

Original paper

## Structured multiparametric retrograde wedged hepatic venous portography assessment before Meso-Rex bypass in children: a standardised imaging framework

Piotr Adam Rago<sup>1,A,B,C,D,E,F,#</sup>, Agnieszka Pytlewska<sup>1,B,D,E,#</sup>, Urszula Zienkiewicz<sup>1,B,D</sup>, Jan Bartuszek<sup>1,B,D</sup>, Marek Stefanowicz<sup>2,B,D</sup>, Adam Kowalski<sup>1,2,B,D</sup>, Dorota Broniszczak-Czyszek<sup>2,B,D</sup>, Weronika Chacińska<sup>2,B,C,D</sup>, Elżbieta Jurkiewicz<sup>1,A,D,E</sup>

<sup>1</sup>Department of Diagnostic Imaging, The Children's Memorial Health Institute, Warsaw, Poland

<sup>2</sup>Department of Paediatric Surgery and Organ Transplantation, The Children's Memorial Health Institute, Warsaw, Poland

#These authors contributed equally to this study.

### Abstract

**Purpose:** Preoperative qualification for Meso-Rex bypass (MRB) in children with extrahepatic portal vein obstruction integrates Doppler ultrasonography, computed tomography/magnetic resonance imaging, portomesenteric inflow and conduit assessment, and surgical judgement. Retrograde wedged hepatic venous portography (RHVP) has a distinct role: direct angiographic evaluation of intrahepatic portal venous anatomy. This study presents a structured RHVP framework focused on that component.

**Material and methods:** This retrospective single-centre study included consecutive children referred as potential MRB candidates and evaluated with RHVP between January 2023 and June 2026. The RHVP analysis assessed the transverse and umbilical portions of the left portal vein, left-right portal venous communication, peripheral branches, collaterals, veno-venous communications, calibre, filling defects, and stenoses. Findings were correlated with intraoperative observations and early Doppler-confirmed graft function.

**Results:** Forty-seven RHVP examinations were performed in 45 patients; 2 required repeat RHVP and 1 underwent additional direct transhepatic portography, not counted as RHVP. Median age at RHVP was 11.3 years (range 0.4–17.7); the cohort included 18 girls and 27 boys. Access was via the right internal jugular in 29 and upper extremity in 18 examinations; no RHVP-related complications occurred. Fifteen patients were disqualified, 4 for surgical/clinical reasons and 11 on RHVP assessment. Thirty patients underwent MRB; 27 had early successful hepatopetal graft flow and 3 were unsuccessful.

**Conclusions:** Structured multiparametric RHVP complements type-based classifications by documenting mandatory eligibility criteria together with additional findings that may affect surgical complexity, portal inflow, and early graft function. It supports interdisciplinary communication and future validation of imaging-derived modifiers in borderline anatomy.

**Key words:** child, portal vein, hypertension, portal, portography, angiography, digital subtraction, vascular surgical procedures.

### Correspondence address:

Piotr Adam Rago, Department of Diagnostic Imaging, The Children's Memorial Health Institute, Al. Dzieci Polskich 20, 04-730 Warsaw, Poland,  
e-mail: [ridler.rad@gmail.com](mailto:ridler.rad@gmail.com)

### Authors' contribution:

A Study design · B Data collection · C Statistical analysis · D Data interpretation · E Manuscript preparation · F Literature search · G Funds collection

## Introduction

Extrahepatic portal vein obstruction (EHPVO) is the leading cause of prehepatic portal hypertension in children and may result in recurrent gastrointestinal bleeding, hypersplenism, impaired liver function, growth retardation, and neurocognitive impairment. Restoration of physiological hepatopetal portal venous flow by Meso-Rex bypass (MRB) is currently considered the treatment of choice whenever appropriate intrahepatic portal venous anatomy is preserved, providing superior long-term physiological and clinical outcomes compared with non-selective portosystemic shunts [1-7].

Preoperative qualification for MRB is not based on RHVP alone. Doppler ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI) are used to assess extrahepatic portal and portomesenteric venous anatomy, portal venous inflow pathways, liver parenchyma, and postoperative graft surveillance. Ultrasonographic assessment of the internal jugular veins is also used before surgery to evaluate potential autologous conduit quality. These modalities and clinical-surgical criteria play distinct roles in the qualification pathway. RHVP addresses a narrower but critical task: direct angiographic characterisation of the intrahepatic portal venous system, particularly when non-invasive imaging is limited by cavernous transformation, extensive collateral circulation, or hypoplastic intrahepatic portal branches [8-10].

Retrograde wedged hepatic venous portography (RHVP; corresponding to the wedged hepatic venous portography [WHVP] terminology commonly used in previous reports) enables direct angiographic visualization of the intrahepatic portal venous system and has become an important complementary imaging technique for the RHVP-specific component of preoperative evaluation before MRB. Previous studies demonstrated its value primarily for identification of the Rex recess and assessment of left portal vein patency in patients with EHPVO [8,9,11]. More recently, WHVP-based classification of intrahepatic portal venous system patterns has been used to support surgical decision-making and to explore postoperative haemodynamic outcomes after MRB [12,13].

Since 2021, RHVP has been routinely performed at our institution as part of the preoperative evaluation of children considered for physiological portal venous reconstruction. Based on our experience gained since the introduction of the institutional MRB program in 2023, the examination protocol has evolved from assessment of the Rex recess alone to a structured multiparametric evaluation of the entire intrahepatic portal venous system. The protocol incorporates selective catheterisation of multiple hepatic veins, acquisition of orthogonal anteroposterior and true lateral angiographic projections, and standardised assessment of both mandatory anatomical criteria and additional angiographic findings that may influence surgical planning and early graft function.

Existing type-based classifications provide an important anatomical basis for MRB eligibility by categorising intrahepatic portal venous system patterns and Rex recess involvement. Their practical granularity may be limited, however, because clearly favourable, clearly unfavourable, and intermediate patterns are grouped into broad categories without providing itemised parameters for practical risk stratification. In particular, intermediate anatomy such as type C in the published intrahepatic portal venous system (IHPS) classification may require more detailed radiological description for surgical planning. The present framework was therefore designed as an itemised RHVP reporting complement, not as a replacement for established classifications. It separately documents mandatory eligibility criteria and additional angiographic features such as segmental diameter, focal stenosis, peripheral branch hypoplasia, intrahepatic collaterals, veno-venous communications, and anatomical variants.

The aim of this study was to present a structured multiparametric RHVP assessment focused on the intrahepatic portal venous component of preoperative evaluation before MRB and to correlate itemised angiographic findings with intraoperative observations and early Doppler-confirmed graft function, particularly in patients with intermediate or borderline anatomy.

## Material and methods

### Study design and patients

This retrospective single-centre study included consecutive paediatric patients with EHPVO who were preliminarily selected by paediatric surgeons as potential candidates for MRB and referred for RHVP between January 2023 and June 2026. All such referrals underwent RHVP; from the radiological perspective, no additional exclusion criteria were applied before the examination. Patient age was not used as a radiological exclusion criterion and, in an experienced paediatric interventional radiology team, young age alone did not preclude RHVP. The study summarises the initial experience of our institutional MRB imaging program.

The final study cohort comprised 45 patients. Because of incomplete initial visualisation, 2 patients underwent repeated RHVP examination during the qualification process. In one additional patient, supplementary direct transhepatic portography was performed because RHVP did not provide sufficient anatomical information for final decision-making. This supplementary procedure was not included in the RHVP examination count. Patients were subsequently classified after multidisciplinary review as either undergoing MRB or being disqualified from MRB. Disqualification occurred either for surgical or clinical reasons independent of RHVP findings or after RHVP assessment, including combined radiological-surgical review.

Clinical and procedural data were retrieved from institutional records, including date of birth, date of RHVP, date of MRB when performed, age at RHVP, age at MRB, interval between RHVP and MRB, venous access route, number of wedged contrast injections, angiographic findings, additional direct transhepatic portography when performed, RHVP-related complications, multidisciplinary treatment decision, operative findings, early postoperative graft patency, the standard early postoperative Doppler protocol, and scheduled Doppler follow-up at 1, 3, 6, and 12 months after surgery. As part of routine multidisciplinary qualification, Doppler ultrasonography, CT or MRI, and preoperative ultrasonographic assessment of the internal jugular veins were used when clinically indicated, to evaluate extrahepatic portal and portomesenteric anatomy, venous inflow pathways, liver parenchyma, postoperative surveillance, and potential autologous conduit quality. These examinations were part of the routine preoperative clinical assessment and were interpreted separately from RHVP. Clinical and surgical criteria, together with other imaging criteria derived from CT, MRI, and Doppler ultrasonography, constitute complementary components of the broader multidisciplinary MRB qualification framework, whereas the proposed checklist focuses specifically on RHVP-based assessment of intrahepatic portal venous anatomy. Basic demographic data were available in institutional records but were not used as selection variables, exclusion criteria, or components of the proposed angiographic framework. The aetiology of EHPVO was not incorporated into the proposed radiological framework because aetiological assessment belonged to the broader surgical and hepatological assessment pathway rather than to the angiographic checklist.

This retrospective analysis was based on clinical and imaging data obtained as part of routine preoperative assessment of patients considered for physiological portal venous reconstruction. These data were subsequently compared with intraoperative findings and early graft function. No additional diagnostic or therapeutic procedures were performed for research purposes. According to institutional regulations for retrospective analyses of data collected during routine clinical care, separate local ethics committee approval and additional informed consent were not required. The study was conducted in accordance with the principles of the Declaration of Helsinki. No identifying patient data are included in the manuscript, figures, or submission files.

## RHVP protocol

All examinations were performed in a dedicated angiography suite using digital subtraction angiography (DSA) under general anaesthesia.

Whenever technically feasible, venous access was obtained through a peripheral upper-extremity vein. When jugular access was required, the right internal jugular

vein was used; the left internal jugular vein was not used for RHVP access in this series. This approach was introduced after initial institutional experience to preserve the left internal jugular vein, which is routinely selected as an autologous conduit for MRB. At our institution, the left internal jugular vein is the first-choice conduit. When it is unsuitable or unavailable, alternative autologous grafts, including the inferior mesenteric vein, may be considered according to intraoperative findings. Consequently, the upper-extremity access approach was chosen with the intention of preserving surgical options without compromising RHVP visualisation.

Selective catheterisation of the hepatic veins was performed using standard angiographic techniques. RHVP was routinely acquired in true anteroposterior and lateral projections. Additional oblique projections were obtained only when considered necessary to clarify complex vascular anatomy.

To achieve comprehensive evaluation of the intrahepatic portal venous system, RHVP was performed from multiple hepatic veins whenever required. The number of wedged contrast injections ranged from 1 to 4 per examination and was adapted to the quality of opacification and the complexity of intrahepatic portal venous anatomy. This approach enabled visualisation of the entire portal venous anatomy, including the umbilical portion of the left portal vein (UPLPV), transverse portion of the left portal vein (TPLPV), right portal vein (RPV), peripheral intrahepatic portal branches, collateral venous pathways, and their anatomical relationships.

## Structured RHVP assessment

RHVP examinations were performed and initially interpreted jointly during the procedure by two paediatric interventional radiologists using the same structured institutional reporting protocol. Across the study period, the protocol was applied by four paediatric interventional radiologists.

The structured assessment used for surgical planning was based on intraprocedural consensus of the two radiologists involved in the examination. A second review was subsequently performed by the reporting radiologist during preoperative multidisciplinary discussion with the surgical team.

Three anatomical findings were considered mandatory intrahepatic anatomical criteria supporting suitability for physiological portal reconstruction: (1) patency of the TPLPV; (2) patency of the UPLPV; and (3) communication between the left and right intrahepatic portal venous systems. These criteria were interpreted as part of multidisciplinary assessment rather than as isolated determinants of final operability.

Additional angiographic findings were recorded as supplementary anatomical observations potentially influencing surgical planning and early graft performance.

These included focal stenosis of the TPLPV and UPLPV, vessel diameter, filling defects, vascular irregularity, focal narrowing, relative hypoplasia of the RPV and peripheral portal branches, peripheral portal venous abnormalities, collateral circulation, and other anatomical variations. Vessel-diameter and stenosis categories were pragmatic institutional reporting categories recorded on calibrated DSA images to standardise the description; they were not treated as validated prognostic thresholds.

The complete structured assessment is presented in Table 1.

### Surgical correlation and outcome definitions

RHVP findings were reviewed during multidisciplinary discussions involving paediatric radiologists and paediatric surgeons experienced in MRB. Angiographic findings were correlated with intraoperative anatomy and the standard early postoperative Doppler protocol. Postoperative Doppler ultrasonography was performed on postoperative days 0, 1, 2, 3, 5, and 7; subsequent scheduled Doppler assessment was performed at 1, 3, 6, and 12 months after surgery [14]. Patients remained under surgical follow-up after MRB; longer-term clinical outcomes and subsequent surgical or interventional procedures, including potential treatment of graft stenosis, were beyond the primary radiology-focused scope of this RHVP-focused study.

**Table 1.** Structured angiographic assessment framework for preoperative evaluation before Meso-Rex bypass

| Mandatory anatomical criteria             | Additional angiographic findings                                               |
|-------------------------------------------|--------------------------------------------------------------------------------|
| Patency of the TPLPV                      | TPLPV diameter<br>(< 1.5 mm/1.5-2.0 mm/> 2.0 mm)                               |
| Patency of the UPLPV                      | UPLPV diameter<br>(< 1.5 mm/1.5-2.0 mm/> 2.0 mm)                               |
| Communication between the LPV and the RPV | Focal TPLPV stenosis<br>(< 50%/50-80%/> 80%)                                   |
|                                           | Focal UPLPV stenosis<br>(< 50%/50-80%/> 80%)                                   |
|                                           | Peripheral left portal venous branches<br>(normal/hypoplastic/not visualized)  |
|                                           | Peripheral right portal venous branches<br>(normal/hypoplastic/not visualized) |
|                                           | Intrahepatic porto-portal collaterals<br>(absent/present)                      |
|                                           | Intrahepatic veno-venous communications<br>(absent/present)                    |
|                                           | Portal venous anatomical variants                                              |
|                                           | Other angiographic findings relevant for operative planning                    |

LPV – left portal vein, RPV – right portal vein, TPLPV – transverse portion of the left portal vein, UPLPV – umbilical portion of the left portal vein

For the purposes of this study, early successful MRB was defined as completion of the bypass with maintained hepatopetal portal flow through the graft on Doppler ultrasonography performed according to this early postoperative protocol. An unsuccessful attempt was defined as aborted reconstruction after surgical exploration because suitable Rex recess anatomy could not be identified, or inadequate portal inflow/early graft failure despite technically completed anastomosis. The patient in whom suitable Rex recess anatomy could not be identified intraoperatively was counted as an unsuccessful attempt and was interpreted as incorrect preoperative anatomical assessment on retrospective review.

### Statistical analysis

Because this study aimed to develop and describe a structured radiological framework and only three unsuccessful MRB attempts occurred, formal hypothesis testing and independent risk modelling were not performed. Categorical variables are presented as counts, and continuous variables are presented as medians and ranges. Procedural outcomes are summarised descriptively.

## Results

### Patient cohort

Between January 2023 and June 2026, 47 RHVP examinations were performed in 45 paediatric patients referred for evaluation before potential physiological portal venous reconstruction. Age at RHVP in the entire cohort ranged from 0.4 to 17.7 years, with a median of 11.3 years. The cohort included 18 girls and 27 boys. In 2 patients, the initial RHVP data obtained during qualification were considered insufficient for final multidisciplinary decision-making, and repeat RHVP assessment was therefore performed. In 1 additional patient, direct transhepatic portography was performed because RHVP remained incomplete. This supplementary procedure was not included in the RHVP examination count.

Among the 30 operated patients, age at RHVP ranged from 0.4 to 13.9 years, with a median of 8.5 years. Age at MRB ranged from 0.7 to 14.3 years, with a median of 9.0 years. The operated group included 10 girls and 20 boys. The interval between RHVP and MRB ranged from 18 to 384 days, with a median of 182 days. Among the 15 disqualified patients, age at RHVP ranged from 6.9 to 17.7 years, with a median of 12.9 years; this subgroup included 8 girls and 7 boys. Cohort and procedural characteristics are summarised in Table 2.

RHVP was performed through right internal jugular venous access in 29 examinations and through peripheral upper-extremity venous access in 18 examinations; the left internal jugular vein was not used for RHVP access. The number of selective wedged contrast injections

**Table 2.** Cohort and procedural characteristics

| Characteristic                                                                       | Value                                                                                                                      |
|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Final cohort                                                                         | 45 patients                                                                                                                |
| Age at RHVP, entire cohort                                                           | Median 11.3 years (range: 0.4-17.7)                                                                                        |
| Sex, entire cohort                                                                   | 18 girls; 27 boys                                                                                                          |
| RHVP examinations                                                                    | 47 examinations                                                                                                            |
| Repeated RHVP due to incomplete initial assessment                                   | 2 patients                                                                                                                 |
| Additional direct transhepatic portography                                           | 1 supplementary procedure, not included in RHVP count                                                                      |
| Venous access for RHVP                                                               | 29 right internal jugular (61.7 %); 18 peripheral upper-extremity (38.3 %); left internal jugular not used for RHVP access |
| Selective wedged contrast injections                                                 | 1-4 per examination                                                                                                        |
| RHVP-related complications                                                           | 0                                                                                                                          |
| Patients disqualified from MRB                                                       | 15/45 (33.3%)                                                                                                              |
| Surgical/clinical disqualification independent of RHVP (among disqualified patients) | 4/15 (26.7%)                                                                                                               |
| RHVP disqualification (among disqualified patients)                                  | 11/15 (73.3 %): 8 mandatory criteria not fulfilled; 3 combined radiological-surgical multiparametric assessment            |
| Age at RHVP, disqualified patients                                                   | Median 12.9 years (range: 6.9-17.7)                                                                                        |
| Sex, disqualified patients                                                           | 8 girls; 7 boys                                                                                                            |
| Patients who underwent MRB                                                           | 30/45 (66.7%)                                                                                                              |
| Age at RHVP, operated patients                                                       | Median 8.5 years (range: 0.4-13.9)                                                                                         |
| Age at MRB                                                                           | Median 9.0 years (range: 0.7-14.3)                                                                                         |
| Sex, operated patients                                                               | 10 girls; 20 boys                                                                                                          |
| Interval from RHVP to MRB                                                            | Median 182 days (range: 18-384)                                                                                            |
| Early successful MRB                                                                 | 27/30 (90.0%)                                                                                                              |
| Unsuccessful MRB attempts                                                            | 3/30 (10.0%); 1 girl and 2 boys                                                                                            |
| Early postoperative and scheduled Doppler follow-up                                  | Postoperative days 0, 1, 2, 3, 5, and 7; scheduled follow-up at 1, 3, 6, and 12 months after surgery                       |

MRB – Meso-Rex bypass, RHVP – retrograde wedged hepatic venous portography

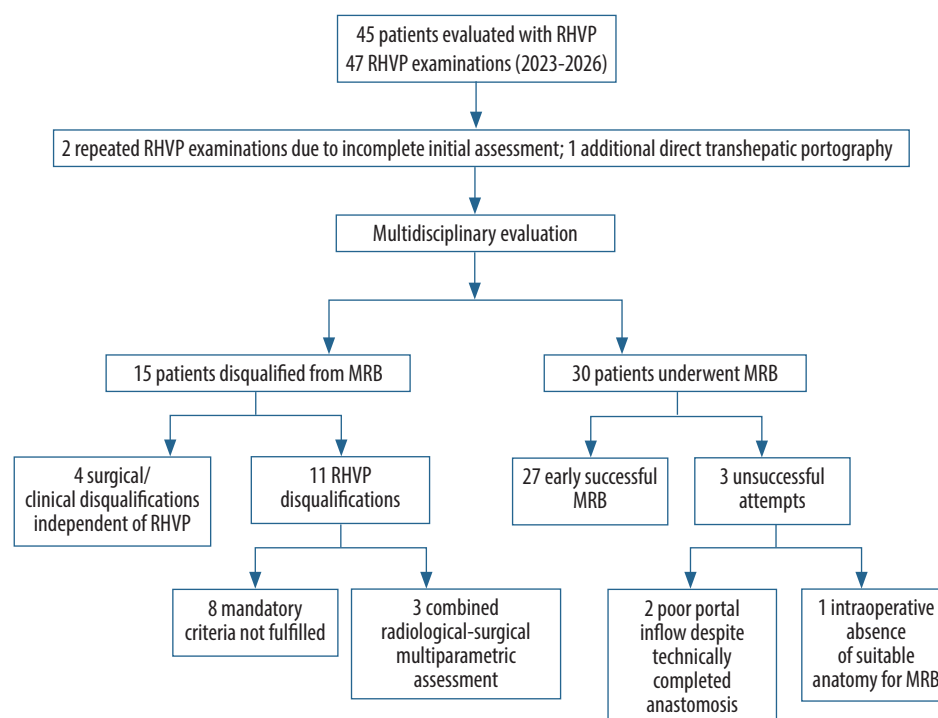
ranged from 1 to 4 per examination. When peripheral upper-extremity access was obtained successfully, no additional technical difficulty or inferior angiographic result was recorded.

Following multidisciplinary evaluation, 15 patients were disqualified from MRB. Four were disqualified for surgical or clinical reasons independent of RHVP findings, including intrahepatic block, lack of patient/guardian consent, and qualification for alternative treatment, including endovascular portal vein recanalisation in a post-transplant patient.

Eleven patients were disqualified on the basis of RHVP assessment. In 8 patients, disqualification resulted from failure to fulfil the mandatory anatomical criteria for physiological portal reconstruction. In 3 additional patients, disqualification was made after combined radiological-surgical multiparametric assessment despite technically preserved mandatory criteria. These patients presented very narrow central portal venous segments, approximately 0.7-1.5 mm in diameter, together with

additional unfavourable findings such as narrow peripheral portal branches, filling defects, vascular irregularity, and focal narrowing.

Thirty patients underwent MRB. Twenty-seven procedures were classified as early successful, with maintained hepatopetal graft flow demonstrated on Doppler ultrasonography according to the institutional protocol on postoperative days 0, 1, 2, 3, 5, and 7, while 3 were unsuccessful. The operated group included 10 girls and 20 boys; the 3 unsuccessful attempts occurred in 1 girl and 2 boys. Of the 3 unsuccessful attempts, all had been considered suitable for surgery during preoperative multidisciplinary assessment. In 2 patients, the mandatory intrahepatic anatomical criteria were preserved, but additional RHVP findings and poorly developed peripheral portal branches were present; after surgery, poor portal inflow through the bypass was observed. In the third unsuccessful case, no suitable anatomical conditions for MRB were identified intraoperatively. Retrospective review of RHVP in this patient indicated misclassification



**Figure 1.** Study flow diagram. Flowchart summarising patient selection and early Meso-Rex bypass (MRB) results. Between January 2023 and June 2026, 47 retrograde wedged hepatic venous portography (RHVP) examinations were performed in 45 patients referred by paediatric surgeons as potential candidates for physiological portal venous reconstruction. In 2 patients, RHVP was repeated because the initial examination provided insufficient information for final multidisciplinary decision-making. In 1 additional patient, direct transhepatic portography was performed because RHVP remained incomplete; this supplementary procedure was not counted as an RHVP examination. Fifteen patients were disqualified from MRB, including 4 for surgical or clinical reasons independent of RHVP findings and 11 after RHVP assessment. Of the 11 RHVP disqualifications, 8 resulted from failure to fulfil the mandatory anatomical criteria and 3 from combined radiological-surgical multiparametric assessment. Thirty patients underwent MRB, resulting in 27 early successful procedures and 3 unsuccessful attempts

of markedly hypoplastic intrahepatic portal anatomy, with central vessels measuring approximately 0.7–1.3 mm, narrow peripheral branches, and filling defects. Figure 1.

### RHVP findings

All early successful MRB procedures fulfilled the three mandatory anatomical criteria defined in the structured RHVP assessment.

No RHVP-related complications were recorded.

All 3 unsuccessful cases had been considered suitable for surgery during preoperative multidisciplinary assessment. In 2 patients, the mandatory intrahepatic anatomical criteria were preserved but additional unfavourable RHVP findings were present, including very small vessel calibre, poorly developed peripheral portal branches, filling defects, vascular irregularity, and focal narrowing. In the third patient, retrospective review indicated misclassification of markedly hypoplastic intrahepatic portal anatomy.

Importantly, additional RHVP findings were also observed in selected patients in the early successful MRB group. Such findings should therefore not automatically be treated as absolute contraindications to MRB but rather as anatomical features requiring careful multidisciplinary interpretation.

### Correlation with surgical findings

In all patients who underwent early successful MRB, intraoperative findings confirmed the angiographic assessment of the mandatory anatomical criteria (Figure 2).

Retrospective comparison of early successful and unsuccessful procedures demonstrated overlap in additional angiographic findings. Although these observations did not preclude successful portal reconstruction, they may represent potential modifiers of surgical complexity, early portal inflow, or the need for subsequent follow-up and possible intervention (Figure 3).

### Discussion

The present study describes a structured multiparametric approach to the RHVP-specific component of preoperative evaluation before MRB. While previous reports have established the value of WHVP/RHVP for identifying a patent Rex recess and confirming left portal vein patency, our protocol extends angiographic assessment to the entire intrahepatic portal venous system by systematic evaluation from multiple hepatic veins using routine anteroposterior and lateral projections [8,9,11].

Early successful MRB depends on accurate identification of anatomical conditions allowing restoration

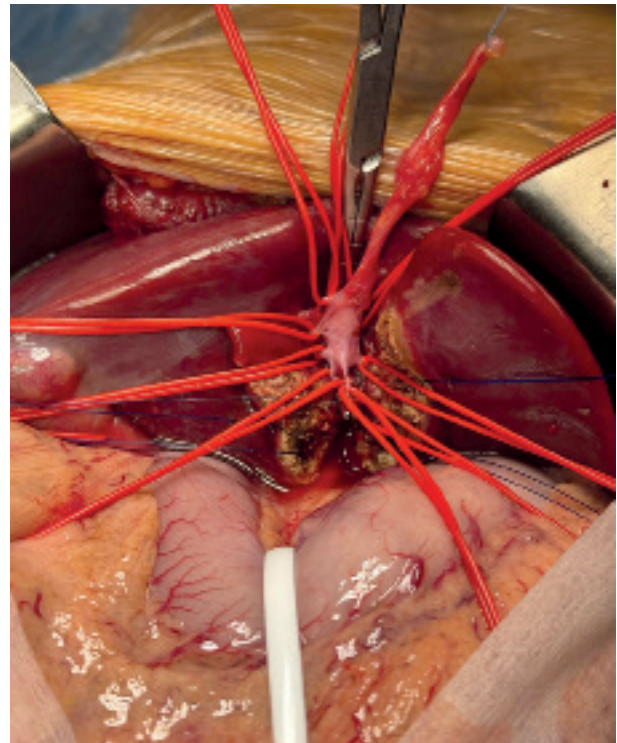
of physiological portal venous flow, but RHVP evaluates only the intrahepatic portal venous component of that process. Consistent with previous surgical series, all early successful procedures in our cohort fulfilled the three mandatory intrahepatic anatomical criteria supporting suitability for portal reconstruction [2-7]. These findings support the role of comprehensive preoperative imaging in multidisciplinary assessment before MRB.

A major strength of the proposed protocol is the comprehensive assessment of the entire intrahepatic portal venous system rather than limiting evaluation to the Rex recess alone. Selective catheterisation of multiple hepatic veins, with 1-4 wedged contrast injections per examination when required, combined with orthogonal angiographic projections enabled detailed visualisation of the TPLPV and UPLPV, communication between the left and right portal venous systems, peripheral portal branches, collateral pathways, and additional anatomical variations that may be relevant for surgical planning.

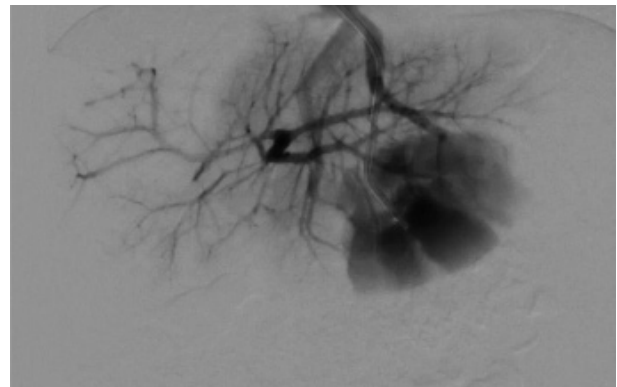
Another practical modification introduced in our institutional protocol was the use of peripheral upper-extremity venous access whenever feasible. This approach was adopted to preserve the left internal jugular vein for potential graft harvesting; the left internal jugular vein was not used for RHVP access in this series. When jugular access was required, the right internal jugular vein was used. The use of upper-extremity access increased during the program and currently accounts for approximately half of examinations in our workflow. In our institutional experience, when peripheral upper-extremity access was obtained successfully, no additional technical difficulty or inferior angiographic result was observed compared with right internal jugular access. Right internal jugular access therefore remains a fallback option when peripheral venous access is not feasible. No RHVP-related complications were recorded in the present series.

Our results demonstrate that fulfilment of the 3 intrahepatic anatomical criteria alone does not completely explain early graft function. In 2 unsuccessful cases, the mandatory intrahepatic criteria were formally fulfilled, but additional RHVP findings and poorly developed peripheral portal branches were associated with poor portal inflow after MRB. In the third unsuccessful case, retrospective review suggested incorrect preoperative anatomical assessment, with a very narrow portal venous system and multiple additional abnormalities. Importantly, similar additional RHVP findings were also observed in some successful cases. These observations suggest that such features should not be interpreted as absolute contraindications to MRB but rather as potential modifiers of surgical complexity and early graft performance.

This approach should be regarded as complementary to existing intrahepatic portal venous system classifications rather than as a replacement for them. The classification proposed by de Ville de Goyet and subsequently evaluated by Bertocchini *et al.* [12] and Chang *et al.* [13]



**Figure 2.** Intraoperative photograph of the Rex recess during Meso-Rex bypass. The operative field demonstrates surgical exposure of the umbilical portion of the left portal vein within the Rex recess after preparation. This area represents the intraoperative correlate of the mandatory anatomical criteria evaluated during preoperative retrograde wedged hepatic venous portography



**Figure 3.** Representative retrograde wedged hepatic venous portography (RHVP) fulfilling the mandatory anatomical criteria for Meso-Rex bypass. RHVP demonstrates a patent umbilical portion of the left portal vein, preserved continuity with the transverse portion of the left portal vein, and communication between the left and right intrahepatic portal venous systems, fulfilling the mandatory anatomical criteria for Meso-Rex bypass. Relative hypoplasia of the right portal vein and its peripheral branches compared with the left portal venous system is also demonstrated, representing an additional angiographic feature recorded as part of the structured RHVP assessment

provides a useful type-based description of intrahepatic portal venous anatomy and its relationship to MRB feasibility and outcomes. However, type-based classification mainly separates clearly favourable, clearly unfavourable, and intermediate patterns. It provides limited granularity

for borderline or intermediate anatomy, particularly type C patterns, where more detailed angiographic characterisation may be clinically useful. The present framework translates RHVP findings into a practical reporting checklist for multidisciplinary planning by separating findings that are mandatory for anatomical eligibility from additional features that may modify surgical complexity, early portal inflow, or follow-up strategy.

From a surgical perspective, structured RHVP assessment does not replace intraoperative evaluation of the Rex recess or the final surgical decision but provides a reproducible anatomical map for preoperative planning. Although the proposed framework focuses on intrahepatic portal anatomy, final qualification for MRB also depends on surgical factors that are not fully captured by angiography alone. These include the quality of portal inflow from the superior mesenteric venous system, the extent of spontaneous portosystemic decompression, the availability, length, calibre, and quality of a suitable autologous conduit, the quality and tension-free configuration of the anastomosis, graft kinking or torsion, competitive outflow through collaterals, intraoperative assessment of vessel quality, and operator experience. Therefore, RHVP should be interpreted as one component of comprehensive multidisciplinary evaluation rather than as an isolated determinant of operability. Additional RHVP findings such as very small central portal venous segments, focal narrowing, filling defects, poorly developed peripheral branches, extensive intrahepatic collaterals, or venovenous communications may nevertheless help anticipate technical difficulty, uncertain portal inflow, and the need for careful multidisciplinary discussion. This interpretation is consistent with previous reports emphasising that MRB feasibility depends on preserved intrahepatic portal venous anatomy and that intermediate IHPS patterns require cautious surgical selection [1,9,13].

The proposed structured RHVP assessment therefore separates mandatory intrahepatic anatomical criteria, which support assessment of anatomical suitability for physiological portal reconstruction, from additional angiographic findings, which should be systematically documented but currently cannot be considered independent predictors of early graft function. This framework may be particularly useful for future refinement of intermediate anatomical categories and for the development of imaging-derived risk stratification once larger multicentre datasets are available.

The present study has several limitations. It represents the initial experience of a single tertiary referral centre with a relatively limited number of surgical procedures. The retrospective design and small number of unsuccessful MRB procedures preclude statistical evaluation of individual angiographic findings as independent predictors of early graft function. The consensus-based interpretation reflects real-world multidisciplinary practice, but formal interobserver agreement testing was not per-

formed. Patient age and sex were not incorporated into the proposed imaging framework because the framework was intended to standardise anatomical RHVP interpretation rather than clinical risk stratification; age itself was not considered a radiological contraindication to RHVP in an experienced paediatric interventional radiology setting. The interval between RHVP and MRB varied substantially and was not analysed as a determinant of early graft function; therefore, potential interval-related changes in portal venous anatomy or clinical condition cannot be excluded. The aetiology of EHPVO and long-term postoperative clinical results were not incorporated into the radiological framework because these were managed within the surgical and hepatological follow-up pathway. Prospective multicentre studies with larger patient populations will be required to validate the proposed assessment framework and determine the prognostic significance of additional angiographic features.

Despite these limitations, the proposed protocol provides a practical and standardised approach to preoperative RHVP interpretation. It was applied in the same format by four paediatric interventional radiologists, with joint intraprocedural assessment by two radiologists and a second review during surgical discussion. By standardising evaluation of the entire intrahepatic portal venous system, it facilitates communication between radiologists and surgeons, improves consistency of preoperative reporting, and provides a structured foundation for future refinement of imaging-based multidisciplinary assessment before MRB.

## Conclusions

Structured multiparametric RHVP enables comprehensive preoperative evaluation of the entire intrahepatic portal venous system before MRB.

Routine assessment from multiple hepatic veins using standard anteroposterior and lateral projections extends angiographic evaluation beyond the Rex recess and provides detailed characterisation of portal venous anatomy relevant to surgical planning.

The proposed structured reporting framework distinguishes mandatory intrahepatic anatomical criteria supporting suitability for physiological portal reconstruction from additional angiographic findings that should be systematically documented. RHVP should be regarded as the angiographic assessment of the intrahepatic portal venous component of a broader qualification pathway, complementing Doppler ultrasonography, CT/MRI, conduit assessment, surgical factors, and multidisciplinary decision-making rather than replacing them. This approach complements existing type-based classifications, may help refine intermediate anatomical patterns, and establishes a foundation for future studies evaluating imaging-derived modifiers of surgical complexity, early graft function, and imaging-derived risk stratification before MRB.

## Disclosures

1. Institutional review board statement: Not applicable.
2. Assistance with the article: None.
3. Financial support and sponsorship: None.
4. Conflicts of interest: None.
5. AI use statement: OpenAI's ChatGPT was used for language editing and formatting assistance during manuscript preparation.

No AI-assisted tool was used for data collection, statistical analysis, image interpretation, or generation of research conclusions. The authors reviewed and edited all AI-assisted output and take full responsibility for the final manuscript.

## References

1. Superina R, Shneider B, Emre S, Sarin S, de Ville de Goyet J. Surgical guidelines for the management of extrahepatic portal vein obstruction. *Pediatr Transplant* 2006; 10: 908-913.
2. Superina R, Bambini DA, Lokar J, Rigsby C, Whittington PF. Correction of extrahepatic portal vein thrombosis by the mesenteric to left portal vein bypass. *Ann Surg* 2006; 243: 515-521.
3. Lautz TB, Keys LA, Melvin JC, Ito J, Superina RA. Advantages of the meso-Rex bypass compared with portosystemic shunts in the management of extrahepatic portal vein obstruction in children. *J Am Coll Surg* 2013; 216: 83-89.
4. Guérin F, Bidault V, Gonzales E, Franchi-Abella S, de Lambert G, Branchereau S. Meso-Rex bypass for extrahepatic portal vein obstruction in children. *Br J Surg* 2013; 100: 1606-1613.
5. Yamoto M, Chusilp S, Alganabi M, Sayed BA, Pierro A. Meso-Rex bypass versus portosystemic shunt for the management of extrahepatic portal vein obstruction in children: systematic review and meta-analysis. *Pediatr Surg Int* 2021; 37: 1699-1710.
6. Zhang J, Li L. Rex shunt for extrahepatic portal venous obstruction in children. *Children (Basel)* 2022; 9: 297. DOI: 10.3390/children9020297.
7. Aurelus PJ, Brenes Guzmán S, Medrano De La Rocha GA, Núñez Enríquez JC, González Chávez JL, et al. Outcomes of meso-Rex bypass for prehepatic portal hypertension in pediatric patients. *J Pediatr Surg Open* 2024; 5: 100105. DOI: 10.1016/j.jpso.2023.100105.
8. Kwan SW, Fidelman N, Durack JC, Roberts JP, Kerlan RK Jr. Rex shunt preoperative imaging: diagnostic capability of imaging modalities. *PLoS One* 2011; 6: e22222. DOI: 10.1371/journal.pone.0022222.
9. Chaves IJ, Rigsby CK, Schoeneman SE, Kim ST, Superina RA, Ben-Ami T. Pre- and postoperative imaging and interventions for the meso-Rex bypass in children and young adults. *Pediatr Radiol* 2012; 42: 220-232.
10. Carollo V, Marrone G, Cortis K, Mamone G, Caruso S, Milazzo M, et al. Multimodality imaging of the Meso-Rex bypass. *Abdom Radiol (NY)* 2019; 44: 1379-1394.
11. Puppala S, Patel J, Woodley H, Alizai NK, Kessel D. Preoperative imaging of left portal vein at the Rex recess for Rex shunt formation using wedged hepatic vein carbon dioxide portography. *J Pediatr Surg* 2009; 44: 2043-2047.
12. Bertocchini A, Falappa P, Grimaldi C, Bolla G, Monti L, de Ville de Goyet J. Intrahepatic portal venous systems in children with noncirrhotic prehepatic portal hypertension: anatomy and clinical relevance. *J Pediatr Surg* 2014; 49: 1268-1275.
13. Chang X, Liu L, Wang J, Liang Q, Liang J, Liu Z, Wen Z. Effectiveness of preoperative intrahepatic portal venous classification system in guiding preoperative surgical decisions and predicting hypotensive effects after Meso-Rex bypass for children with EHPVO. *J Pediatr Surg* 2025; 60: 161990. DOI: 10.1016/j.jpedsurg.2024.161990.
14. Chen W, Rodriguez-Davalos MI, Facciuto ME, Rachlin S. Experience with duplex sonographic evaluation of meso-Rex bypass in extrahepatic portal vein obstruction. *J Ultrasound Med* 2011; 30: 403-409. DOI: 10.7863/jum.2011.30.3.403.