Contrast clearance following hepatic transarterial embolization with radio-opaque and non-radio-opaque micro beads in swine


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Purpose

To evaluate soluble contrast clearance following transarterial embolization (TAE) with radiopaque and radiolucent embolic beads based on changes in enhancement on CBCT over time.
Materials and Methods

1. All studies conducted under a protocol approved by the Institutional Animal Care and Use Committee

2. Domestic swine (n=4) under general anesthesia underwent superselective injections in different lobes of the liver
   i. Embolic beads were suspended in Omnipaque 350 (20:1) and embolized to stasis
   ii. Cohorts
      a. Radio-opaque beads (LC Bead LUMI, 70-150 µm)
      b. Non-radio-opaque beads (LC Bead, 70-150 µm)
      c. Contrast alone (10 mL Omnipaque 350 over 10 minutes)

3. Consecutive CBCT acquired at 2, 4, 8, 16, 24, 32, 40, 48, 56, 64 minutes post TAE or free contrast injection
Materials and Methods

3. Segmentation of enhanced blood vessels on CBCT (included voxels above intensity threshold)

4. Calculation of enhanced blood vessel volume (EVV) and enhanced blood vessel length (EVL) on CBCT at each timepoint based on the segmentation

5. Best curve fit of EVV and EVL using single phase decay equation, 
   \[ Y = Y_0 \cdot e^{-K \cdot t} \], where \( Y \) is the fraction of EVV or EVL remaining relative to 2 min (\( Y_0 \)) post TAE/contrast injection, and \( K \) is the rate constant.
## Results – Enhanced vessel segmentations

<table>
<thead>
<tr>
<th></th>
<th>2 min</th>
<th>16 min</th>
<th>32 min</th>
<th>64 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio-opaque</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>beads + contrast</td>
<td><img src="radio-opaque_beads_2min.png" alt="Image" /></td>
<td><img src="radio-opaque_beads_16min.png" alt="Image" /></td>
<td><img src="radio-opaque_beads_32min.png" alt="Image" /></td>
<td><img src="radio-opaque_beads_64min.png" alt="Image" /></td>
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<tr>
<td>Non-radio-opaque</td>
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<tr>
<td>beads + contrast</td>
<td><img src="non-radio-opaque_beads_2min.png" alt="Image" /></td>
<td><img src="non-radio-opaque_beads_16min.png" alt="Image" /></td>
<td><img src="non-radio-opaque_beads_32min.png" alt="Image" /></td>
<td><img src="non-radio-opaque_beads_64min.png" alt="Image" /></td>
</tr>
<tr>
<td>Contrast only</td>
<td></td>
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<td></td>
<td><img src="contrast_only_2min.png" alt="Image" /></td>
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<td><img src="contrast_only_32min.png" alt="Image" /></td>
<td><img src="contrast_only_64min.png" alt="Image" /></td>
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</tbody>
</table>

Radio-opaque beads + contrast
Non-radio-opaque beads + contrast
Contrast only
Results – Change in enhanced vessel volume (EVV) post TAE/contrast injection

- Points on plot reflect empirical mean +/- SD
- Curves are fitted based on single phase decay
- Data normalized to 1.0 at t=2 min
Results – Change in enhanced vessel length (EVL) post TAE/contrast injection

- Points on plot reflect empirical mean +/- SD
- Curves are fitted based on single phase decay
- Data normalized to 1.0 at t=2 min

![Graph showing the relative vessel length over time for different contrast injections.](image-url)
## Results – Rate of contrast clearance post TAE/contrast injection

<table>
<thead>
<tr>
<th>Group</th>
<th>Clearance, % completion</th>
<th>Time post TAE / contrast injection, min*</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUMI + contrast (K= 0.094 min⁻¹)</td>
<td>50</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>26.9</td>
</tr>
<tr>
<td></td>
<td>99</td>
<td>55.0</td>
</tr>
<tr>
<td>LC bead + contrast (K= 0.266 min⁻¹)</td>
<td>50</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td>99</td>
<td>19.3</td>
</tr>
<tr>
<td>Contrast only (K= 0.836 min⁻¹)</td>
<td>50</td>
<td>2.1</td>
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<tr>
<td></td>
<td>90</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>99</td>
<td>2.9</td>
</tr>
</tbody>
</table>

* Values derived from curve fitting of the change in enhanced blood vessel volume over time.
Conclusions

- Clearance was slower for both bead types compared to contrast alone.

- Change in hepatic arterial vessel opacification post TAE was visible as both reductions in total CBCT segmentation volume and vessel length.

- Curve fits revealed differences in rates of contrast clearance.
  - Radio-opaque and non-radio-opaque beads > 3x slower than for contrast injection alone
  - Radio-opaque beads 2.8x slower than non-radio-opaque beads
Conclusions

- While it is unclear if tumor behaves with similar patterns, the washout curves in normal tissue may still inform timing of CBCT or CT assessment post-TAE with ROB, which often includes normal liver tissue.