Intra-operative contrast enhanced ultrasound in brain tumor surgery


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INCB – US guided surgery

2009 – 2013: 397 procedures
Cerebral tumor: US imaging (B-mode)

- **WHO I**: Pilocytic Astrocytoma
- **WHO II**: Fibrillar Astrocytoma
- **WHO III**: Anaplastic Astrocytoma
- **WHO IV**: Glioblastoma
Fig. 2 A single microbubble in a sound field. This microbubble is shown at rest (left) and during the compression (centre) and rarefaction (right) phases of an ultrasound field. This illustrates the reactive nature of microbubbles to the changing pressures of the ultrasound field because they contain gas. Tissue, being almost incompressible, does not change in volume at diagnostic ultrasound power levels. This microbubble is larger than is used clinically where a maximum diameter of 7 μm is chosen in order to allow passage through the pulmonary capillaries. The size in this experiment was determined by the lower ultrasound frequency used. The white bar is 5 μm in length. (Image courtesy of Dr. Rob Eckersley, Imperial College, London, UK)
Ultrasound contrast agents - UCA

• Gas filled microbubbles – 2nd Generation CA
• Low acoustical pressure: continuous non-linear oscillation
  ⇒ 2nd harmonic imaging
  ⇒ Imaging Real-time
• Contrast specific algorithm: Contrast Tuned Imaging

Courtesy of James E. Chomas et al., University of California, Biomedical Engineering Division, Davis CA, USA
Brain Tumor Imaging with Transcranial Sonography: State of the Art and Review of the Literature

van Leyen K et al. Brain Tumor Imaging... Ultraschall in Med 2011; 32: 572–581

Intraoperative power Doppler ultrasonography with a contrast-enhancing agent for intracranial tumors

HIROSHI KANNO, M.D., YUKIHKO OZAWA, M.D., KATSUMI SAKATA, M.D., HIDEYUKI SATO, M.D., YUTAKA TANABE, M.D., NOBUYUKI SHIMIZU, M.D., AND ISAO YAMAMOTO, M.D.

J Neurosurg 102:295–301, 2005

Intraoperative contrast-enhanced ultrasound for brain tumors

Wen Hea,*, Xiao-qian Jianga, Shuo Wangb, Mao-zhi Zhanga, Ji-zong Zhaoa, Hui-zhao Liu, Jun Mac, Dong-ying Xiang, Li-shu Wang

Clinical Imaging 32 (2008) 419–424
Objective

• The main aim of this study is to describe different brain pathologies by mean of iCEUS, as compared to preliminary baseline US and pre-operative MRI.

• This technique, being dynamic and continuous, allows for a real time direct view of the vascularization and flow distribution patterns of different types of neurosurgical lesions.
CEUS - Methods

- Prospective descriptive single center cohort pilot study
- Patients undergoing craniotomy for brain tumor removal
- US system with neuro-navigation (MyLabTwice with Virtual Navigator, Esaote, Italy).
- 2nd - generation US contrast agent (SonoVue, Bracco, Italy) – 2.4 ml IV
- 3–11 MHz linear US navigated probe (LA 332 – Esaote, Italy)

The EFSUMB Guidelines and Recommendations on the Clinical Practice of Contrast Enhanced Ultrasound (CEUS): Update 2011 on non-hepatic applications

Piscaglia F et al. The EFSUMB Guidelines... Ultraschall in Med 2012; 33: 33–59

- Timing - arterial/venous phase
- Degree of CE - comparison with brain parenchyma
- Contrast distribution - centripetal/centrifugal pattern - afferent/efferent vessels - intra-lesion vessels cystic/necrotic areas.
CEUS - Methods
CEUS - Methods
## CEUS - Results

96 patients (age range: 10 – 76 years; mean: 50 years)

<table>
<thead>
<tr>
<th></th>
<th>Echogenicity</th>
<th>Appearance</th>
<th>Cystic areas and/or necrosis</th>
<th>Art. phase</th>
<th>CEUS peak</th>
<th>Ven. phase</th>
<th>CE</th>
<th>CE pattern</th>
<th>Afferent/efferent vessels</th>
<th>Intralesional vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-grade glioma</strong></td>
<td>Iso-hyperechoic</td>
<td>Diffuse; homogeneous</td>
<td>Small/microcysts</td>
<td>15''</td>
<td>30''</td>
<td>60''</td>
<td>Mild</td>
<td>Diffuse; dotted; homog.</td>
<td>Not visible</td>
<td>None</td>
</tr>
<tr>
<td><strong>Anaplastic glioma</strong></td>
<td>Iso-hyperechoic</td>
<td>Diffuse; homogeneous</td>
<td>Small/microcysts</td>
<td>10''</td>
<td>15''</td>
<td>20-25''</td>
<td>Mild/high</td>
<td>Diffuse; dotted; homog.</td>
<td>Visible</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Glioblastoma</strong></td>
<td>Hyperechoic</td>
<td>Diffuse/circumscribed; heterogeneous</td>
<td>Large necrotic areas</td>
<td>2-3''</td>
<td>5''</td>
<td>10''</td>
<td>High</td>
<td>Nodular; highly heterog. Centripetal Necrotic areas</td>
<td>Visible</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Meningioma</strong></td>
<td>Hyperechoic</td>
<td>Circumscribed</td>
<td>Microcysts</td>
<td>5-10''</td>
<td>20-30''</td>
<td>&gt;60''</td>
<td>High</td>
<td>Nodular; homo/heterog. Centripetal Necrotic areas</td>
<td>Visible</td>
<td>Small/large</td>
</tr>
<tr>
<td><strong>Ganglioglioma</strong></td>
<td>Hyperechoic</td>
<td>Circumscribed; homogeneous</td>
<td>Small/microcysts</td>
<td>2-3''</td>
<td>5''</td>
<td>10''</td>
<td>Mild/high</td>
<td>Nodular; homogenous Centripetal Micro/macrocysts</td>
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<td>Small</td>
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<td><strong>Ependymoma</strong></td>
<td>Hyperechoic</td>
<td>Circumscribed; homogeneous</td>
<td>Small/microcysts</td>
<td>5''</td>
<td>5-10''</td>
<td>20-25''</td>
<td>High</td>
<td>Nodular; homogenous Centripetal Micro/macrocysts</td>
<td>Visible</td>
<td>Small</td>
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<tr>
<td><strong>Ct. neurocytoma</strong></td>
<td>Variably</td>
<td>Nodular; heterogeneous</td>
<td>None</td>
<td>15-20''</td>
<td>40''</td>
<td>60''</td>
<td>Mild</td>
<td>Nodular; heterogenous Centripetal Micro/macrocysts</td>
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<td>None</td>
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<td><strong>Pituitary adenoma</strong></td>
<td>Hyperechoic</td>
<td>Circumscribed; homogeneous</td>
<td>Microcysts</td>
<td>10''</td>
<td>30''</td>
<td>&gt;60''</td>
<td>Mild/high</td>
<td>Diffuse; nodular; homog. Centrifugal Microcysts</td>
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<td>None</td>
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<tr>
<td><strong>Hemangioblastoma</strong></td>
<td>Variably</td>
<td>Circumscribed; homogeneous</td>
<td>None</td>
<td>5''</td>
<td>10''</td>
<td>60''</td>
<td>High</td>
<td>Nodular; homogenous Centrifugal Micro/macrocysts</td>
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<td><strong>Metastasis</strong></td>
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<td>High</td>
<td>Nodular; heterogeneous Centripetal Necrotic areas</td>
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<td>Small/large</td>
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<tr>
<td><strong>Abscess</strong></td>
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<td>30''</td>
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<td>Peripheral rim Necrotic areas</td>
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<td>None</td>
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<td><strong>Radionecrosis</strong></td>
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<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
CEUS - Results

Pilocytic a.
WHO I

Low-grade g.
WHO II

Anaplastic g.
WHO III

Glioblastoma
WHO IV

MRI  B-mode  CEUS

MRI  B-mode  CEUS

MRI  B-mode  CEUS

MRI  B-mode  CEUS

Pituitary aden.
WHO I

Hemangiobl.
WHO I

Ganglioglioma
WHO I

Ependymoma
WHO II

WHO II

* *
Conclusions

- Dynamic and continuous real time imaging
- Visualization and characterization of different brain lesions.
- Dynamic biological information: vascularization, microcirculation, tissue perfusion dynamic
- Completes and integrates the information obtained with standard B-mode and Color-Doppler imaging.
- True real-time feedback during surgery, being less expensive and time consuming compared with other intraoperative imaging modalities.
- Steep learning curve - Operator dependent
THERAGLIO: development of combined imaging technologies for diagnostic and tailored therapeutic interventions, for patients bearing malignant gliomas.