Novel Approach to Real-time MR-Guided TIPS using an Actively Visualized Excimer Laser Catheter and Delivery System

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INTRODUCTION:
Transjugular intrahepatic portosystemic shunt (TIPS) creates a direct connection between the hepatic and portal veins to reduce portal hypertension and associated conditions like varices. Early use of TIPS was shown to be more effective and improve mortality than rescue procedures in patients with cirrhosis and variceal bleeding (1). MRI guidance for TIPS can provide clear visualization of hepatic and portal vein structures without exogenous contrast which may help reduce procedure length, x-ray exposure and risk of significant complications. This procedure has been demonstrated in patients using hybrid MR/X-ray systems (2). Typically performed with needle catheters or stylets, passes may be difficult in patients with fibrotic and cirrhotic livers. Utilizing a vessel crossing system with an energy source could provide a more controlled and effective passage while minimizing regional damage. We have developed and tested the feasibility of a method to perform the TIPS procedure under real-time MRI guidance using an actively visualized excimer laser and delivery system.

METHODS:
An MRI-compatible excimer laser catheter was modified to include a single loop channel at the distal tip enabling active visualization under real-time MRI (Spectranetics, Colorado Springs, CO). The outer diameter of the excimer laser was 0.045" (4 French compatible). The delivery system was manufactured from two insulated, concentric nitinol hypotubes, each with a unique curvature instilled under mechanical stress during annealing, forming the inner and outer conductors of a loopless antenna. The inner hypotube could be advanced and withdrawn as well as rotated within the outer hypotube as necessary to modify the curvature of the inner hypotube and entire system. The inner lumen of the delivery system was 0.057" and the outer diameter of the entire system was 0.120" (<10 Fr). The excimer laser and delivery system were each connected to scanner receive channels via tuning, matching and decoupling circuitry and a multi-channel preamplifier box.

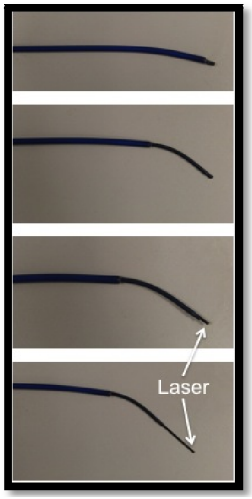

Figure 1: Excimer laser and delivery system in various stages of deployment.

Phantom studies were performed to assess tip visualization of the active laser. The excimer laser and delivery system were also tested in excised liver tissue with intact vasculature and *in vivo* in swine to determine feasibility of laser-mediated TIPS creation under real-time MRI guidance.

Animal protocols were approved by the Institutional Animal Care and Use Committee. All imaging was performed on a short, wide bore Siemens Espree 1.5T MRI scanner (Siemens Medical Solutions, Erlangen, Germany) with a real-time balanced steady-state free precession (SSFP) sequence (TR/TE 3.23/1.67ms, ST 6mm, Flip Angle 45°, FOV 340x340mm, Matrix 192x144) and a separate real-time reconstruction and display system . MR angiograms of the hepatic vasculature were also used as roadmaps.

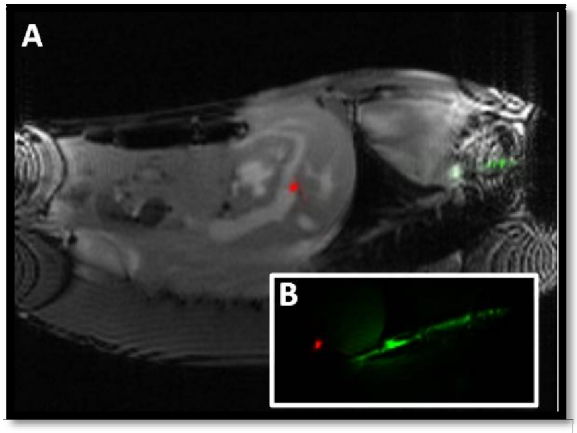

Figure 2: A) Laser tip (red) entering portal vein. B) Projection image of delivery system (green) and laser tip (red).

RESULTS:
The excimer laser and delivery system are shown in various stages of deployment in Figure 1. The signal at the distal tip of the excimer laser provides easy visualization of the laser tip position within the liver vasculature and liver parenchyma (Figure 2A). The delivery system enables visualization of the shaft and the curvature in order to direct the laser tip to the appropriate position and plan the trajectory from the hepatic vein to the portal vein.

During the *in vivo* feasibility study in swine, the excimer laser was able to successfully burn through the hepatic vein wall, the liver parenchyma and into the portal vein, using the delivery system to direct and provide back-up support to the laser. Figure 2A and 2B show the excimer laser entering the portal vein and a projection image of the laser and delivery system.

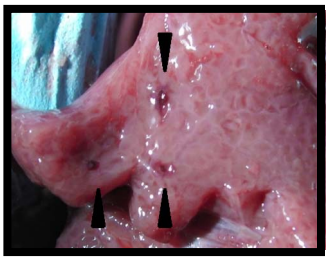

Figure 3: Photo of sample laser passes (indicated by arrowhead) in explanted liver.

DISCUSSION:
The excimer laser and delivery system facilitated targeted passage from the hepatic to portal veins with minimal resistance in naïve swine liver. Figure 3 shows a sample laser pass in the explanted liver. Additional testing in fibrotic livers is necessary. This system provides a visible, controllable and adaptable approach to vessel and tissue passage that could be used for other novel MRI-guided interventions.

REFERENCES:
(1) García-Pagán NEJM 2010 (2) Kee JVIR 2005