Multi-Parametric Visualization in Image-Guided Surgery and Radiation Therapy

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If only, the Physician could “SEE” inside.
Operational Multi-Dimensional Visualization: Applications for Improved Treatment

- Visualization and Imaging Are \textit{In-Vivo} Assays

- Compare the “Content Value” of 2D B&W Images to Multi-Dimensional Visualizations, Manipulable in Real Time, Including “Fly Through” Capability, located at the Clinician’s Desktop and portable device.

- \textbf{AIM 1}: To Improve Patient Safety and Quality of Care Through More Informed Clinical Decision-making and Treatment Planning, Involving Patients in the Process as Appropriate

- \textbf{AIM 2}: To Improve the Knowledge, Education, and Competency of Medical Students, Residents, and Fully-Trained Physicians, including “Flight Simulation” with Real Patients

- \textbf{AIM 3}: To Use FDA Cleared “Near Real-Time Clinical Visualization Technology” to Create Multi-Dimensional Detailed Volumetric Versions of Traditional (B&W, 2D Images) from Slices Acquired by DICOM Compatible MRI, CT, US, and PET Instruments
Advanced Clinical Visualization

In

Plato’s Cave
Plato’s Cave Ancillary Findings
Plato’s Cave - Ancillary Findings
Clinical Volumetric Visualization
2D, Black and White is “Standard of Care”

“Plato’s CAVE is Interactive 3D, Color and Stereoscopic
Current Clinical Users

- Surgical Oncologists—Pediatric and Adult
- Oral Surgeons
- Liver Surgeons
- Radiation Oncologists

Other Clinician Champions

- Cardio-Thoracic Surgeons
- Neurosurgeons
- Skull Base Surgeons
- Cardiologists
- Otorhinolaryngologists
- Oncologists

BUT, IN SPITE OF THEIR ENTHUSIASM AND SUPPORT, IS THERE EVIDENCE THAT MULTIDIMENSIONAL IMAGING LEADS TO GREATER PATIENT SAFETY, IMPROVED CLINICAL DECISION-MAKING, BETTER TREATMENT PLANNING, IMPROVED OUTCOMES, AND IMPROVED MEDICAL EDUCATION AT ALL LEVELS?
Liver Volume Measurement in Cancer Surgery

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Colon Cancer

• 1 Million cases per year
  – 150,000 cases in the US

• 50% have or will develop Liver Metastases
  – Stage IV disease
Colorectal Liver Metastases

80% Unresectable
• Survivals
  – Median: 20 months

20% Resectable
• Survivals
  – 57% @ 5 years
# Colorectal Metastasis Surgery Limitations

<table>
<thead>
<tr>
<th>Past</th>
<th>Present</th>
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<tbody>
<tr>
<td>Arbitrary</td>
<td>Functional</td>
</tr>
<tr>
<td>- Tumor Number</td>
<td>- The amount of liver that remains</td>
</tr>
<tr>
<td>- Tumor Size</td>
<td></td>
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<tr>
<td>- Tumor Location</td>
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The Future Liver Remnant

- Normal liver: 20%
- Chemotherapy: 30%
- Cirrhosis: 40%

If less than 20% liver remains, risk of postoperative liver failure and death rises.
# Liver Volume Measurement in Cancer Surgery

<table>
<thead>
<tr>
<th>Without</th>
<th>With</th>
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<tbody>
<tr>
<td>Inoperable</td>
<td>Resectable</td>
</tr>
<tr>
<td>Palliative</td>
<td>Curative</td>
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<tr>
<td>Poor Survivals</td>
<td>Excellent Survivals</td>
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</tbody>
</table>
Slice complimented with Volumetric Visualization
Clinical Volumetric Visualization
Volumetric Visualization
Clinical Volumetric Visualization
Metrics: The Acid Test

• What to Measure and Why?
• What Does the Clinician Really Need to Know?
• Can We Define Clinically-Relevant, Minimum Datasets Required for Clinical Decision-Making, Treatment Planning, and Post-Treatment Follow-up and Evaluation for Each Clinical Situation (Disease or Injury)?
• Can the Metrics Be Entered Automatically in the Patient’s EHR and the Institution’s QA System?
Metrics

• Purposes
  Guide Treatment Planning
  Measure Treatment Effects
  Improve Clinical Decision-Making
  Improve Multi-Dimensional Visualization
  Improve Health Professions Education and Training
  **Evaluate Comparative Effectiveness** of Multi-Dimensional Visualization

• Types
  Universal
  Clinical Procedure Specific
  Education and training
Universal Metrics

• Used to determine whether multidimensional datasets (visualizations) have an impact on the routine treatment of specific disease processes and injuries

• Used to maximize effectiveness of the visualization process by utilizing the best methods for acquisition and manipulation of the dataset (visualization) (stereoscopic visualization, interactive tools, e.g., trocars, “fly-throughs,” multiuser touch table, etc.)
Enable assessment of whether:

• Multi-dimensional visualization makes a difference in the clinical decision-making and treatment planning processes

• Multi-dimensional visualization make a difference in the patient’s understanding of his/her disease/injury, the available treatment options, and the planned treatment approach

• The use of multi-dimensional visualization increases the patient’s confidence in the physician and comfort with the likely treatment outcome

• The use of multi-dimensional visualization improves the education and competency of fully-trained physicians, residents, and medical students
Disease Specific Metrics

- these are metrics specific to the disease process and are specific to the decision-making process of the team of physicians and other health care professionals

- these metrics define not only the decision-making process but the outcome of the treatment plan
Examples

• Liver Surgery
• Brain Tumor Surgery
Liver Specific Metrics

• three-dimensional evaluation of all segments of the liver
• evaluation of the arterial and venous blood supply to the different segments of the liver
• evaluation of total liver volume and volume of liver remaining after virtual resection
• evaluation of true volume (real) liver resected to the volume of the virtual liver resection that was performed in the CAVE
Liver Specific Metrics

- prediction of re-growth of liver from phenotypic three-dimensional stereoscopic images of the liver
- evaluation of phenotypic three-dimensional stereoscopic images of the liver and the genetic profile of the liver
- evaluation of “fly through” of surgical decision-making blood vessels and bile duct: patent, partially obstructed, obstructed
Liver Specific Metrics

• volumetric measurements of the virtual tumor compared volumetric measurements of the real tumor (tumor that was removed in the operating room)
• compare two-dimensional tumor (T) staging to volumetric staging
• create an objective grading scale for surgical performance from the post operative DICOM datasets
Brain Specific Metrics

• Pre-Treatment Evaluation

• Tumor Characteristics
  • Volume
  • Shape and Size
  • Metastasis

• Delineation and Labeling of Brain Circuit Pathways
  • Serial Non-redundant
  • Parallel Redundant
  • Brain Function Map
  • Shape and Size
  • 3D Location Within Brain Tissue

• Margin Delineation
  • Minimization of Excised or Irradiated Tissue

• Post-Treatment Evaluation
Thank You

Cave Development Team:
Paul Sovelius and Dr Brian Butler