Evaluation of a Novel Catheter-Vessel Model for MRI to Access Infused Drug Distribution in Target Artery and Catheter Design

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BACKGROUNDS: Intra-arterial drug infusion therapy using the vascular interventional radiological procedure is one of the most useful methods for treatment of malignancies of the liver and other upper abdominal organs. One of the most important factors for successful treatment is adequate drug distribution in target organs and tissues during the first pass. Inadequate distribution may result in therapeutic failure, cause complications, and require repeat procedures. Drug distribution is usually evaluated after catheter implantation by means of dynamic computed tomography (CT), digital subtraction angiography (DSA), or nuclear scan by administering contrast media or radioisotopes via the implanted catheter. However, much higher injection rates of contrast media than those used for clinical drug infusions are necessary for evaluation by CT or DSA, which may lead to overestimation of the distribution in the target organs. Nuclear scan provides more accurate information but has the disadvantage of low spatial resolution and high cost. Thus far, catheters have been designed mainly empirically, especially for long-time slow infusion therapy via implanted catheters. To reduce dependency on expertise, a simple evaluation method for drug distribution near the catheter tip has been required. During the past several decades, many investigators have reported vessel phantom studies using dyes (1-4). However, these studies used complicated techniques and equipments and did not make direct evaluation of the lumens of the simulant vessel near the catheter tip, so that observation from outside the simulant vessel could have produced some errors. By making use of advantages of MRI such as high sensitivity to contrast agents and high spatial resolution, we were able to create an original catheter-vessel model for MRI to evaluate drug distribution near the catheter tip by direct visualization of the lumen and optimization of catheter design for intra-arterial drug infusion therapy.

PURPOSE: The purpose of this study was to investigate the efficacy of the model.

MATERIALS AND METHODS: The model consisted of a hepatic artery simulant tube through which water flowed continuously (30 cm/sec) and a 10 cm-deep water cistern (Fig. 1). Catheters were inserted into the tube and a gadolinium contrast medium was injected at a rate suitable for angiographic or computed tomographic evaluation (60 ml/min) and commensurate with the clinical drug infusion rate (5 ml/min). Axial images of the tube were obtained with a 0.2-T scanner and 2-dimensional gradient echo technique (FOV: 200 mm; TR/ TE: 35/10 msec; 5 slices; slice thickness/gap: 10/10 mm; acquisition time: 16 sec). Pre-saturation pulses were used to suppress in-flow related enhancement, and a coil for the knee was used for signal reception. Preliminary studies were conducted to optimize flip angle and gadolinium concentrations and to validate the model. Three types of 5-Fr catheters and a 2.7-Fr catheter were tested. The points where drug and blood were completely mixed (mixing points) were defined as the site with uniform enhancement nearest the catheter tip. Enhancement was visually evaluated on a 3-point scale.

RESULTS: Flip angle and gadolinium concentrations were optimized at 90 degrees, and at 62.5 and 500 mM for the high and low infusion rates, respectively. For validation of the model, the flow velocity inside the tube was found not to affect the signal intensity of the lumen. The uniformly diluted contrast medium produced a uniform signal intensity. At the low gadolinium concentrations (0.05 and 0.1 mM), the tube lumen showed no enhancement, indicating that in-flow related enhancement was canceled by the pre-saturation pulses. Drug distribution near the catheter tips was clearly visualized and mixing points could be determined (Fig. 2 and 3). The drug was mixed in shorter distances via the slit side- than the end- or side-hole catheters, and the smaller diametrical than the larger at either rate (Table 1 and 2).

CONCLUSION: This model appeared to be effective for evaluation of drug distribution and optimization of catheter design.

Figure 1. Schema of the catheter-vessel model.

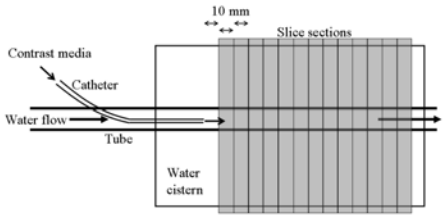
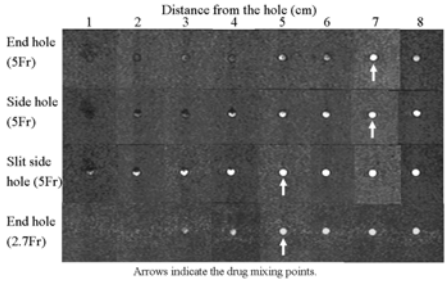
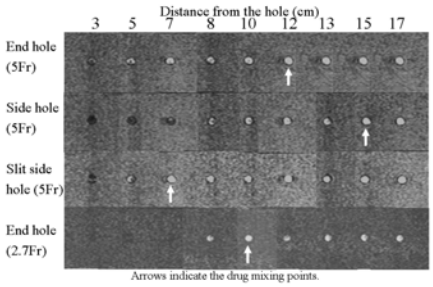


Figure 2. Drug distribution at the high infusion rate (60 ml/min).



Arrows indicate the drug mixing points.

Figure 3. Drug distribution at the low infusion rate (5 ml/min).



Arrows indicate the drug mixing points.

Table 1. Visual Evaluation of Drug Mixing (High Infusion Rate)

Distance from hole (cm)	1	2	3	4	5	6	7	8
Catheter								
End-hole 5 Fr	1.0	1.0	1.0	1.0	2.0	1.7	3.0	2.7
Side-hole 5 Fr	1.0	1.0	1.0	1.0	2.3	2.7	3.0	3.0
Slit side hole 5 Fr	1.0	1.0	2.0	2.3	3.0	3.0	3.0	3.0
End-hole 2.7 Fr	1.0	1.0	1.3	1.7	3.0	3.0	3.0	3.0

Table 2. Visual Evaluation of Drug Mixing (Low Infusion Rate)

Distance from hole (cm)	3	5	7	8	10	12	13	15	17
Catheter									
End-hole 5 Fr	1.3	1.7	2.0	2.3	2.3	3.0	3.0	3.0	3.0
Side-hole 5 Fr	1.0	1.0	1.0	1.3	2.0	2.3	2.0	3.0	3.0
Slit side hole 5 Fr	1.0	1.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0
End-hole 2.7 Fr	1.0	1.0	1.0	2.7	3.0	2.7	3.0	2.7	3.0

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