

Intraoperative ultrasonography of the biliary tract using saline as a contrast agent: a fast and accurate technique to identify complex biliary anatomy

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Background: Intraoperative assessment of biliary tract anatomy is relevant for a number of benign and malignant hepatobiliary diseases. During biliary reconstruction, drainage of all relevant bile ducts is imperative to prevent atrophy of undrained segment, cholangitis and secondary biliary cirrhosis. Intraoperative cholangiography, though widely used for intraoperative imaging of the biliary tract, involves heavy equipment use, radiation risk and has a limited role in the evaluation of isolated segmental bile ducts.

Methods: We evaluated the use of a novel technique of intraoperative ultrasonography of the biliary tract using normal saline as a contrast agent. It involves injecting saline in any part of the biliary system while performing real-time intraoperative 2-dimensional ultrasonography.

Results: This procedure was carried out in intraoperative situations to delineate complex biliary anatomy involving segmental bile ducts. Excellent image quality was obtained in the form of opacification and demarcation of the liver segment to which the duct belongs. The flow of saline microbubbles was clearly visible on real-time ultrasound images, leading to accurate identification of the duct.

Conclusion: Intraoperative ultrasonography with saline as a contrast agent can accurately identify small isolated segmental bile ducts and help in surgery of the biliary tract. It is a simple and inexpensive technique that can be performed with minimum resources.

Contexte : L'examen anatomique peropératoire des voies biliaires est justifié pour un certain nombre de maladies hépatobiliaires bénignes et malignes. Durant la reconstruction biliaire, la vidange de toutes les voies biliaires concernées est nécessaire pour prévenir l'atrophie des segments non drainés, la cholangite et la cirrhose biliaire secondaire. Même si elle est couramment utilisée pour l'imagerie des voies biliaires, la cholangiographie peropératoire fait appel à des équipements complexes, comporte un risque d'irradiation et joue un rôle limité dans l'évaluation de segments isolés des canaux biliaires.

Méthodes : Nous avons évalué l'utilisation d'une nouvelle technique d'échographie peropératoire des voies biliaires à l'aide de solution physiologique comme agent de contraste. La technique repose sur l'injection de solution physiologique dans n'importe quelle portion de l'appareil biliaire sous échographie bidimensionnelle peropératoire en temps réel.

Résultats : La technique a été appliquée dans un contexte peropératoire afin de cerner l'anatomie biliaire complexe de certains segments des canaux biliaires. Des images d'excellente qualité ont été obtenues sous forme d'opacification et de délimitation du segment hépatique auquel le canal appartient. La circulation des microbulles de sérum physiologique était clairement visible sur les images échographiques en temps réel et a permis de visualiser les structures avec précision.

Conclusion : L'échographie peropératoire avec sérum physiologique comme agent de contraste permet de visualiser avec précision de petits segments isolés des canaux biliaires et facilite la chirurgie des voies biliaires. C'est une technique simple et peu coûteuse qui peut être effectuée avec un minimum de ressources.

Encountering aberrant biliary anatomy during dissection of the hepatic hilum is common and well described in the literature.¹ These variations are relevant for a number of operative procedures, such as repair of bile duct injuries, liver transplantation, choledochal cysts and other hepatopancreatobiliary lesions, both benign and malignant. In today's era of laparoscopic cholecystectomy, the incidence of bile duct injury still remains around 0.6%.² Many of these injuries are complex, involving hepatic hilum and vasculature.³ Variations in the anatomy of the ducts and fibrosis due to previous surgeries add to the difficulty of repairing such injuries. Proper identification and drainage of all the relevant ducts is imperative to prevent atrophy of undrained segment, cholangitis and secondary biliary cirrhosis.⁴

Various techniques of evaluating the biliary anatomy are well established. Magnetic resonance cholangiopancreatography (MRCP), endoscopic retrograde cholangiopancreatography (ERCP), fistulography and percutaneous transhepatic cholangiography (PTC) are routine radiological tools for preoperative assessment. Intraoperatively, cholangiography is the most commonly used modality to assess the biliary anatomy.⁵ We believe that intraoperative cholangiography (IOC) has some important limitations:

- Owing to the 2-dimensional (2D) nature of images and overlapping of different segments in the final image, it may not be possible to allocate a segment exactly to an isolated small duct being evaluated.
- Cannulation of a small segmental duct (often without any stump) is difficult. This may lead to leakage of dye and poor image quality.
- Operating rooms may not all be equipped with an IOC set-up.
- This modality comes with a definite risk of radiation to the patient and medical team.
- The modality prolongs the overall duration of surgery, as heavy equipment needs to be moved and placed, and at times multiple images are required.

Contrast-enhanced ultrasonography by injecting a special contrast agent in the biliary tree has been described in the literature.⁶⁻¹⁰ Such a technique also has limitations, including the need for expensive contrast agents, special ultrasonography probes and 3-dimensional (3D) reconstruction software.

In this article, we describe a very simple and novel technique of intraoperative ultrasonography of the biliary tree using normal saline as a contrast agent. Our aim was to discuss the technical feasibility, image characteristics and ease of use of this technique in the accurate identification of complex biliary ductal anatomy.

METHODS

We evaluated the feasibility of intraoperative ultrasonography of the biliary tract using saline as a contrast agent.

For the purpose of this study, we named this procedure "saline sono-cholangiography" (SSC). The procedure involves injecting normal saline in the biliary tree while performing intraoperative, real-time 2D ultrasonography.

Procedure

The SSC procedure involves cannulation of the biliary tract to be able to inject saline. Any part of the biliary system can be cannulated, including the cystic duct, common bile duct, right or left ducts or segmental ducts, depending on the intraoperative scenario. In our study, the bile duct under evaluation was usually cannulated with a Foley catheter. Once the balloon of the Foley catheter was inside the duct, it was inflated with 0.2–1.0 mL of saline, based on the diameter of the duct, to stop or reduce backflow. If the duct was too small even for an 8-Fr Foley catheter, a 5- or 6-Fr infant feeding tube was used instead. The feeding tube was trimmed, if required, to keep all side holes inside the duct, and it was kept in position by gently holding it with tissue forceps. In a dilated duct, a larger Foley catheter was used.

The intraoperative ultrasonography probe was brought into field at this time. We used the ALOKA SSD-4000 (Hitachi-Aloka Medical Ltd.) ultrasonography machine with an intraoperative micro-convex probe (ALOKA UST-995-7.5) at a frequency of 5 MHz. Ultrasonography was performed by the operating surgeon (V.G. or A.C.) in the presence of a board-certified radiologist (M.K.) to ensure the expert opinion of a trained radiologist in the evaluation of this new technique. The probe was then held at the possible segment/s to which the duct belonged. We filled a 10 mL syringe with 9 mL of normal saline at room temperature and 1 mL of air. This was injected into the catheter using a connector in a slow pulsatile fashion, and ultrasound images were assessed and captured (Fig. 1). Injection of saline in a pulsatile fashion enabled it to be churned with air, creating saline bubbles that in turn caused echogenicity visible on the ultrasound.

We assessed the following parameters:

- the ease of identifying flow of saline in the biliary tree on real-time ultrasound as well as the image quality obtained;
- the ease of identifying the effect of saline contrast in the form of echogenicity of the small biliary radicals or liver parenchyma, leading to identification of the segment and its picture quality in real time; and
- the time of retention of saline as a contrast in the biliary tree before the picture quality deteriorates.

The procedure was performed in a total of 11 operative scenarios, and the above-mentioned parameters were evaluated. The cases included postcholecystectomy biliary stricture ($n = 4$), postcholecystectomy external biliary fistula ($n = 3$), choledochal cyst ($n = 3$) and cholangiocarcinoma ($n = 1$).

For the purpose of elaborating the feasibility and clinical utility of SSC, we discuss in detail its use in 2 operative situations. The first is a case of postlaparoscopic cholecystectomy bile duct injury with external biliary fistula taken up for surgical repair. Preoperative MRCP suggested a type E-V biliary injury as per Strasberg classification.¹¹ Intraoperatively, an aberrant duct was found in fibrosed tissue about 2 cm away from the biliary confluence (Fig. 1), and its segmental anatomy was delineated using SSC. The second is a case of type 1 choledochal cyst with 5 different bile duct orifices visible at the confluence after cyst excision.

Postoperative recovery and outcomes of all patients were documented. As this study evaluates the feasibility of an imaging technique, statistical methods were not used. We obtained consent to use this technique during surgery from all patients. All cases involved the same operating surgeons (A.C. or V.G.) and the same radiologist (M.K.).

RESULTS

Scenario 1

The patient in this scenario had a postlaparoscopic cholecystectomy bilioma. It was drained percutaneously, and the patient was referred to our institute with an external biliary fistula. Imaging with MRCP suggested complete transection of the common bile duct with a separate aberrant right posterior duct. She was taken for surgery after 6 weeks. Intraoperatively we identified confluence

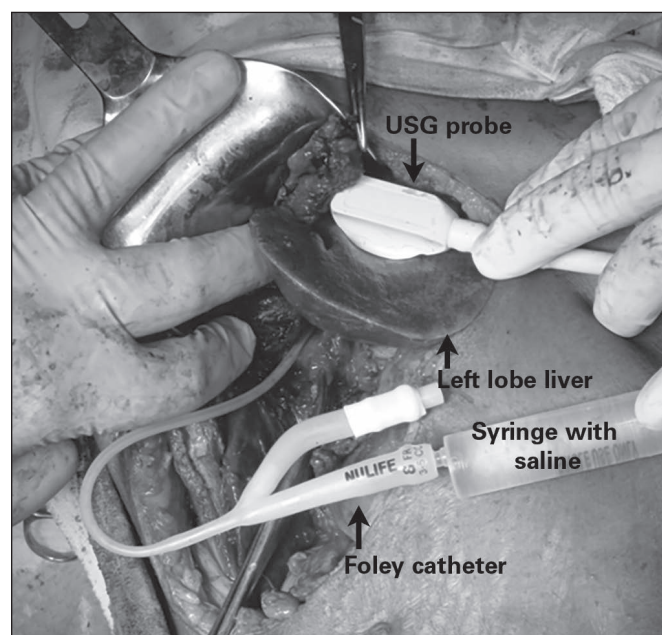


Fig. 1. “Saline sono-cholangiography” being performed with a no. 8 Foley catheter inside the left duct with the ultrasonography probe over the left lobe of the liver. Saline bubbles are being pushed through a 10 mL syringe.

of 2 ducts at the end of the fistulous track, with complete transection of the common bile duct. To confirm the biliary anatomy, a catheter was inserted in the right-sided duct at the confluence, and SSC was performed. While pushing saline in the catheter, we obtained a very clear ultrasound of saline bubbles causing echogenicity of the right anterior segment of the liver (Fig. 2A). The left duct at the hilum was also cannulated to obtain an SSC (Fig. 2D), which sharply demarcated the left lobe of the liver.

The SSC images confirmed the findings of earlier MRCP and led us to search for the missing right posterior duct. On further dissection of the fibrotic tissue, bile was seen coming out of a small opening (Fig. 2B). This opening was then cannulated with an infant feeding tube, and SSC was performed, which confirmed it to be the right posterior duct (Fig. 2C). We confirmed a type E-V biliary injury as per Strasberg classification.¹¹ We performed a roux-en-Y double hepaticojejunostomy with transanastomotic stenting of the right posterior sectoral duct. A stentogram obtained on postoperative day 10 showed no leak; the stent was then clamped and the patient was discharged. The stent was removed after 4 weeks, and the patient was doing well on follow-up, with normal liver function tests.

Scenario 2

The patient in this scenario presented with recurrent pain in the abdomen and a large cystic common bile duct visible on an abdominal ultrasound. Imaging with MRCP suggested a type 1 choledochal cyst. The patient was taken for surgery. Intraoperatively, after excision of the cyst, the biliary confluence revealed 5 different openings (Fig. 3). We evaluated the use of SSC to delineate these individual ducts. Figure 4A–C shows SSC of the segment 3 duct. Figure 4D shows SSC of the segment 4 duct.

Image characteristics

The amount of parenchymal echogenicity visible on ultrasound after saline injection varied from starkly intense to more subtle white streaks. However, in all 11 patients, the segmental differentiation could easily be identified. Ultrasonography in real time clearly showed the saline entering the biliary duct and diffusing rapidly into the parenchyma (Fig. 5). The resulting echogenicity lasted for 1–2 minutes before slowly fading away. In some instances, echogenicity faded quickly (within a minute, $n = 3$), whereas in others it persisted for more than 10 minutes ($n = 2$). Additionally, while saline was being pushed, the bile duct dilated and became distinctly visible on the real-time ultrasound. The catheter lying inside the duct also rendered itself visible on ultrasound, thus revealing the anatomy of duct (Fig. 5B). The ability

of this technique to clearly demarcate the segment to which a duct belongs will be useful in a large number of biliary surgeries, especially when an aberrant ducts needs evaluation.

DISCUSSION

A normal extrahepatic biliary confluence of the right and left hepatic ducts is present in 72% of the population, and the rest have one or the other variation.¹ Precise knowledge of the biliary anatomy is important in various benign and malignant diseases. Biliary injuries during laparoscopic cholecystectomy often lead to atrophy and hypertrophy complex with rotation of the liver hilum, which along with fibrosis of previous surgeries makes the identification of the ducts difficult at the time of reoperation. It is necessary to drain all the seg-

ments of the liver for a good postoperative outcome. The same is true in patients undergoing liver transplantation and all major hepatobiliary surgeries requiring biliary reconstruction.

Preoperative evaluation of the bile ducts generally includes MRCP, ERCP, PTC or fistulography. The gold standard of these modalities is MRCP;¹² however, the sensitivity and specificity of MRCP is low in cases of biliary strictures (67%).^{13,14} These techniques have a limited role when an intraoperative confirmation of biliary ductal anatomy is required.

Intraoperative cholangiography using iodinated contrast and intraoperative radiography are standard investigations to define the biliary tree during surgery.^{5-10,15} The contrast leak in the surgical field may result in poor image quality, especially when small ducts are being evaluated. Also, owing to the 2D nature of the image, accurate

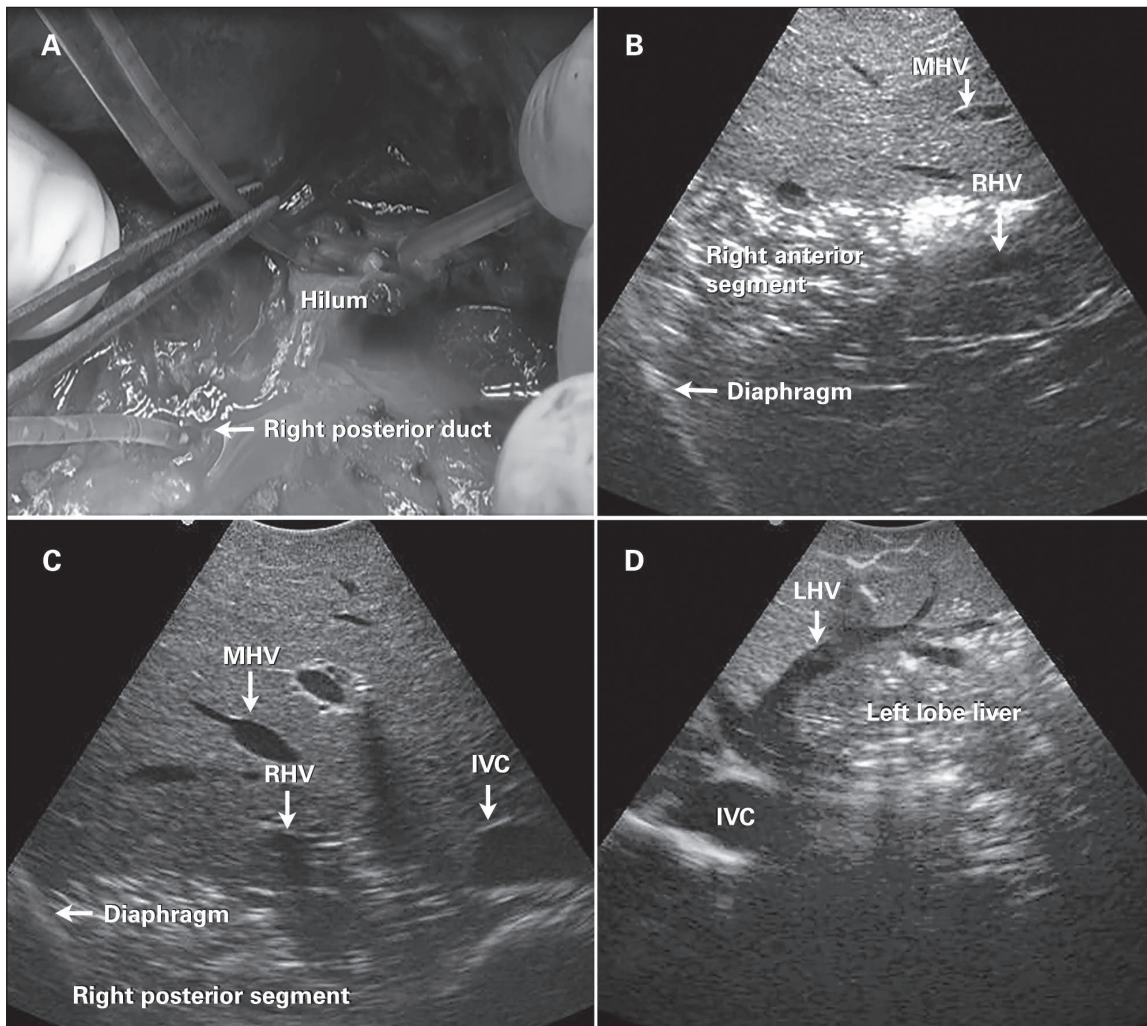


Fig. 2. (A) Intraoperative photograph of complex biliary stricture. The hilum is formed by the junction of the right anterior and left main duct. The aberrant right posterior duct is visible 2 cm away from the hilum. (B). “Saline sono-cholangiography” (SSC) of the right anterior bile duct. The right anterior segment (segment 5+8) is rendered echogenic by saline bubbles. The diaphragm and the right (RHV), middle (MHV) and left (LHV) hepatic veins are marked. (C). The right posterior duct clearly demarcates the right posterior segment on SSC. (D). Bright, echogenic left lobe of the liver clearly demarcated on SSC.

identification of 2 overlapping liver segments is very difficult. Many operating theatres (like ours) may not be adequately set up for performing an IOC.

The use of ultrasonography along with various biliary contrast agents either through a percutaneous biliary catheter or T-tube catheter has been described in preoperative and postoperative settings.⁷⁻⁹ The main use of these techniques is to define the level and extent of biliary obstruction (total or partial). Plain ultrasonography without using any biliary contrast does not accurately identify intrahepatic (especially undilated) ducts. Urade and colleagues⁶ have described using intrabiliary injection of perfluorobutane microbubbles through a cystic duct catheter combined with ultrasonography to define the biliary anatomy intraoperatively. With 3D reconstruction software, the correct identification of biliary anatomy was possible in 90% of cases in their study. However, the images obtained

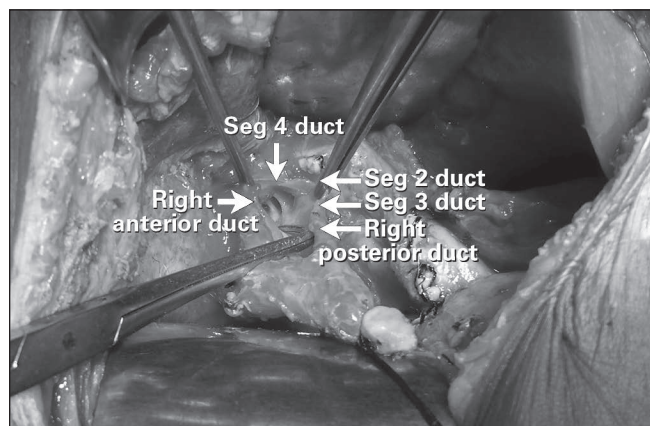


Fig. 3. Type 1 choledochal cyst. Five bile duct openings at the hilum, right anterior, right posterior (tip of mixer) and segment 2, 3 and 4 ducts are marked. These ducts were identified using “saline sono-cholangiography.”

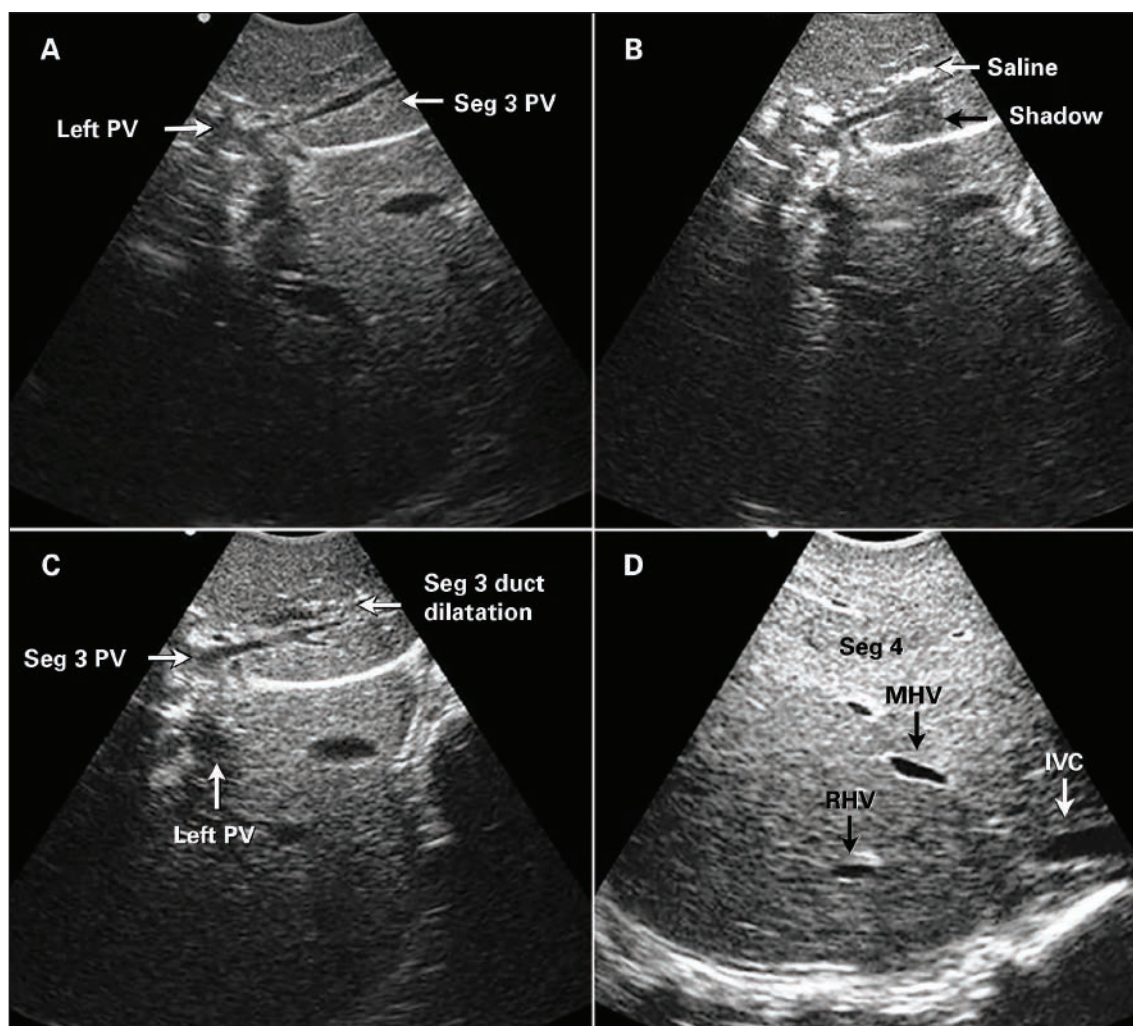


Fig. 4. (A) “Saline sono-cholangiography” (SSC) of the left lobe, showing the junction of the left portal vein (PV) and segment 3 PV before instillation of biliary contrast. (B) Instillation of biliary contrast in the segment 3 duct. Bright saline bubbles travelling in the segment 3 biliary duct next to segment 3 PV can be clearly seen (white arrow). Pooled saline contrast is also casting a sonic shadow (black arrow). (C) Saline travelling in the segment 3 biliary duct next to the segment 3 PV has led to a dilated segment 3 duct (arrow). This dilatation and flow of saline is very clearly seen in real time. (D) Segment 4 duct demarcating segment 4 of liver on SSC.

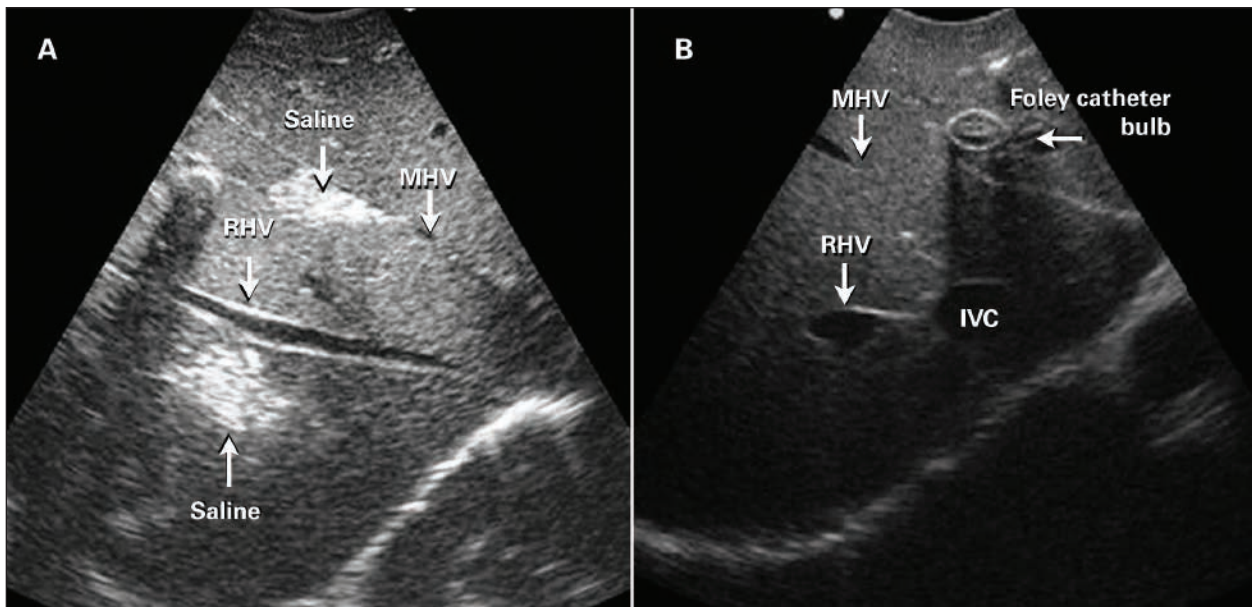


Fig. 5. (A) “Saline sono-cholangiography” (SSC) of the right main biliary duct. The saline is slowly starting to diffuse into the right liver parenchyma (arrow). **(B).** The Foley bulb is visible on ultrasound. Its position suggests that it is inside the segment 2 duct. The inferior vena cava (IVC) and the right (RHV), middle (MHV) and left (LHV) hepatic veins are marked.

using this technique were similar to an MRCP image and did not show the kind of parenchymal echogenicity visible with SSC. Their technique also depended on the use of an expensive contrast agent, a 4-dimensional probe and 3D reconstruction software, which are not universally available. In a similar technique, Xu and colleagues¹⁰ used phospholipid stabilized microbubbles of sulfur hexafluoride as an ultrasonography contrast agent though the cystic duct during living donor hepatectomy.¹⁰ The limitations of their technique were similar to the ones described for the technique of Urade and colleagues.⁶

In our region, we routinely see a large number of referred patients with postcholecystectomy bile duct injuries.^{16,17} We remain more concerned about an undrained major segmental duct (e.g., right anterior or posterior duct), which is likely to be missed in cases of a high biliary stricture. The SSC procedure is helpful for identifying the draining ducts or an undrained segment in cases of difficult anatomy or fibrosis from previous surgery.

CONCLUSION

Intraoperative ultrasonography of the biliary tract using normal saline as a contrast agent provides excellent images for correctly identifying the segmental anatomy of bile ducts, especially in patients with complex biliary injuries and variant anatomy. This technique is fast, accurate and easy to perform with equipment present in a usual hepatobiliary operating theatre.

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Competing interests: None declared.

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