

Interventional MRI-Guided Local Delivery of Agents into Swine Bile Duct Walls Using MR Compatible Needle-Integrated Balloon Catheter System

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Purpose: Systemic chemotherapy has limited therapeutic effect on pancreatobiliary cancers due to the insufficient drugs delivered to the tumors. This study was to investigate the possibility of interventional magnetic resonance imaging (MRI)-guided local agent delivery into pig common bile duct (CBD) walls by using a newly-designed MR compatible needle-integrated balloon catheter system.

Materials and Methods: Animal studies with eight pigs were approved by the Institutional Animal Care and Use Committee. Under X-ray imaging guidance, a custom MR compatible needle-integrated balloon catheter system was placed in the CBD via a transcholecystic access (**Fig. 1**). T1-weighted MR imaging (T1WI) was used to localize and reposition the needle/balloon system in the target bile duct. 0.5-mL mixture of motexafin gadolinium (MGd, Pharmacyclics, Inc.) and trypan blue dye was delivered into the CBD wall of each pig through the needle/balloon system. Post-infusion T1WI was obtained and contrast-to-noise ratios (CNR) of CBD walls between pre- and post-MGd/blue infusions were statistically compared by a paired t-test. In addition, post-infusion cholangiography was achieved to evaluate the potential injuries of CBDs by the needle/balloon system. Subsequent histologic analysis was correlated to confirm the penetration and distribution of MGd/blue and any mechanical damages of CBD walls.

Results: Post-infusion cholangiogram didn't show any extravasation of contrast agent. MR imaging demonstrated the clear enhancement of the target bile duct walls by the MGd/trypan blue. The average CNR of the post-infusion bile ducts was significant higher than that of the pre-infusion bile ducts (110.6 ± 22 vs 5.7 ± 2.8 , $p < 0.0001$) (**Fig.2**). Histology depicted the blue dye stains and red fluorescence of MGd through the target CBD walls, which was well correlated with the imaging findings (**Fig. 3**).

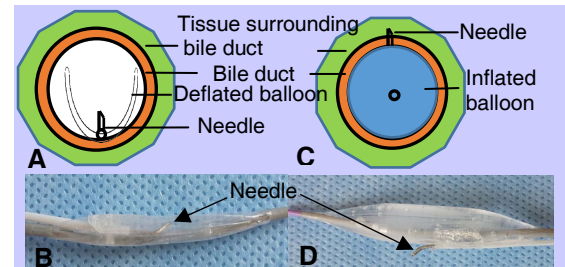


Fig.1. The intrabiliary agent delivery system is comprised of an MR-compatible needle and a balloon catheter. (**A&B**) The needle is attached onto the surface of the balloon. The deflated balloon can provide a protective covering for the needle. (**C&D**) When the balloon is positioned in the target bile duct, the inflated balloon can push the needle to puncture the bile duct wall and surrounding tissue for drug delivery.

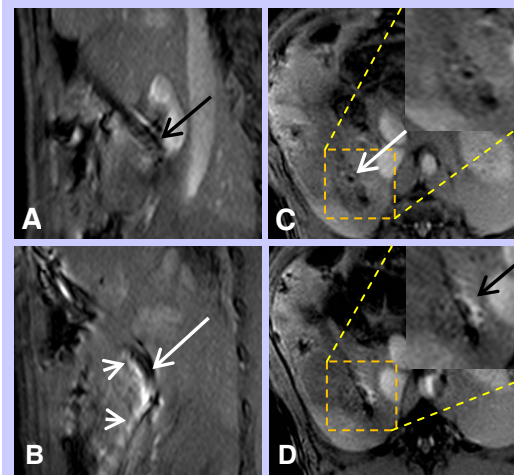


Fig. 2. MRI-guided local delivery of MGd/blue dye mixture into the pig CBD wall via the MR-compatible needle-integrated balloon. (**A**) Sagittal T1WI clearly displayed the needle in the CBD (arrow). (**B**) MRI-guided needle puncture into the CBD wall (arrow) and delivery of MGd into the tissue, which is shown as bright signal penetrating the tissue (arrowheads). (**C&D**). Cross-sectional view of the CBD wall before (arrow on **C**) and after local injection of MGd shows the infiltration of MGd in the CBD wall and adjacent tissue (arrow on **D**).

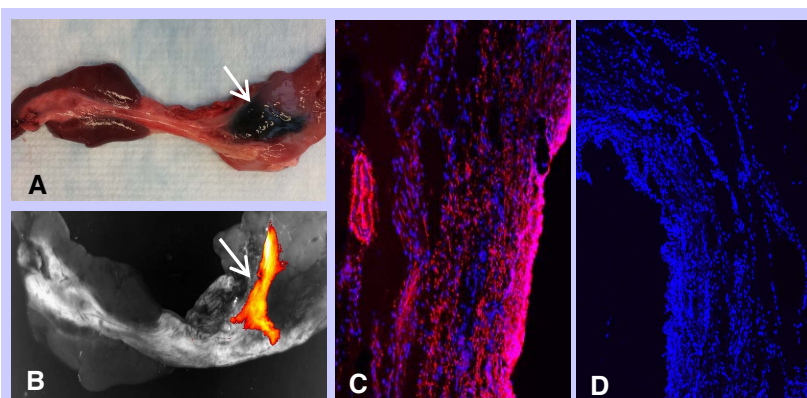


Fig. 3. (**A**) Representative gross specimen of the CBD delivered with MGd and trypan blue mixture, showing the blue dye staining of the CBD and surrounding tissue (arrow). (**B**) Fluorescent optical imaging shows MGd-emitting fluorescence in the CBD wall (arrow). (**C&D**) Confocal microscopy confirms the infiltration of MGd-emitting red fluorescence through the bile duct wall and adjacent tissue (**C**), which is not seen in the bile duct without MGd injection (**D**).

Conclusions: It is feasible to use the new MR compatible needle-integrated balloon catheter system for local agent delivery into pig CBD walls under MR imaging guidance, which may open new avenues for efficient management of pancreatobiliary malignancies using MR-guided interventional oncology.

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