Optimized Biopsy Procedures for Estimating Gleason Score and Prostate Cancer Volume

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Motivation

Prostate Cancer

Life-threatening?

Clinically-Significant Prostate Cancer

How to evaluate?

Surrogate Markers (e.g., Cancer Volume, Gleason Score)

Our objective: To estimate CV and GS of Prostate Cancer
Motivation (cont.)

- Biopsy – standard diagnostic procedure
- However,

No biopsy protocols specifically for estimation of surrogate markers.
Hypothesis

• Prostate cancers of different surrogate marker values may exhibit different spatial patterns, which could be sampled by optimally-placed biopsy needles.

Spatial Pattern:

\[ [1 \ 0 \ 0 \ 0 \ 0 \ 1] \quad [0 \ 1 \ 1 \ 0 \ 0 \ 0] \]
Method
Normalization of Prostate Specimens into Common Prostate Space
Cancer Volume Used as the Surrogate Marker for Clinical Significance of Prostate Cancer

Gleason Score Used as the Surrogate Marker for Clinical Significance of Prostate Cancer
Cancer Volume Used as the Surrogate Marker for Clinical Significance of Prostate Cancer

Clinically-Significant Cancers  Clinically-Insignificant Cancers

\[ F(p_1) = [B_{p_1}(u_1), B_{p_1}(u_2), \ldots, B_{p_1}(u_j), \ldots, B_{p_1}(u_M)] \Rightarrow C(p_1) \]

\[ F(p_2) = [B_{p_2}(u_1), B_{p_2}(u_2), \ldots, B_{p_2}(u_j), \ldots, B_{p_2}(u_M)] \Rightarrow C(p_2) \]

\[ \vdots \]

\[ F(p_N) = [B_{p_N}(u_1), B_{p_N}(u_2), \ldots, B_{p_N}(u_j), \ldots, B_{p_N}(u_M)] \Rightarrow C(p_N) \]

Common prostate space

\[ u_j \]

\[ j \text{-th feature} \]
Results

Cancer Volume Used as the Surrogate Marker for Clinical Significance of Prostate Cancer

For Estimating Cancer Volume
Results (cont.)
Results (cont)

For Estimating Gleason Score

A. Classification Rate as a function of the number of optimal features/needles

B. ROC (7 needles used)

Classification rate = 81.93% when 7 needles are optimized

$\kappa$: the number of optimal features (needles)
Thank you!
Effects of Variations in Optimization Parameters

Transperineal Protocols for Gleason Score

A

Classification Rate
(T fixed at 0.5, \(\sigma\) varies)

Classification rates when 7 needles are optimized

\(\kappa\): Number of optimal features (needles)

ROC for 7 needles
(T fixed at 0.5, \(\sigma\) varies)

\(\sigma = \) 1, 2, 5, 10, 20, 50

False Positive Rate

Transrectal Protocols for Gleason Score

B

Classification Rate
(\(\sigma\) fixed at 20, \(T\) varies)

Classification rates when 7 needles are optimized

\(\kappa\): Number of optimal features (needles)

ROC for 7 needles
(\(\sigma\) fixed at 20, \(T\) varies)

\(T = \) 0.4, 0.5, 0.6, 0.7, 0.8
Effects of Variations in Training Populations

Fig. 11: Bootstrapping distribution of the classification rates in 850 simulated populations. The mean and standard deviation is established at 87.18±5.79%, for using transperineal optimized biopsies to estimate Gleason Score. Similar results are found in transperineal / transrectal sampling protocols when estimating Gleason Score / cancer volume.
Why different protocols for CV and GS?

High CV does not necessarily indicate high GS, and vice versa.

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<th></th>
<th>High CV</th>
<th>Low CV</th>
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<td>16</td>
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</tr>
<tr>
<td>Low GS</td>
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<td>21</td>
<td>36</td>
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<td><strong>Total</strong></td>
<td><strong>46</strong></td>
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