Predicting End Tidal CO\textsubscript{2} from Respiration Volume Per Time for Breath-Hold Cerebrovascular Reactivity Mapping

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Background

- Cerebrovascular reactivity (CVR) is the ability of brain vasculature to dilate, increasing blood flow to the brain.
- CVR is used in analyzing brain health in various conditions such as stroke, TBI, arteriosclerosis, brain tumors, substance abuse, and aging.\textsuperscript{6}
- Clinicians measure CVR by modulating blood gases: blood CO\textsubscript{2} is a strong vasodilator and can be temporarily increased using breath-holding (BH).
- The vasodilatory response in the brain is measured using a functional MRI scan.
- Exhaled CO\textsubscript{2} is used to calculate end-tidal CO\textsubscript{2} (P\textsubscript{ET}CO\textsubscript{2}), an estimate of arterial CO\textsubscript{2}, to calculate CVR.
- It may be difficult for some populations to BH or follow instructions, decreasing P\textsubscript{ET}CO\textsubscript{2} measurement quality.

Methods

- Each subject performed BH task in supine with a nasal cannula attached to gas analyzer and respiratory belt at the xiphoid process.
- An MRI head coil was placed around the head with a mirror secured above to monitor displaying instructions.
- Participants performed 1 practice BH followed by 10 BH trials, with paced breathing, BH, and recovery time parameters randomized.
- BH’s without sufficient increase in CO\textsubscript{2} were excluded.
- Each data set was randomly split into segments consisting of 2-7 “good” BHs resulting in a final total of 293 data sets.

Summary of 4 Machine Learning Models

<table>
<thead>
<tr>
<th>Layer Model</th>
<th>1 Layer Model</th>
<th>2 Layer Model</th>
<th>3 Layer Model</th>
<th>4 Layer Model</th>
<th>5 Layer Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.756 ± 0.0982</td>
<td>0.782 ± 0.0722</td>
<td>0.834 ± 0.0775</td>
<td>0.864 ± 0.0772</td>
<td>0.864 ± 0.0772</td>
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<tr>
<td>MAE</td>
<td>0.042 ± 0.0046</td>
<td>0.042 ± 0.0046</td>
<td>0.042 ± 0.0046</td>
<td>0.042 ± 0.0046</td>
<td>0.042 ± 0.0046</td>
</tr>
<tr>
<td>MAPE (%)</td>
<td>5.95 ± 4.52</td>
<td>4.67 ± 3.52</td>
<td>5.33 ± 3.25</td>
<td>5.33 ± 3.25</td>
<td>3.26 ± 3.55</td>
</tr>
<tr>
<td>MSE</td>
<td>0.062 ± 0.150</td>
<td>0.060 ± 0.086</td>
<td>0.051 ± 0.181</td>
<td>0.035 ± 0.100</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions

- The best-performing model produced a correlation coefficient of \textit{r}=0.846±0.077, suggesting the feasibility of machine learning to predict P\textsubscript{ET}CO\textsubscript{2} from RVT.
- This work has clinical research applications on improving CVR accuracy in clinical populations.
- The generalizability of the algorithm would further improve with increased data sets of a more diverse population, including cohorts with varying lung volumes, ages, CVP conditions, and cognitive abilities.