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FLUORESCENCE-GUIDED LAPAROSCOPIC LIVING-DONOR HEPATECTOMY TO ACQUIRE AN S2 GRAFT

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Background. Liver transplantation (LT) in children with low body weight using the left lateral segment from a living donor is associated with large-for-size syndrome (LFSS). We present the first Russian clinical case of laparoscopic living-donor hepatectomy to acquire an S2 graft. **Materials and methods.** A six-month-old child who had biliary atresia-induced liver cirrhosis was prepared for transplantation. The child's 20-year-old mother was the donor. The left lateral segment had a volume of 426 mL (graft-to-recipient weight ratio, GRWR, was 5.9%). Indocyanine green fluorescence-guided laparoscopic intracorporeal reduction up to the S2 segment was performed. **Results.** Donor operation time was 230 minutes, blood loss was 50 ml. The postoperative period was uneventful; the donor was discharged on day 9. The recipient had no surgical complications; a rejection episode was successfully managed. The child was discharged with a satisfactory graft function. **Discussion.** Fluorescence-guided laparoscopic living-donor hepatectomy to acquire an S2 graft is effective and safe. The presented technique may be an effective solution when performing monosegmental LT under the high-risk conditions of LFSS.

Keywords: monosegment liver transplantation, laparoscopic living-donor hepatectomy, pediatric transplantation, indocyanine green.

INTRODUCTION

Pediatric liver transplantation (LT) has seen remarkable advancements over the years, leading to excellent short-term and long-term survival rates [1–3]. For many children with advanced liver disease, it is considered the only curative treatment option, providing a definitive solution to their end-stage liver condition [3, 4]. Certain pediatric cases present significant challenges in transplantation, often carrying higher risks. For instance, children weighing less than 7 kg face increased postoperative mortality [5, 6], primarily due to their small anthropometric parameters and the potential mismatch between graft size and the recipient's abdominal cavity. In living donor liver transplantation, the left lateral segment (LLS) of the liver (Couinaud segments 2 and 3) is commonly used. However, even the LLS may be too large for the recipient, increasing the risk of large-for-size syndrome [7, 8].

The graft-to-recipient weight ratio (GRWR) is a widely used and simple method to assess the suitability of a living related donor for a LT, expressed as a percentage. A GRWR ≥4% is considered a significant risk factor for developing over-sized graft syndrome [9]. This syndrome is characterized by the development of respiratory failure against the background of diaphragmatic excursion disorders, insufficient visceral perfusion, graft compression in the abdominal cavity, which may eventually affect the function and survival of graft and recipient [10–11].

Performing either an "anatomic" or "non-anatomic" reduction of the LLS graft is a potential solution to manage excess graft material in LT [12–16]. Each method has its own advantages and limitations. Non-anatomic reduction may not always adequately address the issue of excess graft thickness. On the other hand, anatomic reduction, which involves removing one of the segments to achieve monosegmental grafting, is considered technically more complex.

Over the past decade, minimally invasive surgery for living donors has become increasingly common in major transplant centers. While initially limited to a few cases in the mid-2010s, by the early 2020s, this approach has been widely recognized as the gold standard, particularly for LLS sectionectomy in living donors [17–19]. Our center adopted this technique in 2016, and it has since become routine practice [20]. Given the need for graft reduction in certain cases and our extensive experience with laparoscopic liver surgery, we have integrated existing technologies and surgical techniques to perform

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laparoscopic liver resection in living donors to obtain an S2 graft. Similar cases have already been reported in global clinical practice [7, 21, 22].

Thus, we present a detailed description of our clinical case, marking the first such intervention performed in Russia.

CLINICAL CASE

The patient, a 6-month-old infant weighing 8 kg, was admitted to our center with cirrhosis due to congenital biliary tract malformation (biliary atresia). At the time of admission, the calculated PELD score was 20. Following a thorough multisystem evaluation, the patient was deemed eligible for a liver transplant, with no absolute contraindications to surgery. Abdominal MSCT revealed a Hiatt 3 variant arterial anatomy, where the left hepatic lobe artery originated from the common hepatic artery and the right hepatic lobe artery arose from the superior mesenteric artery. The portal and hepatic vein anatomy were found to be standard.

The recipient's mother, a 20-year-old woman with a body mass index of 24.4, was assessed as the sole potential related liver donor. A thorough evaluation of her health status, liver function, and parenchymal quality revealed no contraindications to donation. Bolus contrast-enhanced abdominal MSCT was performed to analyze her vascular anatomy. The arterial anatomy was classified as Hiatt 4, where the left hepatic artery bifurcated into branches supplying S4 and S3, while the artery to S2 originated independently from the left gastric artery. Portal vein anatomy followed the standard Nakamura type A configuration, with sequential branching into S3 and S2. The S3 and S2 veins converged to form the left hepatic vein, with all three hepatic veins draining separately into the inferior vena cava (IVC) (Fig. 1).

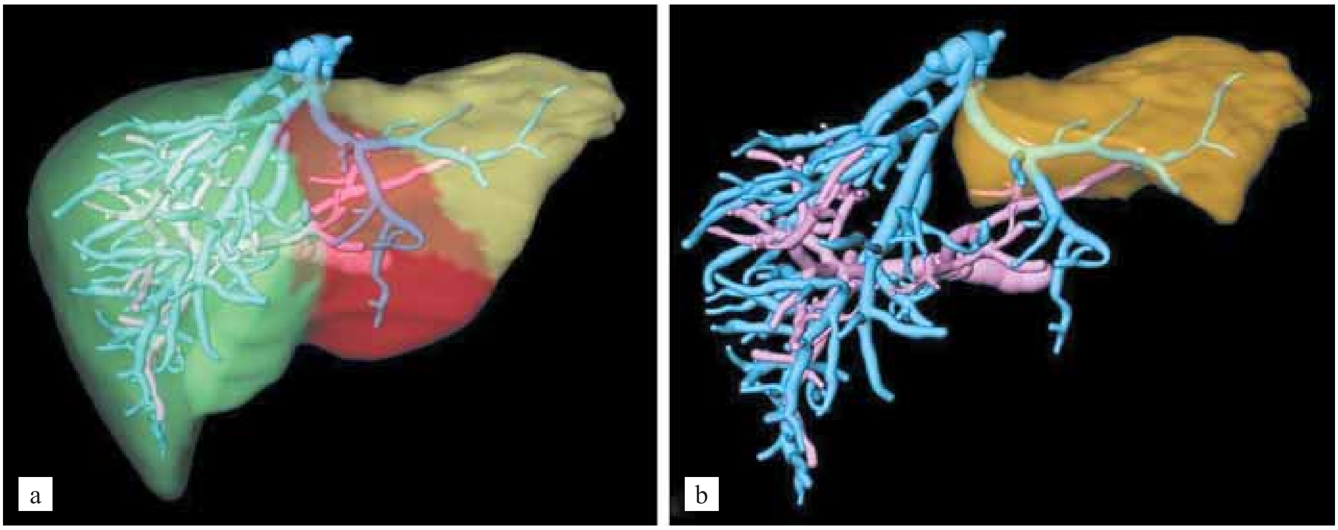

Fig. 1. 3D reconstruction of contrast-enhanced CT images of the hepatic veins (blue) and portal vein branches (pink) 2D CT images. a, whole liver; b, second segment

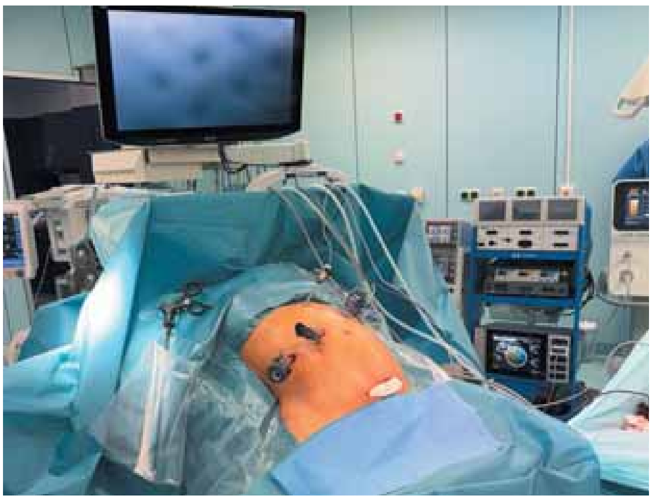

Fig. 2. Donor position and trocar placement on the operating table

Magnetic resonance cholangiopancreatography (MRCP) revealed no biliary tract anomalies. Computer volumetry and 3D modeling estimated the left lateral segment (LLS) volume at 426 mL, with a GRWR of 5.9%. The maximum LLS thickness-to-recipient anteroposterior abdominal dimension ratio was 1.08. The estimated S2 monosegmental volume was 206 mL, with a GRWR of 2.86%. Given these findings, the optimal approach was an intracorporeal anatomic reduction of the donor's LLS under fluorescence guidance to obtain an S2 graft.

SURGICAL TECHNIQUE

Surgery in the donor

The donor was positioned in reverse Trendelenburg (table tilted flat with legs down) with legs spread to maintain the French position (Fig. 2). Four trocars *were inserted into the abdomen (one 10 mm, two 12 mm, and one 5 mm) as illustrated in Fig. 2. The procedure was performed under an intra-abdominal pressure of 12 mmHg using 30-degree optics and a high-resolution laparoscopic system with ICG mapping functionality (Olympus, Japan).*

The liver left lobe was mobilized by transecting the round and left triangular ligaments. The falciform ligament was dissected down to the caval gate, exposing the middle and left hepatic veins. The lesser omentum was also divided, allowing for the isolation of the S2 artery along its course. As an additional anatomical landmark, the inferior pubic ligament was identified and transected at the mouth of the left hepatic vein.

Subsequently, the LLS was rotated counterclockwise, facilitating the isolation of key elements of the hepatoduodenal ligament, including the left hepatic artery and the left branch of the portal vein. Parenchymal transection was performed 5 mm lateral to the falciform ligament using an ultrasonic dissector, bipolar coagulation, and a harmonic scalpel. Tubular structures were clipped and transected during the separation process. Following parenchymal division, the left hepatic vein was bypassed, leaving the LLS connected only by the main afferent vessels and the umbilical plate, which contains bile ducts and their vascular supply.

Next, the Glissonean pedicle of segment 3 (G3) was isolated separately, and a bulldog vascular clamp was applied. Indocyanine green (ICG) was then injected intravenously at a dose of 0.05 mg/kg body weight. Under fluorescence navigation, the boundaries of segment 3 were clearly visualized, allowing for precise intracorporeal reduction of the left lateral segment (LLS) (Fig. 3).

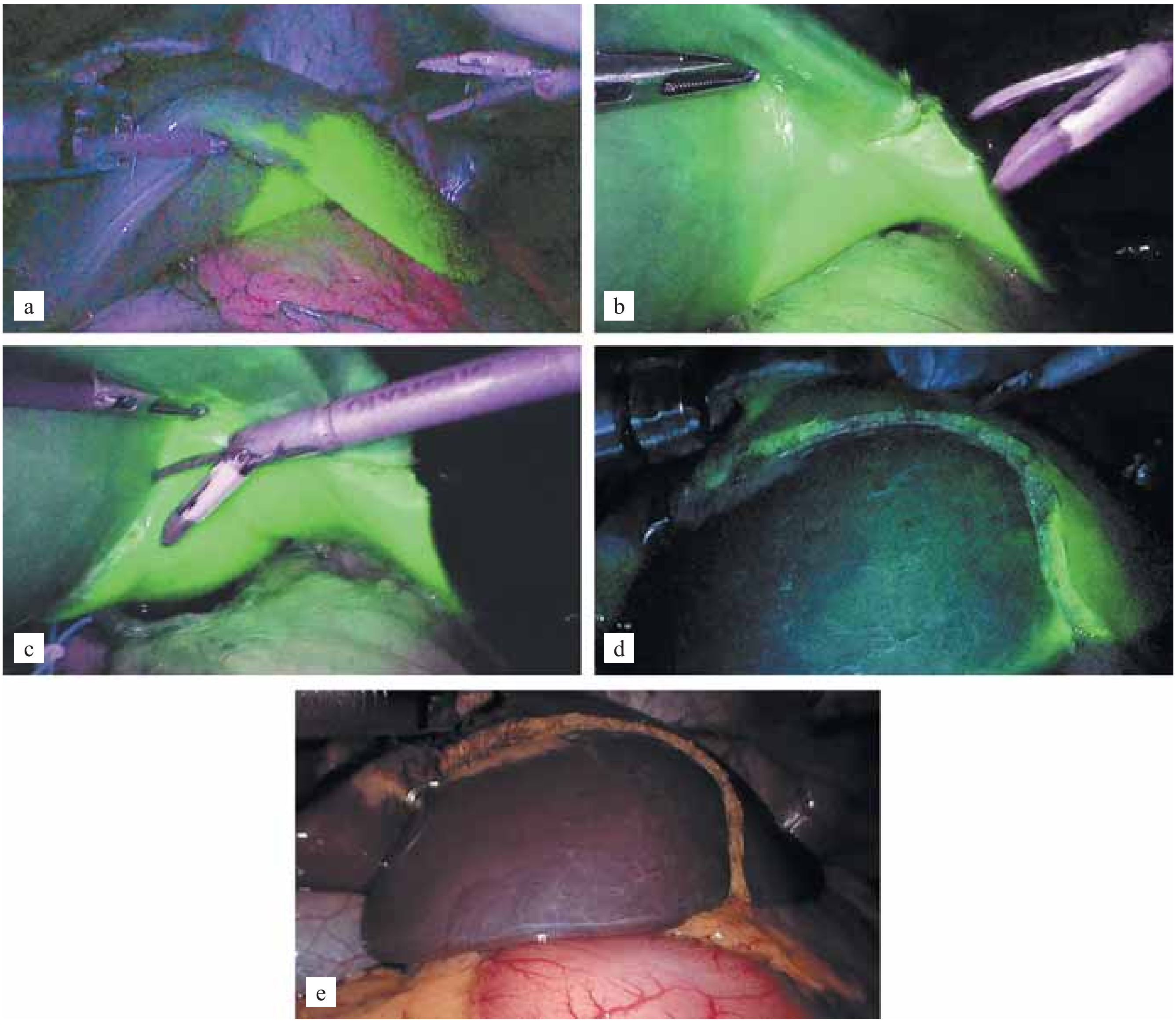

Fig. 3. ICG guided liver resection: a–d, Boundaries of the S2 segment under ICG guidance; e, parenchyma transection line between S2 and S3

During parenchymal dissection, the S3 vein was carefully clipped and transected. In the final stage, segment 3 was completely separated from the future graft, and a hem-o-lok clip was applied to the Glissonean pedicle to ensure vascular control.

Next, a Pfannenstiel laparotomy was performed, and a trocar was placed for the self-opening extraction bag. Using fluorescence navigation, the confluence of the lobular bile ducts was visualized, and the transection line for the left lobular duct was outlined. After that, The left lobular bile duct, aberrant artery to S2, and left branch of the portal vein were sequentially clipped and transected. The left hepatic vein was then divided using a unilateral linear stapler. The S2 graft, along with the separated S3, was placed in a container and extracted through the prepared incision.

The graft was transferred to the dissecting table for preservation and preparation for subsequent implantation. The final mass of the monosegment S2 graft was 180 g.

Surgery in the recipient

Transplantation of the S2 liver fragment was performed using a bisubcostal incision. Following hepatectomy with IVC preservation, the graft was positioned in the recipient's abdominal cavity. The implantation technique followed the standard protocol for LLS revascularization used at the Center.

So, caval anastomosis was established between the graft's hepatic vein and the common confluence of the recipient's three hepatic veins using a continuous twisted suture with a 5/0 polydioxanone monofilament. The portal vein was reconstructed with a 6/0 suture, adapting the difference in vein diameters through longitudinal dissection of the recipient's portal vein, following the Center's standard approach.

Arterial reconstruction was performed end-to-end between the graft artery and the recipient's right hepatic artery using the parachute technique with a 7/0 Prolene suture. Biliary reconstruction was carried out on a Roux-en-Y jejunal loop with a knot suture and an external frame drainage. Notably, no bleeding or bile leakage was observed along the graft reduction plane.

RESULTS

Operation on the donor lasted 230 minutes with a blood loss of 50 mL. The postoperative period was uneventful; the donor was discharged on postoperative day 9. A comprehensive outpatient examination one month later showed no signs of liver dysfunction or any deterioration in the donor's health or quality of life.

The recipient experienced no surgical complications postoperatively but developed an episode of graft rejection. This was successfully managed with glucocorticoid pulse therapy and an adjustment of maintenance immunosuppression. The child was subsequently discharged with satisfactory graft function under outpatient follow-up.

DISCUSSION

In this clinical case, we presented the first Russian experience of using a laparoscopic approach for the removal of a monosegmental graft for pediatric liver transplantation. The combination of fluorescent navigation and the Glissonean approach enabled the intracorporeal separation of segment 3, allowing for the retrieval of a viable segment 2 graft.

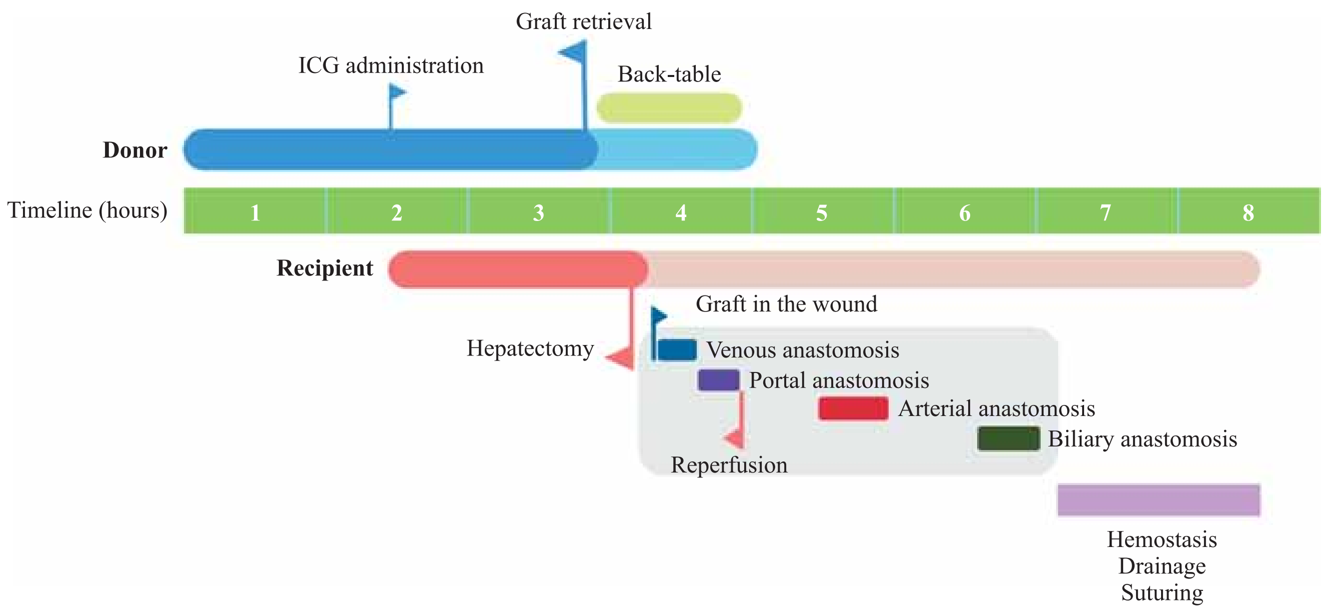

Fig. 4. Sequence of surgical steps of donor and recipient surgery

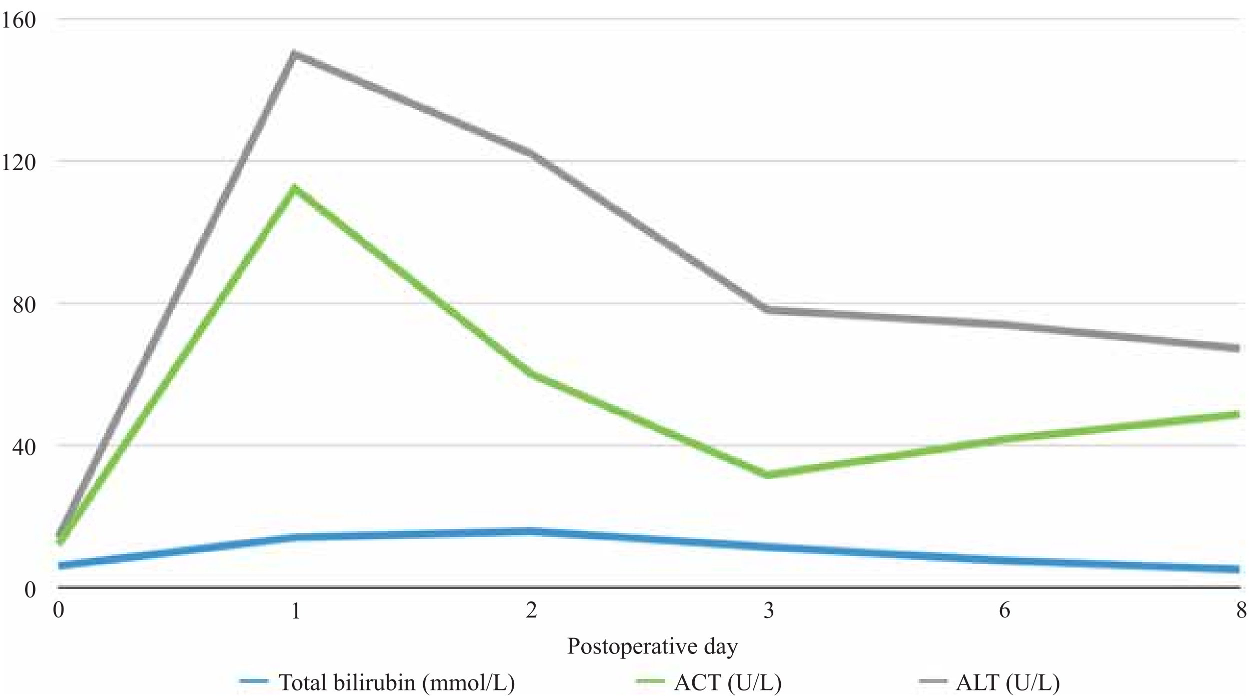

Fig. 5. Dynamics of the main laboratory parameters of the donor in the first 8 days after surgery

LT in children with low body weight is often constrained by the unavailability of an appropriately sized liver fragment from a related donor. Large-for-size syndrome poses a significant risk, potentially leading to complications such as impaired visceral perfusion, graft compression, and restricted diaphragm excursion. Essentially a variant of abdominal compartment syndrome, this condition makes low-weight pediatric patients particularly vulnerable. Anatomic reduction of the left lateral segment of the donor liver is one of the key strategies to mitigate these risks and improve transplant outcomes.

Laparoscopic removal of liver fragments for transplantation is still considered a technically demanding procedure, and is generally performed only at high-volume transplant centers by experienced surgeons [18, 19, 23]. To date, only four such operations using laparoscopic techniques have been reported, including our case [21, 22, 24]. Interestingly, ICG fluorescence imaging and in-situ separation technique were used in each of them, while the Glissonean approach was used in only two cases.

ICG navigation is becoming a prevalent tool in laparoscopic liver surgery, particularly for intraoperative cholangiography, its ability to accumulate in certain tumors and finally for mapping of anatomical fragments of the liver as in our case. And this is by no means a complete list of ways to use this dye [25, 26].

Thus, the presented technique offers several distinct advantages. First, the laparoscopic approach has already been widely recognized as an effective and safe method for donor hepatectomy. According to multiple studies, laparoscopic lateral sectionectomy in living donors is increasingly regarded as the new standard for this procedure [19]. Second, the combination of ICG-negative staining and the Glissonean approach enables precise delineation of the perfusion zone, ensuring that only viable parenchyma is preserved within the graft. Third, performing *in situ* graft reduction minimizes ischemia time compared to reduction on the dissecting table. Additionally, when comparing *in situ* reduction in the donor versus *in situ* reduction in the recipient, donor-stage reduction is preferable as it reduces both blood loss and the surgical complexity for the recipient. Moreover, meticulous preoperative surgical planning plays a crucial role in optimizing outcomes for living donor liver transplantation.

CONCLUSION

In this clinical case, we reported the first Russian experience of laparoscopic liver resection in a living donor to obtain an S2 graft under fluorescence navigation. This technique minimized risks for both the donor and recipient while ensuring high precision and safety. The integration of laparoscopic methods with ICG fluorescence imaging for real-time navigation has significantly enhanced outcomes in segmental liver transplantation for young children with low body weight, a population for whom conventional transplantation techniques may be unsuitable. Our experience underscores the potential of this approach and highlights the need for further research to establish fluorescence-guided laparoscopic resections as a standard practice in pediatric liver transplantation.

The authors declare no conflict of interest.

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