Portal vein embolization is widely used to induce hypertrophy of the future liver remnant before extended hepatectomy, decreasing the risk of postoperative liver failure. However, this percutaneous procedure has not been previously reported in a young child. The present report describes the case of a 14-month-old patient with a large multifocal mesenchymal hamartoma of the entire right liver, successfully resected after induction of future liver remnant hypertrophy by portal vein embolization.

Mesenchymal hamartoma of the liver (MHL) is the second most common benign hepatic tumor in childhood and is typically discovered as a large mixed solid-multicystic mass in patients younger than 3 years. Even though MHL is considered to be a congenital malformation, cytogenetic data have recently demonstrated translocations and aneuploidy, suggesting that these lesions are neoplastic. Interestingly, similar anomalies have also been described in undifferentiated embryonal sarcoma of the liver. Therefore, although MHL has been classically considered to present no potential for malignant transformation, several common pathologic, immunohistochemical, and cytogenetic features suggest a possible relation between these 2 entities and justify radical treatment.

The preferred treatment option for MHL is primary complete excision by hepatic resection. Large or multifocal lesions may be sometimes unresectable, because insufficient future liver remnant (FLR) volume could lead to postoperative liver failure. Portal vein embolization (PVE) is a well-established percutaneous procedure, which stimulates growth of the FLR. Various techniques have been described, using different embolic agents. Overall, the technical and clinical success of PVE is very high in experienced hands. However, published data and accumulated experience come exclusively from adult studies.

The present report describes the case of a 14-month-old patient with large hepatic mesenchymal hamartoma successfully resected after FLR hypertrophy induced by percutaneous PVE.

**PATIENT PRESENTATION**

A 14-month-old girl was referred to our hepatobiliary pediatric center for the management of a growing cystic mass in the liver. Imaging workup after birth (34 weeks of amenorrhea) had revealed multiple cystic lesions in the right liver, suggesting mesenchymal hamartoma.

At admission, the patient was asymptomatic, fed normally, and had regular bowel habits. Her weight was 6.9 kg (± 2 SD) and her height was 68 cm (± 2 SD), whereas her vital signs
were normal. Physical examination revealed an abdominal distension with a painless, firm, and smooth liver mass, palpable 7 cm below the right costal margin. Laboratory studies revealed a prothrombin time-international normalized ratio of 1.15 and normal liver function tests, including albumin (38 g/L [normal: 35–48 g/L]) and total bilirubin (8 μmol/L [normal: 7–25 μmol/L]). The serum α-fetoprotein was slightly elevated (28 μg/L [normal: 15 μg/L]), and β-human chorionic gonadotropin (<1 U/L) was within normal range. Ultrasonography and MRI revealed 2 predominant complex cystic masses with multiple small cystic satellites throughout the parenchyma of the right hepatic lobe (Fig 1). The first mass was located in segments 4b, 5, and 6, measuring 8.9 × 7.8 × 6.9 cm³, whereas the second one was in segments 4a and 8, measuring 6.6 × 6.0 × 6.1 cm³. A contrast-enhanced computed tomography (CT) was performed to assess the hepatic vessels. The volume of the FLR, including segments 1, 2, and 3, measured 104 cm³. This corresponded to 1.6% of body weight and 21.5% of the liver volume, excluding the volume of all tumors. Clinical presentation, imaging, and evolution were sufficiently suggestive of MHL, to avoid biopsy of the tumor. During a multidisciplinary meeting, right hepatectomy extended to segment 4 was considered as the best treatment option, because of tumor progression, mild failure to thrive, and potential for malignant transformation. Preoperative embolization of the right portal vein was considered necessary to reduce the probability of postoperative liver failure. The risk of a small-for-size liver was weighted with the risk of complications related to PVE, which could potentially render a resectable patient unresectable.

PVE was performed under general anesthesia (2 hours and 10 minutes) and after intravenous infusion of 50 mg/kg ceftriaxone (Rocephin, Roche Pharma, Switzerland). After local anesthesia with 3 mL 1% lidocaine (Rapidocain, Sintetica, Switzerland), the portal branch of segment 7 was punctured with a 22-G needle under ultrasound guidance. A 4-F introducer sheath was placed at the splenomesenteric confluence, and 200 mg heparin was injected. The basal portal pressure was 9 mm Hg, whereas the central venous pressure was 6 mm Hg. Digital subtracted portography was performed to assess portal anatomy (Fig 2). After selective catheterization with a 4-F Simmons 1 catheter (Radiofocus, Terumo, Belgium), the portal branches of segments 5, 6, 7, and 8 were successively embolized, under pulsed fluoroscopic guidance. Segment 4 was not embolized, because the 3 feeding branches were considered too small. A total of 2.8 mL of ethylene-vinyl alcohol copolymer (Onyx 18, ev3, France) was injected downstream through a 2.4-F microcatheter (Rebar 18, ev3), previously flushed with 1.5 mL dimethyl sulfoxide solution. The final portal pressure was 8 mm Hg and the control portography confirmed a complete occlusion of the right portal vein (Fig 2). The puncture track was embolized with Onyx (ev3). A total of 30 mL of iohexol 270 mg I/mL contrast media (Visipaque, GE Healthcare, Switzerland) was injected, and the total delivered dose was 11 Gy·cm². No complication was observed during the 4-day hospital stay. Doppler ultrasound study revealed a normal hepatopetal flow in the portal vein and left portal branch. During
12 days, the patient received subcutaneous enoxaparin (Clexane, Sanoﬁ-Aventis, Switzerland) 2 × 500 U per day for thromboprophylaxis. After 35 days, FLR volume grew to 216 cm³ corresponding to 3.0% of body weight and 42.6% of the liver volume, excluding the volume of all tumors. The relative volume gain of FLR was 108%, and the kinetic growth rate was 4.22% per week, which was above the threshold of 2% per week (Fig 3).6 The nonembolized segment 4 had a relative volume gain of 8% and a kinetic growth rate of 0.02% per week.

Right hepatectomy extended to segment 4 was performed. After dissection and ligation of the right hepatic duct and right hepatic artery, the parenchymal transection was done by clamp crushing along the descending left hepatic vein. Pringle maneuver and caval exclusion were necessary to control a small tear of this vessel. The integrity of the left bile duct and bile conﬂuence were controlled at the end of the operation. The 12-day recovery of the patient was uneventful. The total bilirubin (16 µg/L [normal: 7–25 µmol/L]) and V factor activity (100% [normal: >70%]) stayed within normal ranges. The right lobectomy specimen weighted 533 g. On cut section, there were multiloculated cysts containing serous fluid and separated by trabecular walls with some hyalinized or myxoid nodules (Fig 4). Microscopically, the cysts were lined by biliary-type epithelium expressing cytokeratins 7 and 19 and were surrounded by a mesenchymal stroma, confirming the diagnosis of MHL. No malignant cells were observed, and the margins of resection in the liver parenchyma were at least 5 mm. The portal vein branches were occluded by embolization material. The venous wall was partially destroyed and was surrounded by gigantocellular reaction of the foreign body type.

Four years postoperatively, the child was thriving and doing well. Yearly Doppler-US studies revealed a normal liver parenchyma and normal flow of the hepatic vessels, without bile duct dilatation. Biological parameters were normal.

**DISCUSSION**

MHL is the second most frequent benign tumor of the liver in children, developing in most cases before the age of 3, with a boy to girl ratio of 2:1.7. The preferred treatment option for MHL is primary complete excision with hepatic lobectomy or nonanatomic resection, because of the potential risk of malignant transformation. Other alternatives are incomplete resection, marsupialization, and decompression drainage, although all of these carry a risk of tumor recurrence.8 Liver transplantation may become necessary if the above options cannot be performed."
When performed, hepatic resection should preserve enough functional liver parenchyma, leading to minimal postoperative morbidity. However, in case of large or multifocal lesions, the FLR volume may be too small and patients may be deemed initially unresectable. Before resection of liver malignancies, PVE has been extensively used in adults for promoting preoperative hypertrophy of the FLR, increasing the resection rate and limiting the risk of postoperative liver failure.\(^5\) PVE leads to apoptotic necrosis of the embolized liver and triggers hepatocellular regeneration of the FLR, by means of growth factor production and redirection of portal flow toward the FLR.

Numerous technical variants have been described, but in all cases, the final end point is the complete obstruction of the targeted branches and redistribution of flow to the FLR branches only. PVE procedure is mainly performed with a tranhepatic approach, the portal branches being generally catheterized with 5-F or more diameter materials. Various embolic agents have been used for PVE, including gelatin sponge, glue, beads, alcohol, coils, and plugs.\(^9\) The mixture of n-butyl cyanoacrylate and iodized oil seems to have a greater effect on hypertrophy.\(^5\) However, use of the latter is more difficult and requires more experience of the radiologist, because delivery must be very precise to prevent embolization of nontargeted branches. Overall, both reported technical and clinical success rates of PVE are very high, ranging from 95% to 100%, with complication rates lower than 1%.\(^4\) Nevertheless, all these results come from adult populations.

No consensus exists on the minimal volume of functional liver parenchyma that should be left in place after an extended hepatectomy.\(^10,11\) In the present case, preoperative PVE was decided to stay on the safe side. Consequently, similar threshold as those applied to adults were considered (ie, a FRL volume at least 25% to 30% of the liver volume or at least 2% of body weight). Overall, hypertrophy of the FLR was considered satisfactory, whereas no complication occurred.

Reported cases of portal vein occlusion before hepatic resection in pediatric population are very scarce.\(^12\) To our knowledge, there is currently no published case of PVE performed in an infant. The main reasons are technical limitations related to the small body size of this population and the absence of tailored materials to pediatric patients in interventional radiology. The first challenge is to get a percutaneous access to small caliber portal vessels. The puncture should be performed with a thin 22-G needle under ultrasound guidance, whereas portal branches should be catheterized with the smallest materials possible, such as microcatheters. The second issue is to prevent any embolization of nontarget portal branches, which could be achieved with the use of an embolic agent, such as ethylene vinyl alcohol copolymer (Onyx; ev3). This product is delivered with very accurate control, because it is a liquid nonadhesive to catheter materials and it has an optimal radiopacity for visualization under fluoroscopy. This reduces the risk of unintentional reflux and prevents embolization of nontargeted branches.\(^13,14\) Its use as an embolic agent in PVE procedures needs further validation on larger clinical series.\(^15\)

**CONCLUSIONS**

PVE is feasible in very young children when an extended liver resection is indicated. However, there is a need to develop appropriate materials for pediatric patients, to warrant the safety profile of this procedure.

**ABBREVIATIONS**

CT: computed tomography
FLR: future liver remnant
MHL: mesenchymal hamartoma of the liver
PVE: portal vein embolization

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