Liver perfusion imaging for cirrhosis, HCC, and colorectal cancer liver metastases

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## Dual blood supply

<table>
<thead>
<tr>
<th></th>
<th>Portal vein</th>
<th>Hepatic artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal liver</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>HCC</td>
<td>37%</td>
<td>63%</td>
</tr>
</tbody>
</table>

Liver perfusion imaging

- Determine hepatic artery versus portal vein supply to liver and liver tumors.

- **Cirrhosis**: Shift from portal vein to hepatic artery supply.

- **Tumor vascularity**: HCC recruits arterial blood supply.

- **Response to arterially directed therapies**: TAE, TACE, Y90
How many phases are needed to get perfusion parameters?

- Traditionally, liver perfusion involves scanning at ~ 20 time points.
- How much information can we get from just 3 time points?
Three phases is sufficient for liver perfusion

Enhancement of liver tumor in a pig (9 phases).

Simple perfusion model (3 phases, 2 parameters) fits actual enhancement curves.
Color liver perfusion imaging

Assumptions:
- Rapid blood flow
- Contrast stays intravascular
Color liver perfusion imaging

Portal vein

Hepatic artery

Hepatic veins
## Perfusion measurements from triphasic CT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Interpretation</th>
<th>Formula</th>
</tr>
</thead>
</table>
| Hepatic artery coefficient | Hepatic artery perfusion      | \[
\frac{v_1(x_3-x_2)+v_2(x_1-x_3)+v_3(x_2-x_1)}{a_1(v_2-v_3)+a_2(v_3-v_1)+a_3(v_1-v_2)}
\] |
| Portal vein coefficient  | Portal vein perfusion         | \[
\frac{a_1(x_3-x_2)+a_2(x_1-x_3)+a_3(x_2-x_1)}{a_1(v_3-v_2)+a_2(v_1-v_3)+a_3(v_2-v_1)}
\] |
| Arterial enhancement fraction | Hepatic artery perfusion      | \[
\frac{x_2-x_1}{x_3-x_1}
\] |
|                         | Total perfusion               | \[
\frac{x_2-x_1}{x_3-x_1}
\] |

\(a_1, a_2,\text{ and } a_3\): hepatic artery Hounsfield units in the non-contrast, arterial, and portal venous phases

\(v_1, v_2,\text{ and } v_3\): portal vein Hounsfield units in the non-contrast, arterial, and portal venous phases

\(x_1, x_2,\text{ and } x_3\): liver lesion Hounsfield units in the non-contrast, arterial, and portal venous phases.
HCC: Increased hepatic artery perfusion

Cirrhosis: Decreased portal perfusion

![Graph showing portal vein perfusion for cirrhotic and non-cirrhotic patients. The graph indicates a significant difference in portal perfusion between the two groups, with a p-value of $4 \times 10^{-12}$. There are 105 patients in total.](image_url)

Hepatic arterial buffer response

PVC = -0.90 HAC + 0.43

$\text{r}^2 = 0.95$

Portal vein coefficient (PVC) vs. Hepatic artery coefficient (HAC)

PVC versus HAC of background liver in 63 HCC patients
Background liver perfusion predicts survival

- Liver HAC predicts survival after embolization of HCC ($p=0.015$).
- In our patient population (mostly Child Pugh A5 or A6), Child Pugh score did not predict survival ($p=0.83$).
Normal bilirubin ≠ Normal liver.

Liver perfusion detects early cirrhotic changes that predict survival.
HCC tumor perfusion predicts survival

Overall survival after embolization of HCC:

**Microvascular invasion**

- No MVI
- MVI

**Degree of differentiation**

- Well differentiated HCC
- Moderate to poorly differentiated HCC

**Hepatic artery coefficient**

- Tumor HAC ≤ -0.07
- Tumor HAC > -0.07

*(p=0.45) (p=0.87) (p=0.011)*
**Colorectal liver mets: Response to Y-90**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Non-responders</th>
<th>Responders</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial phase enhancement (HU)</td>
<td>11 ± 11</td>
<td>14 ± 14</td>
<td>0.32</td>
</tr>
<tr>
<td>Portal venous phase enhancement (HU)</td>
<td>29 ± 17</td>
<td>26 ± 19</td>
<td>0.64</td>
</tr>
<tr>
<td>Hepatic artery coefficient (HAC)</td>
<td>−0.025 ± 0.039</td>
<td>−0.018 ± 0.069</td>
<td>0.62</td>
</tr>
<tr>
<td>Portal vein coefficient (PVC)</td>
<td>0.24 ± 0.15</td>
<td>0.22 ± 0.14</td>
<td>0.66</td>
</tr>
<tr>
<td>Arterial enhancement fraction (AEF)</td>
<td>0.29 ± 0.59</td>
<td>0.74 ± 1.02</td>
<td>0.038 *</td>
</tr>
</tbody>
</table>
Colorectal liver mets: Response to Y-90

- 47% response rate for lesions with arterial enhancement fraction ≤ 0.25
- 42% response rate for lesions with arterial enhancement fraction 0.25 – 0.5
- 65% response rate for lesions with arterial enhancement fraction 0.5 – 0.75
- 78% response rate for lesions with arterial enhancement fraction > 0.75

60 tumors

$p = 0.038$
Colorectal liver mets: Response to Y-90

<table>
<thead>
<tr>
<th>Non-contrast</th>
<th>Arterial phase</th>
<th>Portal venous phase</th>
<th>AEF</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>46 HU</td>
<td>47 HU</td>
<td>59 HU</td>
<td>0.08</td>
<td>progression</td>
</tr>
<tr>
<td>30 HU</td>
<td>47 HU</td>
<td>53 HU</td>
<td>0.74</td>
<td>partial response</td>
</tr>
</tbody>
</table>
Summary

Liver perfusion imaging detects:

• **Early cirrhotic changes** that are not reflected in Child Pugh score, and that predict survival.

• **Aggressiveness of HCC** that is not detected on core biopsy, and that predicts survival.

• **Response to radioembolization** of colorectal liver metastases.
References

