using P-QST

2) Evaluate whether the QST profiles of these patients correlate with QOL and psychologic variables
Methods

Multicenter study
- University of Pittsburgh Medical Center
- The Johns Hopkins University Medical Center
- Aalborg University Hospital

CP definition
- At least one of the following:
  - Calcification(s) (definitive M-ANNHEIM)
  - Marked/severe ductal changes (Cambridge classification III or IV)

Pain Subset: Clinical phenotype
- Painful: constant or intermittent pain
- Painless: previous pain, no pain at time of enrollment
- Silent: presented with no pain
Methods

P-QST Testing in all CP Patients

Questionnaire Assessment:
  1) Pain: Modified Brief Pain Inventory-short form (mBPI-sf)
  2) Quality of life: European Organization for the Research and Treatment of Cancer Quality of Life Questionnaire (EORTC-QLQ-C30)
  3) Psychological impact of pain:
     a. Hospital Anxiety and Depression Scale (HADS)
     b. Patient Catastrophizing Scale (PCS)
### Demographic characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total n=162</th>
</tr>
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<tbody>
<tr>
<td>Male, n (%)</td>
<td>96 (59)</td>
</tr>
<tr>
<td>Age, Mean Yr (SD)</td>
<td>53.8 (13.6)</td>
</tr>
<tr>
<td>Race, n (%)</td>
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<tr>
<td>Caucasian</td>
<td>142 (89)</td>
</tr>
<tr>
<td>African American</td>
<td>12 (8)</td>
</tr>
<tr>
<td>Asian</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Etiological risk factors, n (%)*</td>
<td></td>
</tr>
<tr>
<td>Toxic</td>
<td>121 (75)</td>
</tr>
<tr>
<td>Idiopathic</td>
<td>20 (13)</td>
</tr>
<tr>
<td>Genetic</td>
<td>12 (7)</td>
</tr>
<tr>
<td>Autoimmune</td>
<td>0 (0)</td>
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<tr>
<td>Recurrent and severe acute pancreatitis</td>
<td>40 (25)</td>
</tr>
<tr>
<td>Obstructive</td>
<td>10 (6)</td>
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<tr>
<td>EPI, n (%)</td>
<td></td>
</tr>
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<td>Yes</td>
<td>101 (62)</td>
</tr>
<tr>
<td>No</td>
<td>52 (32)</td>
</tr>
<tr>
<td>Undetermined</td>
<td>9 (6)</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
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</tr>
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<td>Yes</td>
<td>61 (38)</td>
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<tr>
<td>No</td>
<td>95 (59)</td>
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<tr>
<td>Undetermined</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Prior endoscopic treatment, n (%)</td>
<td>86 (53)</td>
</tr>
<tr>
<td>Pancreatic surgery, n (%)</td>
<td>19 (12)</td>
</tr>
</tbody>
</table>
P-QST Phenotype Distributions in CP

- Normal Pain Processing (n=58, 36%)
- Widespread Hyperalgesia (n=75, 46%)
- Segmental Hyperalgesia (n=29, 18%)
### Pain and Psychological Variables

<table>
<thead>
<tr>
<th></th>
<th>All patients (n=162)</th>
<th>Normal sensory profile (n=58)</th>
<th>Segmental hyperalgesia (n=29)</th>
<th>Widespread hyperalgesia (n=75)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opioid treatment, n (%)</strong></td>
<td>81 (50)</td>
<td>25 (43)</td>
<td>17 (59)</td>
<td>39 (52)</td>
<td>0.37</td>
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<tr>
<td><strong>Adjuvant analgesics, n (%)</strong></td>
<td>67 (41)</td>
<td>25 (43)</td>
<td>14 (48)</td>
<td>28 (37)</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>BPI pain score</strong></td>
<td>4.0 (1.5-5.5)</td>
<td>3.8 (0.5-5.3)</td>
<td>3.0 (0-5.6)</td>
<td>4.5 (2.0-5.8)</td>
<td>0.16</td>
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<tr>
<td><strong>BPI interference score</strong></td>
<td>3.5 (0.3-6.0)</td>
<td>3.0 (0-5.9)</td>
<td>2.9 (0-6.1)</td>
<td>4.1 (1.3-6.3)</td>
<td>0.25</td>
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#### Psychological variables

<table>
<thead>
<tr>
<th></th>
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<th>Widespread hyperalgesia (n=75)</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td><strong>Pain catastrophizing</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Conditional</strong></td>
<td>20.0 (7.0-31.0)</td>
<td>16.0 (6.0-29.0)</td>
<td>20.0 (7.0-30.0)</td>
<td>23.0 (8.0-33.0)</td>
</tr>
<tr>
<td><strong>Situational</strong></td>
<td>23.0 (12.0-33.0)</td>
<td>22.0 (12.0-32.0)</td>
<td>20.5 (9.5-32.0)</td>
<td>26.0 (12.0-34.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th>Widespread hyperalgesia (n=75)</th>
<th>P-value</th>
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<tbody>
<tr>
<td><strong>HADS</strong></td>
<td></td>
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<tr>
<td><strong>Depression score</strong></td>
<td>6.0 (3.0-10.0)</td>
<td>5.0 (2.0-9.0)</td>
<td>5.0 (1.0-9.0)</td>
<td>6.5 (4.0-10.0)</td>
</tr>
<tr>
<td><strong>Anxiety score</strong></td>
<td>7.0 (4.0-11.0)</td>
<td>7.0 (4.0-12.0)</td>
<td>7.0 (4.0-9.0)</td>
<td>8.0 (5.0-12.0)</td>
</tr>
<tr>
<td>Pain characteristics</td>
<td>All patients (n=162)</td>
<td>Normal sensory profile (n=58)</td>
<td>Segmental hyperalgesia (n=29)</td>
<td>Widespread hyperalgesia (n=75)</td>
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<tr>
<td><strong>Pancreatic pain phenotype, n (%)</strong></td>
<td></td>
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</tr>
<tr>
<td>Painful CP</td>
<td>128 (79)</td>
<td>40 (69)</td>
<td>21 (72)</td>
<td>67 (89)</td>
</tr>
<tr>
<td>Painless and silent CP</td>
<td>34 (21)</td>
<td>18 (31)</td>
<td>8 (28)</td>
<td>8 (11)</td>
</tr>
<tr>
<td><strong>Pain pattern, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermittent pain</td>
<td>48 (38)</td>
<td>20 (50)</td>
<td>6 (29)</td>
<td>22 (33)</td>
</tr>
<tr>
<td>Constant pain</td>
<td>80 (63)</td>
<td>20 (50)</td>
<td>15 (71)</td>
<td>45 (67)</td>
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</tbody>
</table>
## Quality of Life

<table>
<thead>
<tr>
<th></th>
<th>All patients (n=162)</th>
<th>Normal sensory profile (n=58)</th>
<th>Segmental hyperalgesia (n=29)</th>
<th>Widespread hyperalgesia (n=75)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global health</strong></td>
<td>50.0 (33.3-66.7)</td>
<td>58.3 (33.3-83.3)</td>
<td>58.3 (41.7-83.3)</td>
<td>41.7 (33.3-58.3)**##</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Functional scales</strong></td>
<td></td>
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<tr>
<td>Physical functioning</td>
<td>73.3 (60.0-93.3)</td>
<td>80.0 (66.7-93.3)</td>
<td>93.3 (66.7-100)</td>
<td>66.7 (46.7-86.7)**##</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Role functioning</td>
<td>66.7 (33.3-83.3)</td>
<td>66.7 (33.3-91.7)</td>
<td>66.7 (33.3-100)</td>
<td>50.0 (33.3-66.7)</td>
<td>0.11</td>
</tr>
<tr>
<td>Emotional functioning</td>
<td>66.7 (50.0-83.3)</td>
<td>75.0 (41.7-91.7)</td>
<td>75.0 (50.0-100)</td>
<td>58.3 (50.0-83.3)</td>
<td>0.08</td>
</tr>
<tr>
<td>Cognitive functioning</td>
<td>66.7 (50.0-100)</td>
<td>83.3 (50.0-100)</td>
<td>100 (66.7-100)</td>
<td>66.7 (33.3-83.3)#</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Social functioning</td>
<td>66.7 (33.3-100)</td>
<td>66.7 (33.3-100)</td>
<td>83.3 (50.0-100)</td>
<td>58.3 (33.3-83.3)</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Symptom scales / items</strong></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Fatigue</td>
<td>55.6 (33.3-66.7)</td>
<td>55.6 (22.2-77.8)</td>
<td>33.3 (22.2-55.6)</td>
<td>55.6 (33.3-77.8)</td>
<td>0.06</td>
</tr>
<tr>
<td>Nausea and vomiting</td>
<td>16.7 (0-50.0)</td>
<td>16.7 (0-33.3)</td>
<td>0 (0-33.3)</td>
<td>33.3 (16.7-50.0)**##</td>
<td>0.005</td>
</tr>
<tr>
<td>Pain</td>
<td>66.7 (33.3-83.3)</td>
<td>50.0 (16.7-83.3)</td>
<td>50.0 (16.7-66.7)</td>
<td>66.7 (33.3-83.3)#</td>
<td>0.04</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>0 (0-33.3)</td>
<td>0 (0-33.3)</td>
<td>0 (0-33.3)</td>
<td>0 (0-33.3)</td>
<td>0.99</td>
</tr>
<tr>
<td>Insomnia</td>
<td>33.3 (0-66.7)</td>
<td>33.3 (0-66.7)</td>
<td>33.3 (33.3-66.7)</td>
<td>33.3 (0-66.7)</td>
<td>0.92</td>
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<tr>
<td>Appetite loss</td>
<td>33.3 (0-66.7)</td>
<td>33.3 (0-66.7)</td>
<td>0 (0-33.3)</td>
<td>33.3 (0-66.7)</td>
<td>0.06</td>
</tr>
<tr>
<td>Constipation</td>
<td>0 (0-33.3)</td>
<td>33.3 (0-66.7)</td>
<td>0 (0-33.3)</td>
<td>33.3 (0-66.7)</td>
<td>0.88</td>
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<tr>
<td>Diarrhoea</td>
<td>33.3 (0-33.3)</td>
<td>33.3 (0-33.3)</td>
<td>0 (0-33.3)</td>
<td>0 (0-33.3)</td>
<td>0.77</td>
</tr>
<tr>
<td>Financial difficulties</td>
<td>33.3 (0-66.7)</td>
<td>33.3 (0-66.7)</td>
<td>0 (0-66.7)</td>
<td>33.3 (0-66.7)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Significance of the difference between patients with widespread hyperalgesia and normal sensory profile: *P<0.05, **P<0.01
Significance of the difference between patients with widespread hyperalgesia and segmental hyperalgesia: #P<0.05, ##P<0.01
Conclusions: P-QST

- It is feasible to phenotype CP patients by apparent level of nociception.
- CP patients with widespread sensitization (Central Sensitization) have more pain and significantly lower QOL.
- P-QST characterizes the sensory profiles independently of psychological status (anxiety, depression, catastrophizing) and thus provides an unbiased proxy of pain processing or nociception.
Hypothesis

- Presence of central sensitization renders patients less likely to respond to invasive local therapies indicated for the treatment of pain in CP
Future Directions

• Evaluation of whether P-QST phenotype is predictive of likelihood of response to invasive local therapy
  – Can pre-procedural QST pain phenotypes predict outcomes after intervention in painful chronic pancreatitis?

• Facilitate tailored therapies for CP patients with pain
Thank You

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Questions?