Display Techniques for Virtual Colonoscopy

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Virtual Colonoscopy - Definition

- Thin Section Helical CT
- Gas Distended
- Cleansed Colon
- Image Reconstruction
- Image Review / Interpretation

Perception of Virtual Colonoscopy

Axial CT images are obtained

And then converted into ...

Virtual Colonoscopy

Detection of Suspect Lesions

- Display method should allow:
  - Easy means for navigation through the colon
  - Display lesion on screen for sufficient detection time
  - Differentiate polyps from normal features of colon
  - Visualize the entire colonic mucosa
  - Detection beneath obscuring fluid, tagged stool, etc.
  - Integration of CAD targets

- Purpose of Reconstruction and Review
  - Detection of suspect lesions
    - Determines sensitivity
      - Increase True Positives & Reduce False Negatives
  - Characterization of detected lesions
    - Determines specificity
      - Reduce false positives
Virtual Colonoscopy

- Detection - Display Methods
  - 2D
    - Lumen tracking
    - 3D Problem solving
  - 3D methods
    - 3D cube
    - Fly-through
    - Unfolded cube
    - Fillet
    - Flattened

2D Detection

Initial 2D Interpretation

- Stack mode – 2D Cine
- Lumen tracking:
  - The colonic lumen is followed on serial axial images from rectum to cecum
  - The entire lumen is viewed, NOT just along the centerline

Center Tracking vs. Lumen Tracking

Center Tracking

Center Tracking
Lumen Tracking - Manual

2D Detection

+++ Visualization of entire colonic mucosa
+++ Detection beneath obscuring fluid, stool, etc.
+++ Simultaneous characterization of density
+++ Integration of CAD targets
+/– Differentiation of polyps from normal colon
– Easy means for navigation through the colon
– Display lesion on screen for sufficient time

2D Detection – 3D Characterization

3D Display Methods

3D Display methods should allow:
– Easy means for navigation through the colon
– Display lesion on screen for sufficient detection time
– Perception of polyps from normal features of colon
– Visualization of entire colonic mucosa
– Detection beneath obscuring fluid, tagged stool, etc.
– Integration of CAD targets

3D Navigation

– Determine air-filled structures
– Extract colon
– Determine centerline for fly-through

3D Endoluminal Review

GE
TeraRecon
Viatronix

Philips
Vital Images
Siemens
Newer Visualization Strategies

- **3D Review Methods**
  - Increase the visible surface area per unit time
  - Increased time for lesion detection (longer screen dwell time)
  - Increased conspicuity of small lesions
  - Allows for simultaneous detection and characterization of lesion morphology
  
  ... but need to confirm or provide means of viewing the entire colonic mucosa

Problems with Primary 3D Fly-through

- Difficulty to see around folds
  
- Inability to confirm complete colonic visualization

Polyp Hidden Behind Fold

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Problems with 3D Fly-through

- With endoluminal 3D reading, one needs to verify that one has visualized the entirety of the colonic surface
  
  - Complete antegrade and retrograde flight paths
  
  - Mucosal “painting”
  
  *OR*
  
  - Offer display method capable of viewing behind folds during review

Mucosal “Painting”

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Solving the “Hidden Colon” Problem

- Paint visualized areas of the colon, then...
  
- Visualize un-seen areas of colon with 2nd look
  
  *OR* (equally valid) provide:
  
  - Advanced display technique
    
    - Allows visualization around / behind folds;
      
      Eliminate need for mucosal painting
    
    - Added benefit of increase the amount of displayable colonic surface in a given unit of time
Virtual Colonoscopy

**Interpretation and Display Methods**

- **2D**
  - Lumen tracking
  - 3D Problem solving
- **3D methods**
  - 3D cube
  - Fly-through
  - Fillet view (opened colon)
  - Flattened
  - Unfolded cube

Fillet Views

- Instead of looking down the colon, the view faces the wall

Fillet view

Courtesy of: Rendoscopy

Fillet view

Virtual Colonoscopy

**Interpretation and Display Methods**

- **2D**
  - Lumen tracking
  - 3D Problem solving
- **3D methods**
  - 3D cube
  - Fly-through (and Fly-around)
  - Fillet
  - Unfolded cube
  - Flattened
In addition to looking down the colon, the view faces in all directions (including reverse)

Courtesy of Philips
Panoramic View - Unfolded Cube

Virtual Colonoscopy

- Interpretation and Display Methods
  - 2D
    - Lumen tracking
    - 3D Problem solving
  - 3D methods
    - 3D cube
    - Fly-through
    - Fillet
    - Unfolded cube
    - Flattened (Virtual Pathology)

Fillet view – Flattened & Straightened

Flattened Colon Display

Flattened Colon Display

Combined Display

 Courtesy of: Siemens

 Courtesy: GE Medical Systems

Courtesy: GE Medical Systems
Detection of Suspect Lesions

- Display method should allow:
  - Easy means for navigation through the colon
  - Display lesion on screen for sufficient detection time
  - **Visualization of entire colonic mucosa**
  - Perception of polyps from normal features of colon
  - Detection beneath obscuring fluid, tagged stool, etc.
  - Integration of CAD targets

Visualization of the Entire Colon

- New visualization methods try to eliminate need for "mucosal painting" by viewing entirety of colonic mucosa

**Radiology** 2003;228:878-885

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Detection of Suspect Lesions

- Display method should allow:
  - Visualization of entire colonic mucosa
  - Easy means for navigation through the colon
  - Display lesion on screen for sufficient detection time
  - Perception of polyps from normal features of colon
  - Detection beneath obscuring fluid, tagged stool, etc.
  - Integration of CAD targets
Electronic Cleansing - Subtraction

Display Techniques

- Purpose of Reconstruction and Review
  - Detection of suspect lesions
    - Determines sensitivity - Increase True Positives & Reduce False Negatives
  - Characterization of detected lesions
    - Determines specificity - Reduce false positives

Characterization of Lesions

- Display method should allow for rapid characterization
  - Morphology
    - Polyps don't have angular shapes (polyps are roughly hemispheric)
    - Stool can appear cubic or needle-like
  - Density
    - Polyps have soft tissue density (lipoma has fat density)
    - Stool can be very high or low density
  - Mobility
    - Stool shows positional change from prone to supine
    - BUT not all stool moves and not all that moves is stool

Lesion Characterization

- Morphology
  - Polyps don't have angular shapes (polyps are roughly hemispheric)
  - Stool can appear cubic or needle-like
- Density
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Morphology

- Main weakness of 2D review:
  - Does not allow for full demonstration of lesion morphology
  - Complex lesion shapes can be difficult to interpret
  - Detection of small lesions may be limited

Complex Fold or Polyp?
**Polyp on Fold**

- Morphology
  - Polyps don’t have angular shapes (polyps are roughly hemispheric)
  - Stool can appear cubic or needle-like
- Density
  - Polyps have soft tissue density (lipoma - fat density)
  - Stool can be very high or low density
- Mobility
  - Stool shows positional change from prone to supine
  - BUT not all stool moves and not all that moves is stool

**Density – Soft Tissue**

- Polyp
- Soft Tissue
- Stool
- Gas Density within lesion
- Lipoma
- Fat Density

**Lesion Characterization**

- Main difficulty with primary 3D interpretation is the “inability” to characterize lesion density without 2D review
  - Difficult to differentiate polyp from stool
- Primary 3D with 2D problem-solving
  - Detection on 3D review with 2D images used for characterization

**Characterization Difficulty - Density**

- Stool
- Polyp
- Lipoma

**Problems with Primary 3D Fly-through**

- Pneumatosis Cystoides
- Cecal Mucocele
- Barium Tagged Stool
**Translucency**

- Application of alternate color-opacity histogram to the volume-rendered image, allows for simultaneous display of density during 3D review.

![Graph showing the application of alternate color-opacity histogram](image)

From: Pickhardt AJR 2004; 183:429-436

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**Characterization Difficulty - Density**

- **Stool**
- **Polyp**
- **Lipoma**

![Images of stool, polyp, and lipoma](image)

**Pneumatosis Cystoides**
**Barium Tagged Stool**
**Cecal Mucocele**

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**Lesion Characterization**

- **Density**
  - Polyps have soft tissue density (lipoma has fat density)
  - Stool can be very high or low density

- **Morphology**
  - Polyps don’t have angular shapes (polyps are roughly hemispheric)
  - Stool can appear cubic or needle-like

- **Mobility**
  - Stool shows positional change from prone to supine
  - BUT not all stool moves and not all that moves is stool
  - Polyps maintain position between prone and supine

![Images showing stool mobility](image)

**Mobility - Stool**

- **Supine**
- **Prone**
Mobility

- Need to confirm position between prone and supine
  - Positional registration
  - Rotational registration

Positional Registration

![Image of positional registration]( Courtesy of Viatronix Courtesy of Vital Images Works in Progress Pending FDA Approval)

Uses a combination of length and user defined points along centerline to create two registered datasets

Rotational Registration

![Image of rotational registration]( Courtesy of Dr. Ron Summers Virtual Endoscopy & CAD Lab NIH Clinical Center)

Uses tenia coli to create coordinate system to register datasets

Conclusion

- Accurate interpretation of Virtual Colonoscopy is based on the ability to detect and characterize lesions.

- New display methods will continue to change and improve our ability to accomplish both of these tasks in a reasonable amount of time