Supporting Document 1

The dynamic curve at each voxel represents the temporal changes in MR signal intensities after contrast injection. A relative signal enhancement (RSE) at time t, $E(t)$, after contrast injection compared with signal baseline (SB), S_0, is computed using the following equation:

$$E(t) = \frac{S(t)-S_0}{S_0}, \quad (1)$$

where $S(t)$ is the signal intensity of a DCE curve at time t. S_0 can be determined by averaging measured data points before bolus arrival time (BAT) to the target tissue. The BAT was determined by fitting a RSE curve derived from the pulmonary artery under the assumption that difference in the BAT between the feeding artery and tissue is negligible for simplicity. For fitting the arterial input curve, Lee's arterial input function (AIF) model was adopted (Lee et al., 2015). The RSE was assumed to be proportional to the contrast agent concentration in the tissue for simplicity.

Peak Enhancement (PE)

PE is defined as the maximum RSE at all time steps:

$$PE = \max_{0<t\leq \mathrm{T_{end}}} E(t), \quad (2)$$

where $\mathrm{T_{end}}$ is the elapsed time of the last temporal phase.

Time-to-peak (TTP)

TTP is computed as the time in minutes at which PE occurs, minus BAT in the feeding artery:

$$TTP = \left[\arg \max_{0<t\leq \mathrm{T_{end}}} E(t)\right] - \mathrm{T_{BAT}}, \quad (3)$$

where $\mathrm{T_{BAT}}$ is the BAT in the feeding artery.

Time-to-half-peak (TTHP)

TTHP is computed as the time in minutes at which a half PE occurs during the initial uptake of contrast agent, minus BAT in the feeding artery:

$$TTHP = \left[\arg \min_{0<t<\mathrm{TTP}+\mathrm{T_{BAT}}} \{E(t) - 0.5 \cdot PE\}\right] - \mathrm{T_{BAT}}, \quad (4)$$

Wash-in-slope (WIS)

WIS is the slope of the initial uptake of contrast agent until PE:

$$WIS = \frac{PE}{TTP}, \quad (5)$$

Wash-out-slope (WOS)

WOS captures the drop in the uptake rate of the contrast agent after PE is achieved.

$$WOS = \begin{cases} \frac{PE - E(\mathrm{T_{end}})}{\mathrm{T_{end}} - (\mathrm{TTP}+\mathrm{T_{BAT}})} & \text{if } \mathrm{T_{end}} \neq \mathrm{TTP} + \mathrm{T_{BAT}} \\ 0 & \text{otherwise} \end{cases}. \quad (6)$$

Initial Gradient (IG)

IG is defined as the slope of a straight line obtained by applying linear regression to the RSE curve between 10% PE and 70% PE.

$$IG = \frac{COV(t,E(t))}{Var(t)}$$
$$\text{for } \arg\min_{0<t<\mathrm{TTP}+\mathrm{T_{BAT}}}\{E(t) - 0.1 \cdot PE\} \le t \le \arg\min_{0<t<\mathrm{TTP}+\mathrm{T_{BAT}}}\{E(t) - 0.7 \cdot PE\}, \quad (7)$$

where $Var(\cdot)$ and $COV(\cdot)$ are the sample variance and sample covariance, respectively.

Washout Gradient (WG)

WG is defined as the slope of a straight line obtained by applying linear regression to the RSE curve between 1 and 2 min elapsed from $\mathrm{T_{BAT}}$.

$$WG = \frac{COV(t,E(t))}{Var(t)}$$
$$\text{for } \mathrm{T_{BAT}} + 1 \text{ min} \le t \le \mathrm{T_{BAT}} + 2 \text{ min}. \quad (8)$$

Signal Enhancement Radio (SER)

SER is defined as the ratio between RSEs taken at two-time points, 0.5 and 2.5 min, elapsed from $\mathrm{T_{BAT}}$.

$$SER = \frac{E(\mathrm{T_{0.5}})}{E(\mathrm{T_{2.5}})}, \quad (9)$$

where $\mathrm{T_{0.5}} = \mathrm{T_{BAT}} + 0.5$ min and $\mathrm{T_{2.5}} = \mathrm{T_{BAT}} + 2.5$ min.

Initial Area Under the Curve (IAUC)

IAUCt is defined as the area under the RSE curve until a stipulated time t in minutes elapsed from $\mathrm{T_{BAT}}$.

$$IAUCt = \int_{T_{BAT}}^{T_{BAT}+t} E(\tau)d\tau. \quad (10)$$

We calculated IAUC30, IAUC60, IAUC90, IAUC120, IAUC150, IAUC180, IAUCttp and IAUCtthp until 30, 60, 90, 120, 150, 180 seconds, TTP and TTHP elapsed from T_{BAT} using trapezoidal integration of the RSE with time, respectively.