Quantitative Angiography

A new frontier in hepatic intervention

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Shortcomings of Current TACE Practice

Identification arteries feeding tumor is subjective

Identification of stasis endpoint is entirely visual (reflux from overembolization)
Optimal Degree of Embolization

- Insufficient tumor necrosis
- Increased damage to healthy tissue

Blood Flow

Degree of Embolization
There is no *objective, intra-procedural* metric for when to end embolization
Quantifying Blood Velocity Using DSA

\[ d: \text{distance of bolus transit} \]

\[ \tau: \text{time of bolus transit} \]

Intensity [AU]

cardiac pulsatility

time [s]
Finding the temporal shift in time-concentration curves

**Shifted Least-Squares Algorithm**

$$\varepsilon(\tau_{ij}) = \frac{1}{T} \sqrt{\sum_{t=1}^{T} [c_i(t - \tau_{ij}) - c_j(t)]^2}$$

shifted least squares difference
Shifted least-squares algorithm

\[ \varepsilon(\tau_{ij}) = \frac{1}{T} \sqrt{\sum_{t=1}^{T} [c_i(t - \tau_{ij}) - c_j(t)]^2} \]

find \( \tau^0_{ij} \) which minimizes \( \varepsilon(\tau_{ij}) \)

\[ \tau^0 = \alpha \cdot d + b \]

where \( \alpha = \frac{1}{velocity} \)
Visualization of Contrast Waveform along Centerline

- Time [s]
- Position along centerline [pixel]
- Proximal
- Distal
Feasibility of a DSA Quantification Method

1. Hepatic blood flow in patients is heterogeneous
   - Different heart rates and blood pressures

2. Hepatic blood vessel location in patients are heterogeneous
   - Different degrees of vessel overlap
1. Hepatic blood flow in patients is heterogeneous
2. Hepatic blood vessel location in patients are heterogeneous
DSA Quantification in an *in vivo* Porcine Model

- **left hepatic artery**
- **embolization site**
- **left hepatic artery**
Incremental embolization decreases calculated blood velocity until complete stasis is achieved, at which point turbulent flow and reflux affect velocity calculations.
Conclusions

A shifted-least squares approach for quantifying blood velocity in hepatic DSAs may represent a way to objectively standardize embolization procedures

- Shows in vitro immunity to the effects of variation in contrast injection rates and non-optimal projection angles
- Demonstrates a progressive decrease in velocity with increased degree of embolization in vivo
**Future Work**

- Develop an embolization-flow reduction curve by titrating amount of embolic particles delivered.
- Utilize 4D-DSA flow calculations to bookend procedure and validate flow reduction calculations.
- Analyze liver samples to see if calculated flow reductions correlate with tissue-level changes.

**Relative Velocity vs. Amount of Embolic Particles Delivered**

- The graph shows a decrease in relative velocity as the amount of embolic particles delivered increases, reaching a minimum point before increasing again.

**Pathology Apps**
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Transarterial chemoembolization (TACE) uses chemotherapy-coated embolic particles to block blood flood flow to the tumor and causing ischemia and necrosis.