1. Motivation of Direct Estimation Of Permeability Maps

- Stroke patients are exposed to excessive radiation for diagnosis and prognosis using Computed Tomography Perfusion (CTP).
- Low radiation dose CTP is an active area for reducing patient’s radiation exposure.

⇒ This work is the first method by integrating the reconstruction and estimation process of low radiation dose CTP.

2. Advantage for Direct Estimation Of Permeability Maps

- Limitations of existing CTP methods
  - Address reconstruction and estimation separately
  - Demand high radiation dose and high computer resources.
- Benefits of proposed direct estimation of permeability maps
  - Directly estimate the hemodynamic parameters (k and Vp)
  - Computationally efficient and reduce necessary radiation exposure

3. Methodology: Direct Estimation Of Permeability Maps

- Hemodynamic parameters (Kt, Vp) are estimated with the Patlak Model using multi-variate linear regression from the contrast concentration C(t) and population-based arterial input function C0(t).

\[
K(t, v) = \text{regress}(C(t), C_0(t))
\]

- Contrast concentration C(t) is computed from signal intensity S(t) by subtracting the baseline image S0 and corrected hematocrit factor \(\kappa\).

\[
C(t) = (S(t) - S_0(t)) \times \kappa
\]

- Signal intensity S(t) in the time-series images is reconstructed using image reconstruction algorithms (IR) e.g., FBP, ASIR, regularized optimization, etc.

\[
S(t) = iR(r(t))
\]

4. Direction Hemodynamic Estimation for CTP

Direct Model: The difference between the measured sinogram signal r(t) and the estimated sinogram signal from hemodynamic parameters (Kt, Vp) are minimized with spatial regularization of the parameter maps, where \(\beta\) is the regularization function.

\[
(K_t, v_p) = \arg\min_{K_t, v_p} \| r(t) - \text{IR}(K_t, v_p) \|_2 + \lambda \text{Reg}(K_t, v_p)
\]

5. The Forward Model of Hemodynamic Parameter Maps

- Patlak Model AIF
- Base Image Hematocrit Factor
- CT Signal Intensity S(t)
- Low-dose Sinogram

6. Results I. FBP, TV and Direct Method Noise Comparison

<table>
<thead>
<tr>
<th>Projection</th>
<th>Reference</th>
<th>FBP+Patlak</th>
<th>TV+Patlak</th>
<th>Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR</td>
<td>180</td>
<td>120</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>180 Projections</td>
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<td>90 Projections</td>
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<td>45 Projections</td>
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</tr>
</tbody>
</table>

Kt maps are estimated with 180, 90, and 45 projection angle.

6. Results II. FBP, TV and Direct Method Noise Comparison

Comparison of Parameter estimation accuracy

ROI near the artery enlarged in perfusion phantom

6. Results III. FBP, TV and Direct Method Noise Comparison

<table>
<thead>
<tr>
<th>Projection</th>
<th>Reference</th>
<th>FBP+Patlak</th>
<th>TV+Patlak</th>
<th>Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR</td>
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<td>90</td>
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<tr>
<td>180 Projections</td>
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<tr>
<td>90 Projections</td>
<td>2.27</td>
<td>8.59</td>
<td>16.51</td>
<td></td>
</tr>
</tbody>
</table>

Kt and Vp maps estimated from a clinical subject from 90 projection angle.

7. Conclusion and Outlook

- Outperforms the state-of-art two-stage reconstruction + estimation methods such as FBP and TV + Patlak model at low radiation dose.
- Future work: Evaluate the method’s flexibility with model selection for reconstruction and hemodynamic parameter estimation.

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