

TIPS using Truly Hybrid X-ray/MR Guidance

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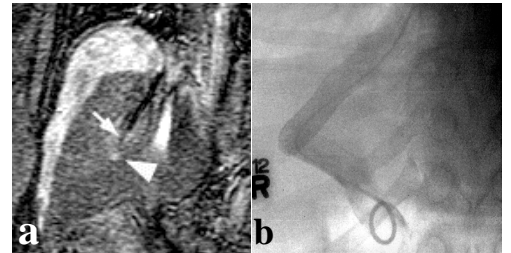
Introduction

Transjugular intrahepatic portosystemic shunt placement (TIPS) establishes a connection between the hepatic vein (HV) and a portal vein (PV), with placement and dilation of a stent. Obtaining PV access is usually the most challenging step in the procedure as the PV cannot be punctured directly, and the vessel is difficult to visualize using alternative techniques such as ultrasound and carbon dioxide portal venogram. A second challenge is accurate placement of the stent so as to completely cover the dilated track, while leaving sufficient HV for transplation. We have integrated an x-ray fluoroscopy system into the bore of an interventional MRI unit (0.5 T GE Signa SP), creating a truly hybrid imaging modality [1,2]. MR imaging provides good visualization of the PV, allowing trocar needle, HV and PV to be seen in a single oblique slice [3]. Real-time X-ray guidance is used to access the HV, and has the spatial and temporal resolution for accurate placement of the stent. Although other hybrid imaging systems have been implemented, they require movement of the patient between two gantries separated by several feet, and fast switching between modalities is not possible. We are completing a study of 20 TIPS patients to determine potential advantages of the hybrid system during TIPS. Hardware considerations and results from 14 patients are presented here.

Methods

The system has a fixed anode x-ray tube attached to a support bracket separating the two donuts (anode-cathode axis of the x-ray tube aligned with B_0) and a flat panel detector under the x-ray compatible cradle. During MR imaging, the x-ray detector is turned off to reduce RF noise, and the detector is lowered ~4' to minimize B_0 inhomogeneity. Switching between modalities takes <1 minute. MR and x-ray hardware have changed over the 30 months of the study. For the first three patients, a gradient-echo real-time imaging sequence was used. Because of difficulties visualizing in-plane flow, we changed to an SSFP sequence. Initially, a single channel flexible transmit-receive coil was placed around the liver; at month 12 (after 7 patients) a vertical transmit only body coil was installed (GE, Milwaukee, WI) and used with the flexible body coil in receive-only mode, providing significant improvement in SNR over the volume of interest (see Fig. 1a). For all but the last patient, the x-ray fluoroscopy system used a 300 Watt tube/generator that allowed only continuous fluoroscopy (Brand X-ray, Addison IL/GE Lunar, Madison WI); this system has been upgraded to a 1 kW system that can operate in either continuous or pulsed modes (see Fig. 1b). The x-ray detector is an Apollo flat panel (GE Medical Systems, Milwaukee, WI) with an area of ~20x20cm² and 1024x1024 pixels.

Figure 1 a) An MR oblique plane through the liver (SSFP with vertical body coil) shows trocar in hepatic vein (arrow) and needle heading towards portal vein (arrowhead) b) x-ray image shows portal venogram after expansion of the stent.



All patients gave informed consent and the procedure was approved by our Institutional Review Board. The TIPS placements proceeded using side-dock entry, patient supine for access to the jugular vein. Under x-ray guidance, a 0.035-inch nitinol guide wire and a 5-F Cobra catheter were maneuvered into the right HV. A hand injection of iodinated contrast verified catheter location. Under MR guidance using GE's iDrive software, a specially constructed nitinol TIPS needle set (Cook, Bloomington, IN) was advanced over the guidewire into the right HV. Gradient echo and SSFP (FIESTA) MR images were obtained interactively until both the 16-gauge outer trocar and the PV could be seen in a single image. The inner-sheathed 19-gauge needle was then advanced into the PV. A nitinol Flex stent (Bard, Covington, Ga) or a covered stent-graft (Gore Inc. Flagstaff AZ) was placed with x-ray guidance through the parenchymal tract to bridge the hepatic and portal veins and then expanded using a balloon. The pressure gradient between the PV and the right atrium was measured before and after insertion and inflation of the stent. During each procedure the following information was recorded: total procedure time, total minutes of x-ray exposure, total number of puncture attempts, perceived difficulty of portal vein access (1-5 with 1 = easy and 5 = difficult), average change in pressure gradient and number of switches between imaging modalities.

Results

MR image quality was not sufficient to guide the puncture during the first two cases where flow in the portal vein was too slow to produce enhancement. Use of an SSFP sequence in all subsequent studies alleviated this problem, and the following statistics refer to the remaining 12 studies. The average procedure length was 2.5±0.9 hours, with only 24.4 minutes of fluoroscopy time during catheter placement and stent expansion. On average, 2.5 punctures were required to access the PV, with the difficulty of PV access ranked at 1.7. The average change in pressure gradient was 12 mmHg, with an average post-TIPS gradient of 6±2.3. All post-TIPS gradients were less than 8 mmHg. The number of switches between modalities was between 5 and 6, with a maximum of 8 switches during two particularly challenging cases. One serious complication occurred, an extra-capsular puncture that was dilated and led to intra-peritoneal bleeding. A covered stent was placed under hybrid system guidance, and the patient was moved to the catheter lab (x-ray image quality was reduced by bleeding into a large patient) for successful completion of TIPS. In one case, following puncture under MR guidance, the PV was found to be 90% thrombosed with hepatofugal flow; this case could not have been successfully completed without MR guidance.

Discussion

The TIPS procedure is not without risks; procedural complications have been reported to occur in more than 10% of patients [4] although in experienced hands this number is likely closer to 3-5% [5]. The most critical and difficult part of the TIPS is gaining access to the PV, which can require multiple punctures [4] and can take a number of hours in patients with 'uncooperative' anatomy [5]. Our study has shown that under hybrid guidance, the number of punctures is reduced, and procedure time is only 2.5 hours, even in the presence of ongoing optimization of MR imaging sequences, which added considerably to the MR guidance portion of the procedure. X-ray image quality was not adequate for the largest TIPS patient following intraperitoneal bleeding (> 200 lbs.) because the image noise (from quantum noise as well as electronic noise at low signal levels) dominated the signal from small guidewires. The x-ray generator upgrade described above should remove this limitation. Of enormous benefit during all of the procedures was the ability to quickly switch between imaging modalities. Precise image registration was maintained during switching and there was no risk to sensitive catheter placement.

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