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TECHNICAL INNOVATION

The effective use of acai juice, blueberry juice and pineapple juice as negative contrast agents for magnetic resonance cholangiopancreatography in children

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Abstract Magnetic resonance cholangiopancreatography (MRCP) is commonly performed in the evaluation of known or suspected pancreaticobiliary disease in children. The administration of a negative oral contrast agent can improve the quality of the examination without significant additional cost. We describe our experience with certain brands of acai juice, blueberry juice and pineapple juice as negative oral contrast agents in children. We believe these fruit juices are safe, palatable and may improve MRCP image quality.

Keywords Magnetic resonance imaging · Magnetic resonance cholangiopancreatography · Oral contrast · Children · Acai juice · Blueberry juice · Pineapple juice

Introduction

Magnetic resonance cholangiopancreatography (MRCP) is commonly performed for noninvasive evaluation of the pancreaticobiliary system in children. MRCP can be used in patients with known or suspected biliary obstruction, cholangitis, pancreatitis and congenital pancreaticobiliary anomalies [1]. It is the preferred imaging modality for an initial investigation of the biliary and pancreatic ducts, while endoscopic retrograde cholangiopancreatography (ERCP) is more often reserved for therapy or tissue sampling [2]. Advances in MRI technology and innovations in patient preparation contribute to the modern-day relevance of MRCP in children.

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Description

The use of negative oral contrast agents represents an innovative approach to patient preparation for pediatric MRCP studies. MRCP protocols rely primarily on heavily T2-weighted 2-D and 3-D sequences to optimize visualization of the pancreaticobiliary system. Bile and pancreatic enzymes are inherently hyperintense on fluid-sensitive sequences, which accounts for their bright signal on T2-weighted imaging. In the absence of oral contrast, or the inappropriate selection of oral contrast material, hyperintense signal from fluid within the lumen of the adjacent stomach, duodenum and proximal jejunum can superimpose upon the signal arising from the pancreaticobiliary tree thereby limiting evaluation of biliary anatomy or mimicking pathology [3] (Fig. 1). As such, the selection of a readily available oral contrast agent that is easily tolerable by children and renders the lumen of the proximal gastrointestinal tract relatively hypointense on T2-weighted sequences can help to reduce these potential limitations. (Fig. 2).

We have successfully used certain brands of acai juice, blueberry juice and pineapple juice as negative oral contrast agents on MRCP exams in children for five years. After administration, the MRI technologist documents the volume and type of juice in the DICOM series header. As juice is not considered a medication at our institution , we order it through purchasing rather than through the hospital pharmacy.

In January 2009, we began to routinely administer blueberry juice, pineapple juice or acai juice as negative oral contrast agents for all MRCP exams. Prior to implementation, we performed phantom studies on three different

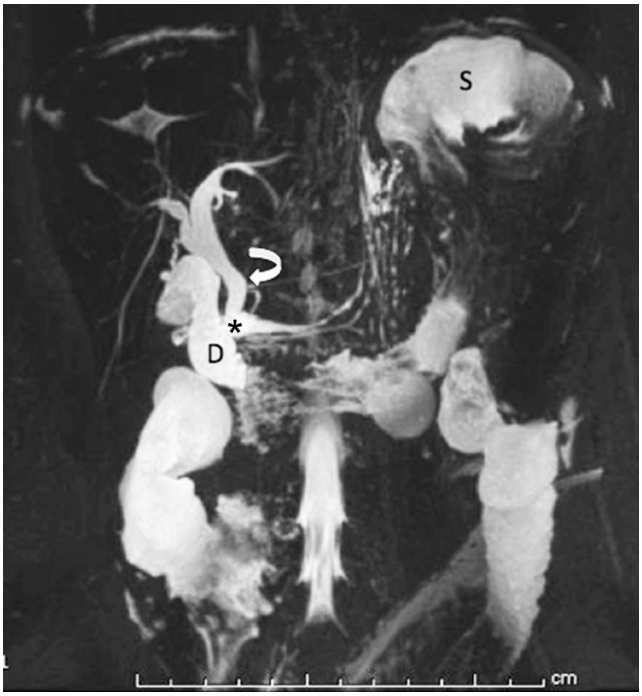

Fig. 1 MRCP without blueberry juice. A 15-year-old male with abdominal pain and dilated common bile duct on US. This coronal 3-D MRCP image shows hyperintense signal within the duodenum (D) and distal stomach (*), which limits evaluation of the distal common bile duct and main pancreatic duct. Fluid signal within the duodenum and stomach can potentially obscure or mimic pancreaticobiliary duct pathology. The common bile duct (*curved white arrow*) is dilated. Fundus of stomach (S)

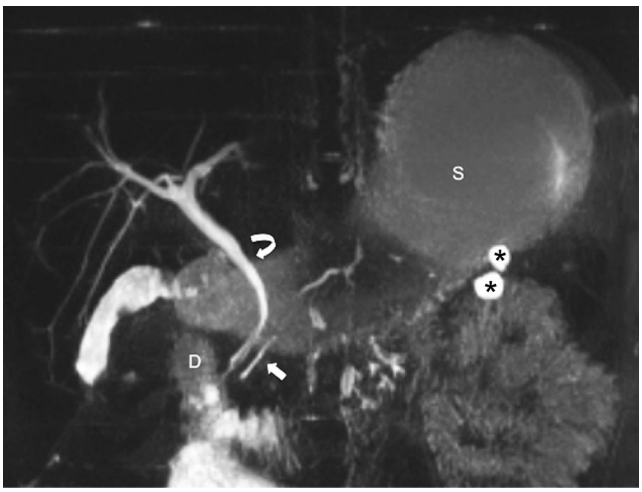

Fig. 2 Blueberry juice effect on MRCP. A 16-year-old female with history of recurrent pancreatitis. This coronal 3-D MRCP image was obtained after the patient consumed blueberry juice. The signal within the duodenum (D) and stomach (S) is decreased due to the T2 shortening effect from the manganese concentration within the juice. Note two small pancreatic pseudocysts (*) near the pancreatic tail, in this girl with recurrent pancreatitis, which are substantially better delineated with blueberry juice in the adjacent stomach and jejunum. The common bile duct (*curved arrow*) and pancreatic duct (*straight arrow*) are well visualized

commercially available blueberry juices using 2-D and 3-D MRCP sequences to mimic the MRCP protocol in vitro to help predict which brand of juice would work best in vivo. The findings from our phantom study in 2009 initially showed that the brand Nature's Place Organic Blueberry Juice™ (Hannaford Supermarkets, Scarborough, Maine) had the most T2 shortening (darkest signal) when compared with the two other tested brands. (Fig. 3). In our experience, certain brands of acai juice (Sambazon™, San Clemente, CA) and pineapple juice (Lakewood Organic ™, Miami, FL) have the same T2 shortening effect and are readily tolerated by children (Fig. 4). The signal characteristics on T1-weighted imaging sequences for all tested juices appeared dark likely due to the fluid content. On conventional T2-weighted imaging, all tested fruit juices demonstrate hyperintense signal. The fruit juices are stored in a refrigerator.

For our current MRCP protocol, patients routinely drink an age-based single dose of acai juice 15–30 min prior to the beginning of the MRCP study (Table 1). Patients are required to be NPO 4–6 h prior to the scan time. In our experience, acai juice is better tolerated than blueberry juice or pineapple juice due to palatability. It is the presence of manganese in these brands of acai, blueberry and pineapple juice that result in T2 shortening on heavily T2-weighted images [4, 5]. Our MRCP protocol consists of 3-D MRCP sequences using an echo time of approximately 910 ms, repetition times between 3,690–5,300 ms. The slice thickness is 1.8 mm, the number of excitations value (NEX) is 1.5 and a 256×256 matrix is used. Field of view (FOV) ranges between 28 and 32 cm. Respiratory triggering technique is used to diminish respiratory motion artifact. Two-dimensional coronal maximal intensity reconstruction (MIP) images and 3-D models are generated from the 3-D data set. The scan parameters of the phantom sequence are the same parameters as those of the MRCP sequence used in clinical practice.

There are three scenarios when there is at least relative contraindication for the use of acai, blueberry or pineapple juice: (1) known allergy, (2) type I diabetes and (3) requirement of sedation or general anesthesia. If there is a known allergy to blueberries, pineapple or acai berries, no oral contrast is administered for the MRCP study. Patients with a latex allergy are reportedly at an increased risk for pineapple allergy and are not offered the pineapple juice option [6]. Due to the sugar content of fruit juices, we avoid their use in patients with type I diabetes. In general, patients requiring sedation or anesthesia for the MRCP exam are not able to receive oral contrast for MRCP because of NPO restrictions.

Discussion

Technological advances in MRI hardware, improved scanning protocols and parameters and innovations in patient

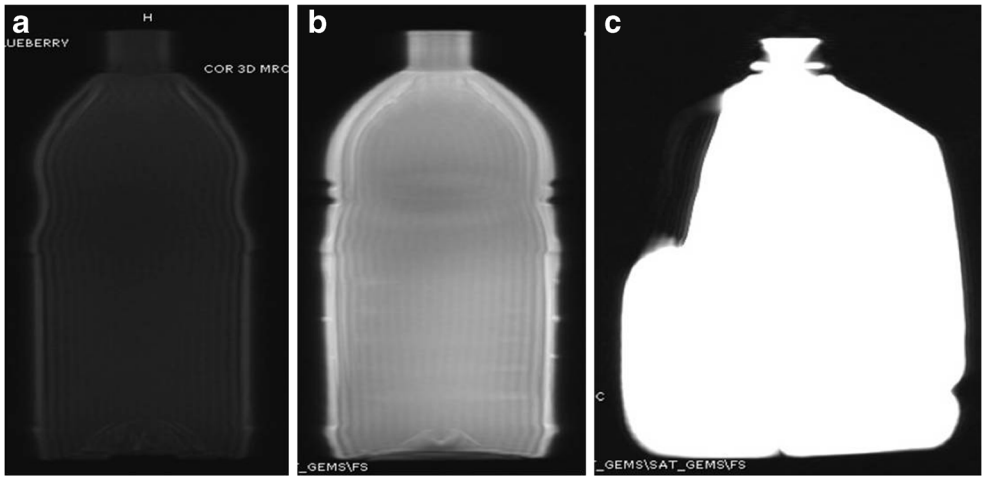

Fig. 3 Phantom study with two commercially available blueberry juices. **a** Coronal 3-D MRCP sequence of a bottle containing Nature's Place Organic Blueberry Juice™ shows hypointense signal, likely due to the manganese concentration. **b** Coronal 3-D MRCP sequence of a bottle containing True Blue Blueberry Juice™ shows intermediate signal intensity, brighter signal than that observed in **a**. **c** Coronal 3-D MRCP sequence of a bottle containing distilled water shows hyperintense signal, similar in intensity to the signal normally seen in the biliary tree

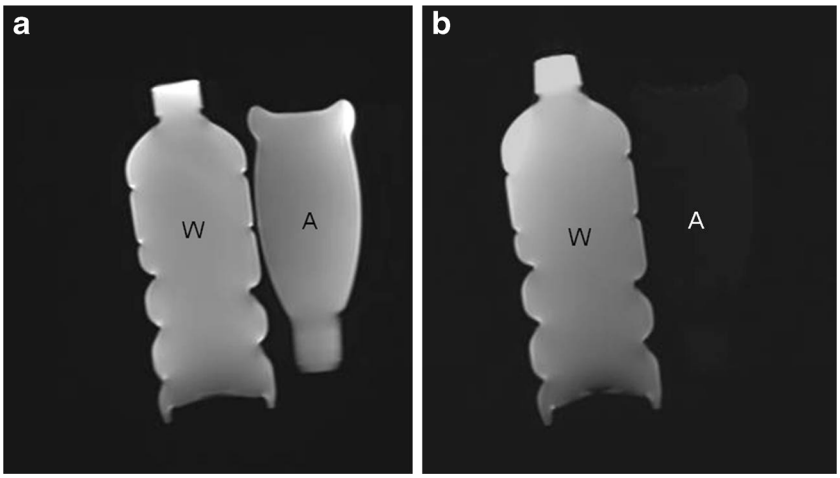

Fig. 4 Phantom study demonstrating the acai juice effect. **a** This coronal T2-weighted fat-suppressed image demonstrates a bottle of distilled water (W) and a bottle of acai (Sambazon™ San Clemente, CA) juice (A). Note that both bottles are hyperintense with conventional T2-weighted images. **b** This heavily T2-weighted coronal MRCP sequence of the same two bottles from **a** demonstrates loss of signal in the bottle of acai juice (A), likely due to the paramagnetic effects of manganese at high TR and TE values. The signal from the water (W) remains hyperintense

Table 1 Juice oral dosing protocol

Age	Juice volume (mL) to be given over 15–30 min just prior to exam
1 yr–6 yrs	180 (6 oz)
6–12 yrs	240 (8 oz)
12–16 yrs	300 (10 oz)
>16 yrs	350 (12 oz)

The volume of fruit juice is based on the patient's age and is administered over 15–30 min just prior to the exam. The volume of juice is the same for acai, blueberry or pineapple juice. If patients require sedation or general anesthesia, no fruit juice is administered

preparation have enabled MRCP to become one the most important noninvasive imaging studies for the work-up of suspected pancreaticobiliary tree abnormalities in children. MRCP relies on heavily T2-weighted sequences to accentuate the fluid content within the ducts.

A potential technical limitation of 3-D MRCP sequences is the overlap of hyperintense intraluminal signal from fluid within the stomach, duodenum and proximal small bowel that can obscure biliary tree anatomy or mimic ductal pathology. Negative oral contrast agents can improve image quality by rendering the proximal GI tract hypointense, which augments visualization of the biliary tree and pancreatic duct. While the use of negative oral contrast agents is not required for a

diagnostic MRCP study in children, image quality can be improved by the use of these contrast agents, particularly the 3-D MRCP sequence (Fig. 2). While final radiological diagnosis may or may not be affected by negative oral contrast agents, their use often aids in demonstration of normal anatomy or pathology for referring physicians, parents and patients by diminishing signal from overlying fluid-filled structures.

There are several commercially available negative oral contrast agents such as ferumoxsil (GastroMARK®; Mallinckrodt Inc., Raleigh, N.C.) as well as manganese chloride, barium sulfate and ferric particles [7] that render the bowel contents dark on T2-weighted images. However, these agents are less palatable and substantially more expensive than acai juice, blueberry juice or pineapple juice.

Not all brands of acai, blueberry or pineapple juice have the same contrast effect on MRI, likely due to differences in concentration of manganese and/or iron with variable paramagnetic effects on MRCP sequences. Our initial phantom studies in 2009 showed that Nature's Place Organic Blueberry Juice™ (Hannaford supermarkets, Scarborough, ME) caused the most T2 shortening (Fig. 4) of the brands we tested and was well tolerated in our pediatric patients.

Currently, we exclusively use Sambazon™ Acai juice (San Clemente, CA) as a negative enteric contrast agent for our MRCP studies. This vendor provides a palatable product, which is available in 10.5-ounce (310 mL) serving containers. This relatively small size allows us to dispense the juice to individual patients (typically 1–2 bottles per study), and allows for easy storage and refrigeration. This product is organic and has an expiration date. We inventory our refrigerated juice supply weekly and dispose of all products prior to their expiration date. If the brands described in this manuscript are not readily available at supermarkets near the reader's institution, one could perform a simple in vitro study with several brands of acai, blueberry or pineapple juice much like we performed in 2009 (Fig. 3) to determine an acceptable alternative.

Review of the literature suggests that the paramagnetic effects of manganese and superparamagnetic effects of iron are responsible for the drop in signal on T2-W. The use of blueberry juice as a negative oral contrast agent in adults was first described by Hiraishi et al. [5] in 1995. These authors showed the T1 and T2 relaxation curves of blueberry juice and manganese chloride have similar signal intensity profiles as a function of manganese concentration, suggesting the blueberry juice effects are mainly due to manganese concentration.

Spectrophotometric analysis of juice samples have also been performed to determine manganese and iron concentrations [8, 9]. The concentration of manganese in blueberry juice depends on the brand of juice (Fig. 4), and measures up to 20.6 mg/L. The iron content in blueberry juice was found to be 3.3 mg/L [8].

Riordan et al. [3] examined the signal-to-noise ratios using various fruit juices and oral contrast agents. They found that pineapple juice had the lowest signal-to-noise ratio of all tested juices. They did not test pure blueberry juice or acai juice.

Hirashi et al. [5] also noted that blood levels of manganese did not change after oral consumption, confirming the safety of blueberry juice in adults as a negative oral contrast agent [6]. To our knowledge, blood levels of manganese have not been tested in children. However, no adverse reactions or side effects have been reported in our patient population.

The image effect, which refers to the qualitative assessment of specific segments in the pancreaticobiliary tree has been tested for blueberry juice and pineapple juice on abdominal MRI and MRCP exams in adults [7, 10, 11]. Typically, radiologists who were blinded to whether the patient drank oral contrast would grade the segments of the pancreaticobiliary tree based on a numerical scale. Panaikolaou et al. [11] studied 37 adults pre-and post-consumption of blueberry juice. They found significant improvement in visualization of the ampulla, common bile duct, common hepatic duct and pancreatic duct. Statistically significant improvement was observed in the common bile duct and main pancreatic duct in this investigation. Riordan et al. [3] evaluated 10 healthy adult volunteers pre-and post-consumption of pineapple juice. They found significantly improved visualization of the ampulla, common bile duct, common hepatic duct and intrahepatic ducts in the images acquired 15 min after juice consumption compared with the images obtained before oral contrast.

Head-to-head comparison investigations of MRCPs with and without negative oral contrast agents in the same children are encouraged to prove our hypothesis that these agents improve MRCP image quality and duct visualization.

In conclusion, certain brands of acai juice, blueberry juice and pineapple juice meet several criteria as optimal oral contrast agents for MRCP examinations in children: they are palatable, safe and substantially improve the quality of MRCP imaging at minimal cost. These enteric contrast agents have been used effectively at our pediatric institution for 5 years and often improve image quality in MRCP. A head-to-head comparison with and without negative oral contrast in children is encouraged to validate our experience.

Conflicts of interest None

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