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Biological abdominal wall expansion in pediatric liver recipients after transplantation with large-for-size organs

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Abstract

Background: After pediatric split liver transplantation, intra-abdominal loss of domain due to large-for-size left lateral grafts is a frequent problem for fascial closure and potentially leads to reduced liver perfusion and abdominal compartment syndrome. Therefore, delayed fascial closure with the use of temporary silastic meshes and reoperation or alternative fascial bridging procedures are necessary.

Methods: Between March 2019 and October 2021, biologic meshes were used for abdominal wall expansion in 6 cases of pediatric split liver transplantation. These cases were analyzed retrospectively.

Results: One male and 5 female children with median age of 6 months (range: 0–57 months) and weight of 6 kg (range: 3.5–22 kg) received a large-for-size left lateral graft. Graft-to-recipient weight ratio (GRWR) was 4.8% (range: 1.5%–8.5%) in median. Biologic mesh implantation for abdominal wall expansion was done in median 7 days (range: 3–11 days) after transplantation when signs of abdominal compartment syndrome with portal vein thrombosis in 3 and of the liver artery in 1 case occurred. In 2 cases, bovine acellular collagen matrix and 4 cases ovine reinforced tissue matrix was used. Median follow-up was 12.5 months (range: 4–28 months) and showed good liver perfusion by sonography and normal corporal development without signs of ventral hernia. One patient died because of fulminant graft rejection and emergency retransplantation 11 months after the initial transplantation.

Conclusions: Biologic meshes can be used as safe method for abdominal wall expansion to achieve fascial closure in large-for-size liver transplant recipients. Usage for primary fascial closure can be considered in selected patients.

KEYWORDS
abdominal compartment syndrome, complications of liver transplantation, large-for-size grafts, pediatric liver transplantation, surgical complications

Abbreviations: BMI, body mass index; ca, circa; cm, centimeter; CRP, C-reactive protein; fig, figure; GRWR, graft recipient weight ratio; kg, kilogram; LDLT, living donor liver transplantation; LLS, left lateral segment; m^2, square meters; mg/L, milligram per liter; min, minutes; mm, millimeter; NPWT, negative pressure wound therapy; PTCD, percutaneous transhepatic cholangiodrainage.

1 | INTRODUCTION

Liver transplantation is a curative treatment option for pediatric patients with advanced liver disease.[1–3] However, finding a size-matching organ often represents a problem due to shortage of cadaveric donors and delayed corporal development of the recipients. Although living donor liver transplantation (LDLT) is a good alternative to cadaveric donors, graft size mismatch remains problematic. In order to avoid complications like abdominal compartment syndrome, reduced liver perfusion with consecutive graft dysfunction and compromised kidney function, some centers propose an optimal graft to recipient weight ratio (GRWR) of 2.5% or lower and not exceeding 4.0%.[4–7] In some cases of transplantations this factor could not always be achieved. Therefore, different therapy strategies like delayed fascial closure with temporary silastic mesh[6,8,9] or polytetrafluoroethylene patch[10] and usage of non-vascularized abdominal rectus muscle fascia as allograft for abdominal wall expansion[11,12] has been developed and described in literature as safe methods. In some cases of large-for-size liver transplantations of children in our department biological meshes were used for definitive abdominal wall expansion to avoid a prolonged open abdomen situation.

2 | METHODS

Since 2008 in total 243 pediatric liver transplantations were performed in 212 patients at our center. After screening these patients, 6 cases of pediatric liver transplantations with large-for-size grafts and abdominal wall expansion using biologic meshes between March 2019 and October 2021 were identified. Analysis included recipient demographics, intraoperative, and postoperative course. Regular follow-up was performed in all cases and was included in the analysis until March 2022. The collected data were stored in Castor EDC clinical data management system. The most important data are summarized for each case individually in Table 1. The study was approved by the ethics committee of the University of Regensburg (Nr. 19-1547-101).

2.1 | Meshes

- **SurgiMend^{R} Integra:** acellular collagen matrix derived from fetal and neonatal bovine dermis (resorbable).
- **OviTex™ 1s:** sterile bioscaffold (6 layers) composed of ovine derived extracellular matrix and reinforced with resorbable polyglycolic acid fibers (resorbable).
- **OviTex™ 2s:** sterile bioscaffold (8 layers) composed of ovine derived extracellular matrix and reinforced with permanent polypropylene fibers (semiresorbable).

2.2 | Graft volume estimation

In case of a planned LDLT, the graft volume is estimated preoperative by a radiologist in our department. The volume is measured from a CT scan using the Siemens healthineers *syngo*.via program.

2.3 | Operative technique

In all cases, a LLS graft either from a living or from a deceased donor was used for transplantation in piggyback technique with end-to-end arterial and porto-venous anastomosis. Anastomosis of the bile duct was always performed as biliodigestive anastomosis. The biologic meshes used consisted of ovine reinforced tissue matrix (Ovitex 1s and 2s, TELA Bio) or bovine acellular collagen matrix (SurgiMend 3mm, Integra). In all cases, the mesh was placed as interposition to close the fascial gap in the median laparotomy and fixated with 1-0 PDS or 0 Vicryl as continuous suture (Figure 1). Skin closure above the mesh was achieved in 4 cases simultaneously to mesh implantation and in 2 cases a subcutaneous negative pressure wound therapy (NPWT) was used as bridging before secondary skin closure after 2–3 days.

3 | RESULTS

3.1 | Indication and preoperative setting

The indication for transplantation was in 3 cases biliary atresia, in 2 cases acute liver failure and in one case Caroli syndrome. The median age of the recipients was 6 months (range: 0–57 months). 1 patient was male and 5 females with a median height of 64 cm (range: 51–116 cm) and a median weight of 6 kg (range: 3.5–22 kg). Consequently, the median BMI was 14.9 kg/m^2 (range: 13.5–17.3 kg/m^2). All 6 recipients reached 3 points at Charlson Comorbidity Index due to their liver disease. The graft was retrieved by living donation in 4 cases, in which the graft volume was underestimated by in median 20.4% (range: 1.6%–23.4%), and by deceased donor liver split in 2 cases. GRWR was 4.8% (range: 1.5%–8.5%) in median.

3.2 | Operation and postoperative course

The primary transplantation surgery lasted in median 388 min (range: 333–478 min). Five transplantations had a normal anatomy with 1 arterial anastomosis, in 1 patient 2 arterial anastomoses were necessary due to an accessory left artery. Immunosuppression therapy was administered per standard with basiliximab (day 0 and 4), prednisolone, and cyclosporin A. Depending on the intraoperative course postoperative anticoagulation was administered with heparin in prophylactic or therapeutic dose and in some cases combined with ASS. In all cases, the mesh implantation was performed delayed with a median of 7 days (range: 3–11 days) after liver transplantation and a median operation time of 76 min (range: 45–113 min). The median fascial gap to bridge was measured with 4 cm (range: 2–6 cm). In 5 cases, an abdominal compartment syndrome with thrombosis of the portal vein in 3 patients and, additionally, of the liver artery in 1 patient was diagnosed before mesh implantation. In these cases, an operative thrombectomy was necessary. No superinfection of the mesh was detected in any of the 6 cases, despite severe

TABLE 1 Overview of the individual cases

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Gender	Female	Female	Female	Female	Female	Male
Age (months)	6	7	0	4	57	6
Weight (kg)	6	7.1	3.5	5.5	22	6.1
Indication for LTx	Caroli-syndrome	Bile duct atresia	Acute liver failure	Bile duct atresia	Acute liver failure	Bile duct atresia
CCI	3	3	3	3	3	3
PELD/MELD/HU	28	17	HU (30)	34	HU (28)	32
LDLT	Yes	Yes	No	Yes	No	Yes
Pre-procurement allograft volume estimation (ml)	257.8	199.2	N/A	227.1	N/A	252,9
Post-procurement allograft volume (g)	262	260	297	282	330	321
GRWR (%)	4.4	3.7	8.5	5.1	1.5	5.3
Post-LTx anticoagulation	ASS, Heparin (therapeutic)	Heparin (prophylactic)	Heparin (prophylactic)	Heparin (therapeutic)	ASS, Heparin (therapeutic)	Heparin (therapeutic)
Length of ICU stay (days)	7	29	12	32	26	16
Length of hospital stay (days)	55	58	104	97	64	72
Interval until mesh implantation (days)	4	9	3	11	8	6
Indication for re-operation	Fascial dehiscence	Pathologic duplex sonography	Raising transaminases and lactate, pathologic duplex sonography	Pathologic duplex sonography	Planned second look	Increased need of catecholamines, raised bladder pressure
Signs of abdominal compartment	Reduced liver perfusion in duplex sonography after fascial closure	Portal vein thrombosis	Liver artery thrombosis	Portal vein thrombosis	Reduced liver perfusion in duplex sonography after fascial closure	Portal vein thrombosis
Fascial gap (cm)	2	3	5	2	6	5
NPWT	No	Yes	No	Yes	No	No
Other complications before mesh implantation	Bleeding at venous anastomosis	Colon perforation and intestinal bleedings before LTx	No	Paralytic ileus after LTX	No	No
Mesh type	OviTex 1 s	Surgimend	Surgimend	OviTex 2 s	OviTex 1 s	OviTex 1 s
Complications after mesh implantation	No	PTCD at 2 months	Acute graft rejection, Re-LTx and Death at 11 months	PTCD at 3 months	PTCD at 1 month	No

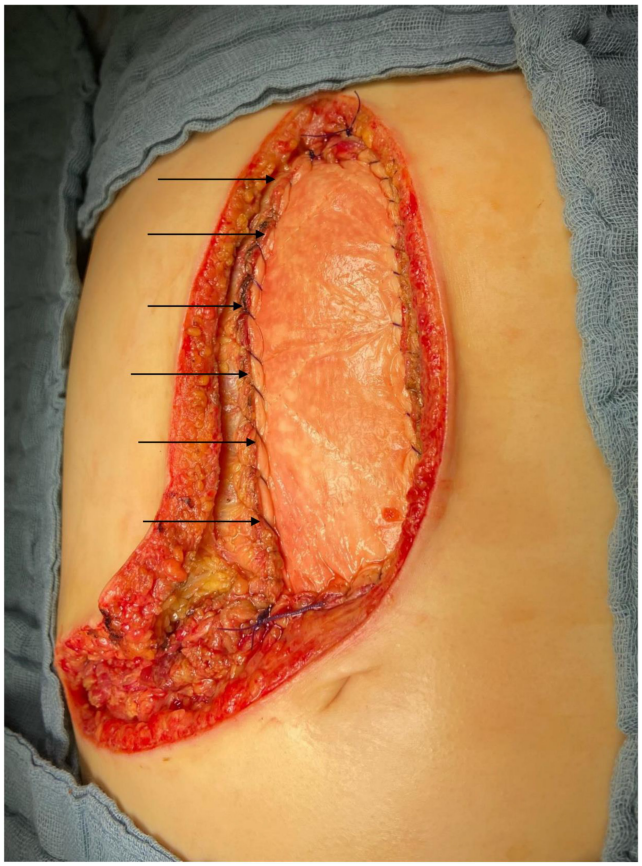

FIGURE 1 Picture shows a L-laparotomy in the right upper quadrant. The biologic mesh is placed as interposition for abdominal wall expansion and fixated with continuous suture (marked with arrows)

abdominal contamination through to an ischemic colon perforation prior to liver transplantation in 1 patient. CRP measurements reached the highest level on Day 2 after mesh implantation with median 146 mg/L (range: 76–229 mg/L) decreasing steadily hereinafter with median results of 62 mg/L (range: 24–89 mg/L), 47.5 mg/L (range: 23–72 mg/L) and 33 mg/L (range: 16–50 mg/L) on Day 4, 6, and 8, respectively. Fever was not seen in any case. Postoperative liver perfusion was evaluated regularly with duplex sonography and good results after the use of the biological mesh were documented (Figure 2). Median initial postoperative stay on intensive care unit and total postoperative hospital stay was 21 (range: 7–32 days) and 68 (range: 55–104 days) days. The wounds had completely healed at hospital discharge in all recipients (Figure 3).

3.3 | Follow-up

The structured follow-up took place every 3 months or on demand with a median follow-up of 12.5 months (range: 4–28 months). One patient died during follow-up because of a fulminant graft rejection and emergency retransplantation 11 months after the initial transplantation. Here, despite the mesh, only moderate adhesions were described by the surgeon. Furthermore, three patients required percutaneous transhepatic cholangiodrainage (PTCD) therapy for stenosis of the biliodigestive anastomosis and bile leckage. In all cases, the corporal development was age-appropriate and pain or restricted movement due to the mesh were not seen or described by the parents. No relevant hernia could be detected either through clinical examination or sonography during follow-up (Figure 3). Each follow-up examination included duplex sonography of the liver perfusion and showed normal duplex signals (Figure 2) in all cases.

4 | DISCUSSION

Finding a suitable size-matched graft either through postmortal or living donation is demanding and represents a serious problem, especially in pediatric liver transplantation.[4–12] Therefore, in many cases grafts with a GRWR exceeding the optimal values recommended in the literature[4–7] of 2.5%–4% have to be used which implicates a higher risk of abdominal compartment syndrome and reduced liver perfusion.[6,7] This was also seen in our case series, where, due to preoperative underestimating of the graft volume by ca. 20% or critical condition of the recipient, large-for-size left lateral grafts with GRWR up to 8.5% had to be used. Consequently, 4 cases of thrombosis of the portal vein or liver artery occurred. In order to reduce initial abdominal pressure and achieve an optimal liver perfusion, methods like delayed fascial closure by temporary implantation of a silastic mesh[6,8,9] or polytetrafluoroethylenepatch[10] are often used. Consecutively, one or more reoperations only for fascial closure are necessary if there are no other reasons for a second look surgery. Furthermore, due to usage of this kind of meshes in combination with NPWT for open abdomen situations a higher risk for intestinal fistulas exists.[13,14] Even though implantation of the biologic mesh in our patients was delayed to the transplantation procedure, usage for primary fascial closure in large-for-size pediatric liver transplantations should be considered in order to avoid second look surgery, especially if the portal-venous liver perfusion is reduced in duplex sonography after fascial closure. Even more, this should also be possible in a contaminated situation which is indicated by our patient with colon perforation and excellent outcome.[14–16]

A similar principle of abdominal wall expansion is applied by using non-vascularized abdominal rectus muscle fascia for fascial closure.[11,12] While this technique can also be used in contaminated situations with good results regarding postoperative wound healing, evolving ventral hernias and optimal liver perfusion, the limited amount of material to cover bigger fascial defects represents a great disadvantage compared with the biologic meshes in spite of their higher costs.

Furthermore, the possibility of a graft volume reduction either through non-anatomically resection or graft thickness reduction to prevent the risk of abdominal compartment syndrome in LDLT with large-for-size grafts is described.[4,5] Especially, recipients in the

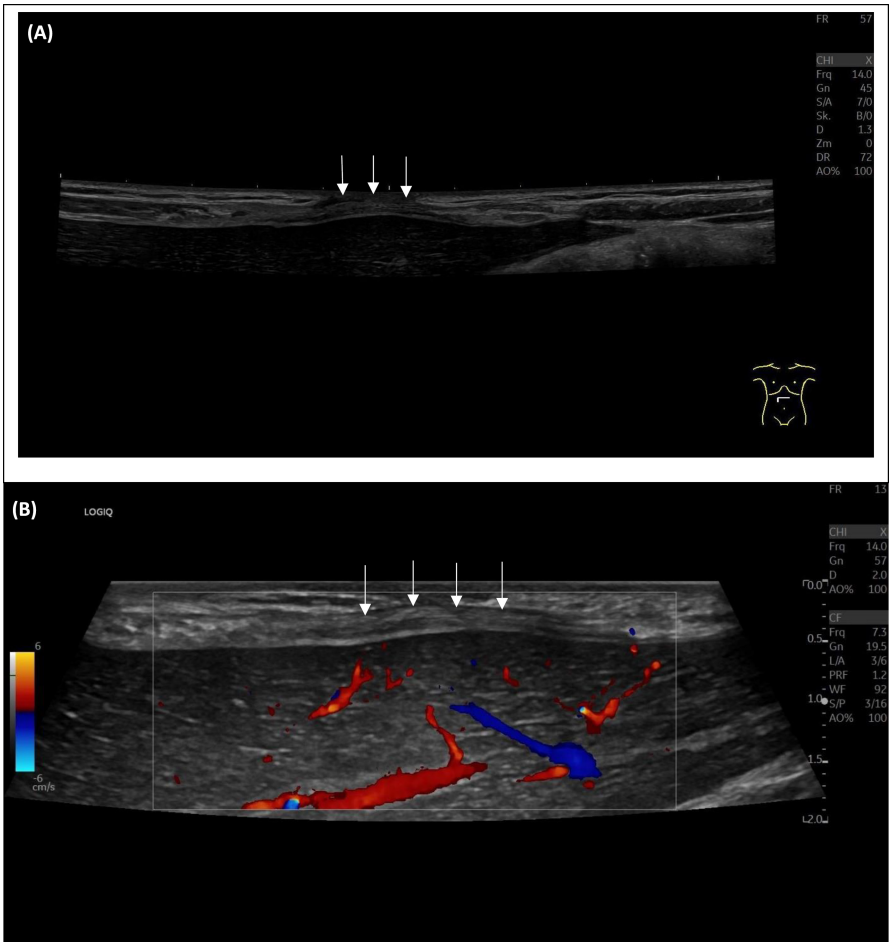

FIGURE 2 (A) Shown is a ultra sonography of the abdomen in the median line. The area of the bridging mesh is marked with arrows. A stable abdominal wall could be seen. (B) Duplex sonography with good liver perfusion. Bridging mesh marked with arrows

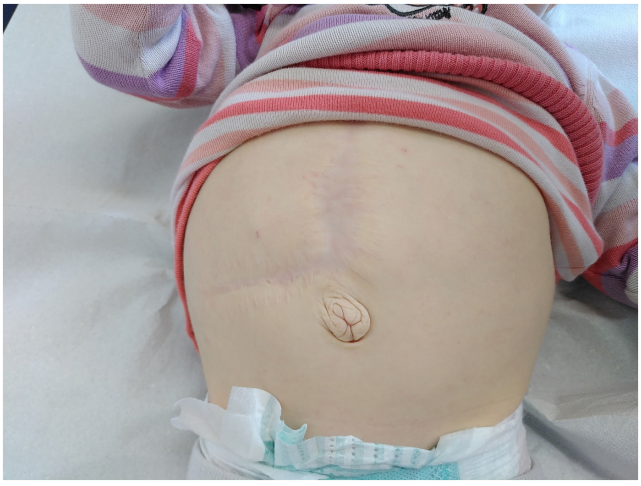

FIGURE 3 Follow-up photography ca. two years after transplantation. Wounds are completely healed. A ventral hernia could not be detected

reduced-thickness group showed good outcomes. Nevertheless, these techniques bear the risk of additional blood loss and complications like biliary leakage. Because of that, recipients have to be in a stable condition during transplantation in order to tolerate graft thickness reduction in our opinion.

Although no ventral hernia was detected in our patients, using resorbable biologic meshes, especially for bridging procedures, has a relevant risk of hernia occurrence.[17] Particularly, for biologic meshes consisting of porcine matrix, which were used in other trials for abdominal wall expansion in pediatric liver recipients,[18,19] recurrence rates up to 50% are reported in contaminated wounds.[20] Nevertheless, the clinical relevance of occurring hernias can still be low in our patient population due to adhesions of the liver graft to the abdominal wall below the developing gap. However, because of the high contamination risk during a biliodigestive anastomosis, which is necessary in many pediatric liver transplantations, and additionally critical ill patients treated with immunosuppressive agents, permanent synthetic meshes can only be used with a very high risk of relevant infections. It is possible that a reduction in hernia occurrence can be achieved by using semiresorbable reinforced tissue matrix. This new kind of biologic mesh showed promising results with low hernia recurrence rates in some clinical trials so far.[21,22]

However, different biologic meshes made of variable materials are available at the moment. In our patients, we used bovine und sheep matrix without seeing a relevant difference in long-term results; moreover, also porcine matrix showed comparable results already in the past.[18,19] At last, superiority of one kind of this biologic

mesh grafts cannot be postulated based on casual data. Therefore, prospective randomized multicenter studies with adequate case numbers have to be done in the future.

5 | CONCLUSION

Biologic mesh grafts can be used as safe method for abdominal wall expansion to achieve fascial closure in large-for-size pediatric liver transplantations. If no other reason necessitates a second look operation, reoperations could possibly be avoided by primary biologic mesh implantation. So far, recommendation of a specific material is not possible.

AUTHOR CONTRIBUTION

Markus Goetz participated in research design, data collection, data analysis, writing of the paper. Maria Jurczyk (no ORCID ID) participated in data collection, data analysis. Dirk Grothues participated in patient information, contributed pictures. Birgit Knoppke (no ORCID ID) participated in writing of the paper. Henrik Junger (no ORCID ID) participated in data analysis. Michael Melter and Hans J. Schlitt participated in writing of the paper. Stefan M. Brunner participated in research design, writing of the paper, contributed pictures. Frank W. Brennfleck participated in research design, data analysis, and writing of the paper.

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CONFLICT OF INTEREST

The author Frank W. Brennfleck has received research grants from the company 3M and is consultant for 3M and TELA Bio, Inc.; the author Birgit Knoppke is a member of the pediatric liver transplant working group (Germany); the authors Markus Goetz, Maria Jurczyk, Dirk Grothues, Henrik Junger, Michael Melter, Hans J. Schlitt, and Stefan M. Brunner declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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