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Effects of Adding Congested Segment IV to the Left Lateral Graft on Short-term Outcomes in Pediatric Living-donor Liver-transplant Recipients

Hikaru Aoki, MD,[1] Takashi Ito, MD, PhD,[1] Masaaki Hirata, MD, PhD,[1] Masashi Kadohisa, MD, PhD,[1] Miki Yamamoto, MD, PhD,[1] Elena Yukie Uebayashi, MD, PhD,[1] Hisaya Shirai, MD, PhD,[1] Shinya Okumura, MD, PhD,[1] Yuki Masano, MD, PhD,[1] Eri Ogawa, MD, PhD,[1] Tatsuya Okamoto, MD, PhD,[1] Hideaki Okajima, MD,[1,2] and Etsuro Hatano, MD, PhD[1]

Background. In some pediatric patients undergoing living-donor liver transplantation, segment IV without the middle hepatic vein can be added to a left lateral segment graft to obtain larger graft volume. Because no clear consensus on this technique exists, this study investigated the effects of congested areas on postoperative outcomes in pediatric patients with biliary atresia undergoing living-donor liver transplantation. **Methods.** We retrospectively reviewed data of recipients with biliary atresia aged ≤15 y who had undergone living-donor liver transplantation at Kyoto University Hospital between 2006 and 2021 and with graft-to-recipient weight ratios (GRWR) of ≤2%. Based on the percentage of congested area in the graft, patients were classified into the noncongestion (n = 40; ≤10%) and congestion (n = 13; >10%) groups. To compare the differences between groups with similar noncongestive GRWRs and investigate the effect of adding congested areas, patients in the noncongestion group with GRWRs of ≤1.5% were categorized into the small noncongestion group (n = 24). **Results.** GRWRs and backgrounds were similar between the noncongestion and congestion groups; however, patients in the congestion group demonstrated significantly longer prothrombin times, higher ascites volumes, and longer hospitalization. Further, compared with the small noncongestion group, the congestion group had significantly greater GRWR and similar noncongestive GRWR; however, the congestion group had significantly longer prothrombin time recovery ($P = 0.020$, postoperative d 14), higher volume of ascites ($P < 0.05$, consistently), and longer hospitalization ($P = 0.045$), requiring significantly higher albumin and gamma-globulin transfusion volumes than the small noncongestion group ($P = 0.027$ and $P = 0.0083$, respectively). Reoperation for wound dehiscence was significantly more frequent in the congestion group ($P = 0.048$). **Conclusions.** In pediatric liver-transplant recipients, adding a congested segment IV to the left lateral segment to obtain larger graft volume may negatively impact short-term postoperative outcomes.

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Although living-donor liver transplantation or split liver from deceased-donor transplantation is a treatment option for overcoming the shortage of deceased donors,[1–3] a concern associated with this procedure is that some grafts have congested areas.[4] However, the function of congested areas in graft livers has not been clarified.[5]

In our institution, left lobe grafts without the middle hepatic vein (MHV) (H234)[6] had been occasionally used for

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[1] Department of Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

[2] Department of Pediatric Surgery, Kanazawa Medical University, Ishikawa, Japan.

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Correspondence: Takashi Ito, MD, PhD, Department of Surgery, Graduate School of Medicine, Kyoto University, 54, Syogoin Kawahara-cho, Sakyo-ku, Kyoto-shi, Kyoto 606-8507, Japan. (itotaka@kuhp.kyoto-u.ac.jp).

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pediatric patients instead of left lateral segment grafts (H23) in the 2010s. This is because this graft enables the reduction of the ischemic area (segment IV, H4) for donors and increase donor safety[7–9] and the acquisition of a larger graft for recipients. However, there is no clear consensus regarding the use of congested segment IV (H4) for improving graft volume.

Therefore, this study aimed to evaluate the effects of adding congested areas to a left lateral segment graft (H23) on outcomes of patients who underwent living-donor liver transplantation for biliary atresia in the past 15 y.

MATERIALS AND METHODS

Patients

Among 181 patients with biliary atresia aged ≤15 y who had undergone living-donor liver transplantation at Kyoto University Hospital between 2006 and 2021, 53 recipients who had received left lateral segment grafts (H23) or left lobe grafts (H234, H234-MHV) with a graft-to-recipient weight ratio (GRWR) of <2% were enrolled in this study. Because the addition of segment IV is an option only when the GRWR is <2%, a GRWR of 2% was set as the threshold. Patients with a preoperative advanced intrapulmonary shunt (preoperative intrapulmonary shunt rate of >40%), those with a left lobe graft including the S1 region (H1234-MHV), and those with a right lobe graft (H5678) were excluded (Figure 1).

Study protocols were approved by the ethical review board of Kyoto University (approval number R1473). All procedures were performed in accordance with both the 2013 Declaration of Helsinki and the 2018 Declaration of Istanbul. Written informed consent was obtained from all parents/legal guardians of patients.

Measurement of Congested Volume

The venous drainage volume of the reconstructed vein (left hepatic vein, fissure veins, and MHV, if reconstructed) was calculated as the noncongested area. Calculations were performed using volume analysis software (Synapse Vincent; Fujifilm, Tokyo, Japan) from preoperative computed tomography (CT) images of donors. The estimated weight of the noncongested area was calculated by multiplying the calculated volume by 0.91. In the case of a left lateral segment graft (H23), the line of dissection varied from surgeon to surgeon and did not follow the simulation. Therefore, the actual liver weight was compared with the estimated weight of the noncongested area to calculate the percentage of congested area in each graft. The correlation between the actual and estimated graft weight via this method has previously been demonstrated as reliable and valid.[10] We also calculated the noncongestive GRWR (ncGRWR). Referring to previous reports examining the effects of congestion, a cutoff of 10% of volume was set for the presence of congestion.[11]

Data Collection

Recipient data, including height, weight, sex, indications for transplantation, preoperative and postoperative blood profiles, type of graft, operation time, cold and warm ischemic times, length of hospitalization, graft and patient survival, reoperation, complications including rejection and infection, amount of postoperative blood transfusion, amount of albumin infusion, and amount of ascites were collected. Donor data, such as age and relationship with the recipient, were also collected.

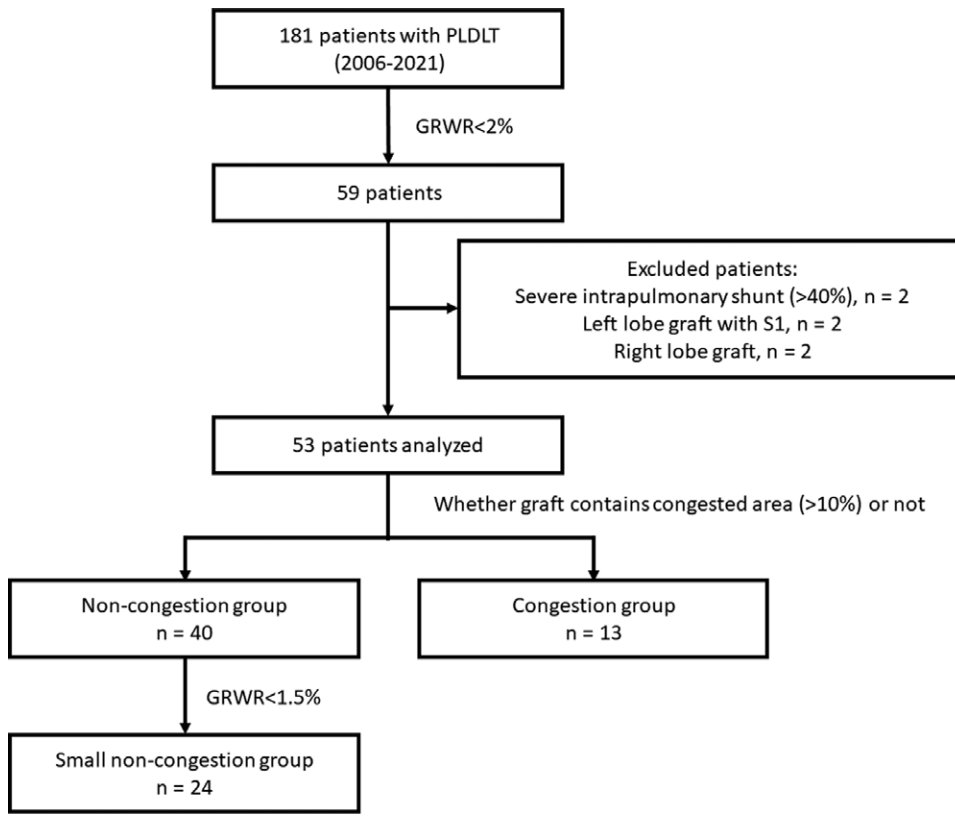

FIGURE 1. Patient recruitment flowchart.

TABLE 1.

Clinical characteristics of recipients and donors in the noncongestion and congestion groups

Variables	Total n = 53	Noncongestion group n = 40	Congestion group n = 13	*P*
Recipient factors				
Age, y	6.7 (5.0–9.8)	6.8 (4.8–10.0)	6.1 (5.1–8.1)	0.57
Female, n (%)	37 (70)	27 (68)	10 (77)	0.52
Height, cm	118 (105–128)	121 (104–129)	111 (106–122)	0.51
Weight, kg	20.6 (17.3–26.8)	21.3 (17.9–28.8)	20.6 (16.7–24.3)	0.40
Graft, n (%)	23 (43)/15 (28)/15 (28)	23 (61)/2 (13)/15 (39)	0 (0)/13 (100)/0 (0)	**<0.001**
Left lobe with MHV/left lobe without MHV/left lateral segment				
Causes, n (%)	13 (25)/12 (23)/16 (30)/12 (23)	9 (23)/10 (25)/11 (28)/10 (25)	4 (31)/2 (15)/5 (38)/2 (15)	0.69
Liver failure/hepatopulmonary syndrome/hemorrhage/cholangitis				
PELD score, n (%) –5/6–9/10–19/20–	35 (66)/9 (17)/5 (9)/4 (8)	26 (65)/7 (18)/3 (8)/4 (10)	9 (69)/2 (15)/2 (15)/0 (0)	0.57
Ascites (+), n (%)	11 (21)	8 (20)	3 (23)	0.81
Donor factors				
Age, y	39.9 (35.7–43.6)	39.5 (35.2–42.8)	40.6 (38.3–44.9)	0.33
Graft weight, g	280 (245–350)	280 (241–355)	280 (255–320)	0.46
GRWR, %	1.39 (1.06–1.70)	1.40 (1.05–1.70)	1.36 (1.24–1.91)	0.48
ABO incompatibility, n (%)	5 (9)	3 (8)	2 (15)	0.40

P values <0.05 are highlighted in bold.
GRWR, graft-to-recipient weight ratios; MHV, middle hepatic vein; PELD, pediatric end-stage liver disease.

Postoperative Management

Immunosuppressants, such as tacrolimus and corticosteroids, were administered. Patients who received transplants from ABO-incompatible donors aged >2 y underwent preoperative plasma exchange and/or rituximab administration as needed.

During hospitalization, patients received blood product transfusions as needed to maintain serum levels of albumin, fibrinogen, γ-globulin, and antithrombin III (AT III) activity at >3 g/dL, >100 mg/dL, >500 mg/dL, and >70%, respectively.

Statistical Analysis

Continuous variables are expressed as medians (interquartile ranges). The Mann–Whitney *U* test was used for continuous variables. Categorical variables are expressed as numbers and percentages. Fisher's exact test was used for categorical variables. A *P* value of <0.05 was considered statistically significant. JMP Pro software (version 16.1.0, SAS Institute Inc., Cary, NC, USA) was used for statistical analysis.

RESULTS

Patient Characteristics

Study participants included 16 boys and 37 girls with a median age, height, and weight of 6.7 y (5.0–9.8 y), 118 cm (105–128 cm), and 20.6 kg (18.1–26.8 kg), respectively. Types of grafts were left lateral segment grafts (H23) in 15, left lobe grafts without MHV (H234) in 15, and left lobe grafts with MHV (H234-MHV) in 23 patients. Table 1 shows these data that were collected from patient medical records. The GRWR and percentage of congested area for each graft are displayed in Figure 2. In patients receiving left lateral segment grafts (H23) or left lobe grafts with MHV (H234-MHV), the percentage of congestion volume was <10%. In patients receiving left lobe grafts without MHV (H234), the estimated congested area was <10% in 2 recipients and >10% in 13 recipients. Patients were divided into 2 groups based on the percentage of congested areas: the congestion group (congested area of >10%) and the noncongestion group (congested area of <10%). All cases of left lateral segment grafts (H23) and left lobe grafts with MHV (H234-MHV) as well as 2 cases of left lobe grafts without MHV (H234) with congestion of <10% were classified into the noncongestion group, and 13 cases of left lobe grafts without MHV (H234) with congestion of >10% were classified into the congestion group (Figures 1 and 2).

Comparison Between the Congestion and Noncongestion Groups

Characteristics, including age, weight, GRWR, and pediatric end-stage liver disease scores, were similar between groups. There were no significant differences in surgery-related factors such as operation times, warm and cold ischemic times, or volumes of blood transfusion. The values for prothrombin time/international normalized ratio (INR) were significantly poorer in the congestion group than in the noncongestion group on postoperative d (POD) 7 and 14 ($P = 0.038$ and $P = 0.0048$, respectively) (Figure 3). Additionally, the volumes of ascites per body weight were significantly higher in the congestion group than in the noncongestion group up to 2 mo after transplantation ($P < 0.05$, consistently) (Figure 3). The duration of hospitalization was significantly longer in the congestion group than in the noncongestion group (90 [53–108] d versus 49 [38–71] d; $P = 0.025$; Figure 3). The doses of albumin infusion, total γ-globulin, and AT III per body weight required during hospitalization were significantly higher in the congestion group than in the noncongestion group ($P = 0.032$, $P = 0.0092$, and $P = 0.030$, respectively) (Figure 3). Finally, reoperations were significantly more frequent in the congestion group than in the

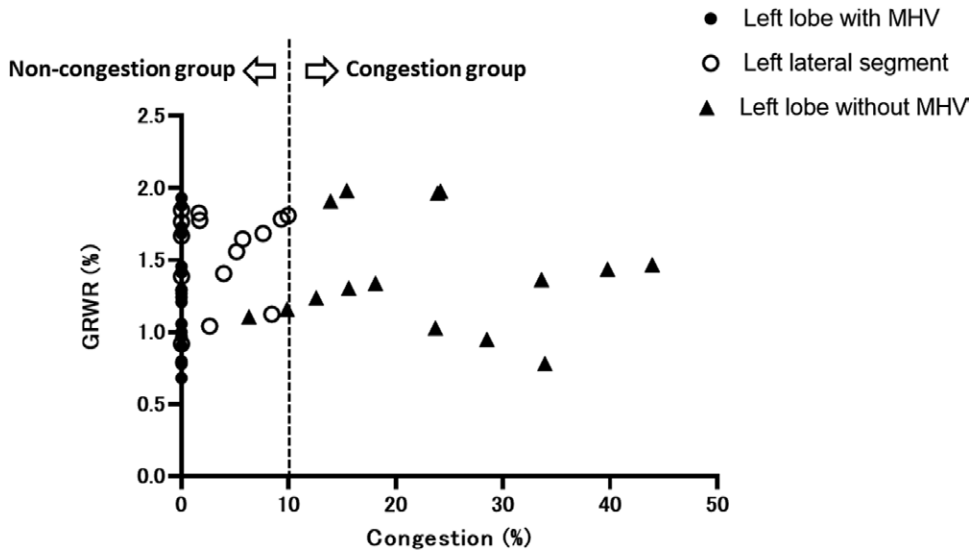

FIGURE 2. GRWR and congestion rates by case. In recipients of left lateral segments (H23) or left lobe grafts with MHV (H234-MHV), the percentage of congestion was <10%. In those using left lobe grafts without MHV (H234), the estimated congested area was <10% in 2 recipients and >10% in 13 recipients. GRWR, graft-to-recipient weight ratio; MHV, middle hepatic vein.

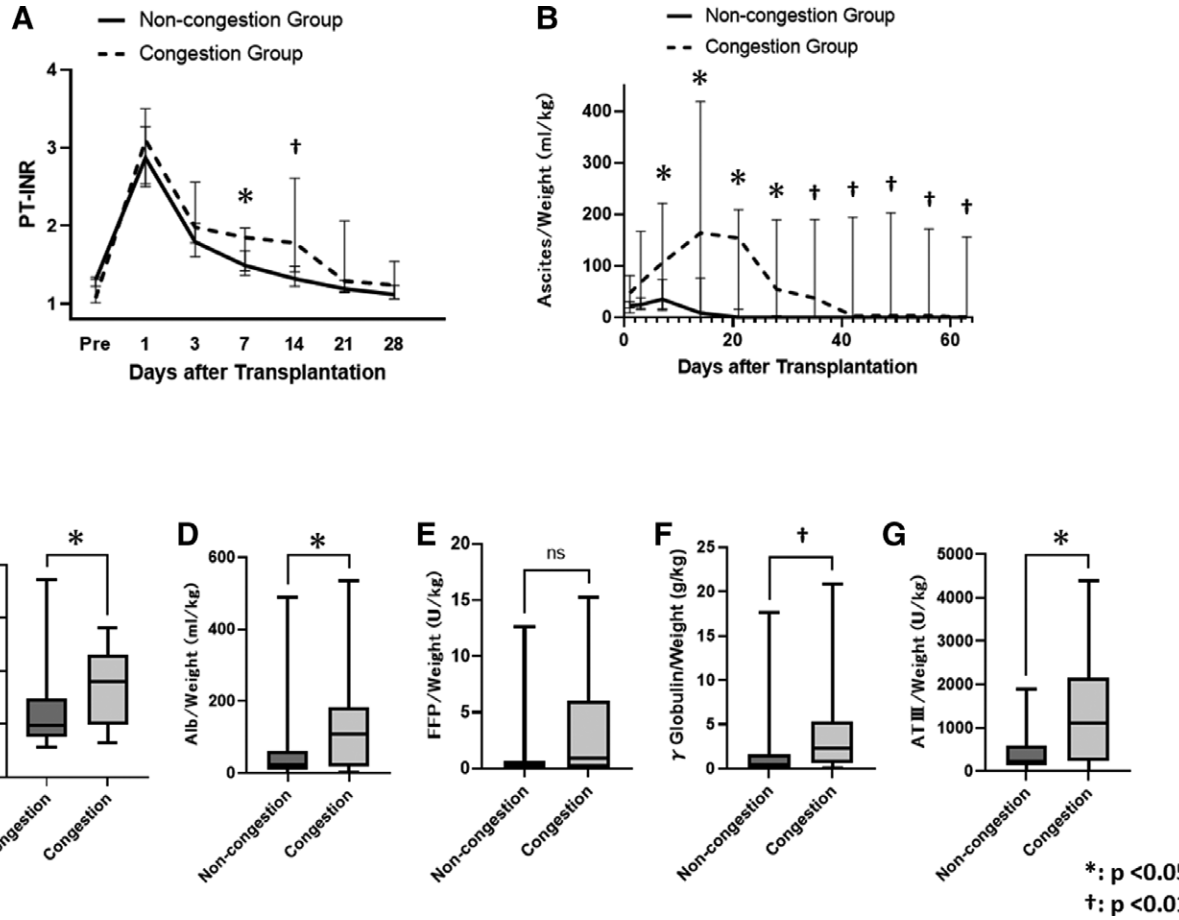

FIGURE 3. Comparison of postoperative results between the noncongestion and congestion groups. (A) Values of prothrombin INR. (B) Volume of ascites per body weight. (C) Hospital d ($P=0.024$). (D) Dose of albumin infusion per body weight ($P=0.032$). (E) Dose of fresh-frozen plasma infusion per body weight ($P=0.22$). (F) Dose of total γ-globulin infusion per body weight ($P=0.009$). (G) Dose of AT III infusion per body weight ($P=0.030$). AT III, antithrombin III; INR, international normalized ratio.

noncongestion group (31% versus 5%; $P=0.011$), especially because of wound dehiscence (15% versus 0%; $P=0.011$; Table 2). Other data are presented in Figure S1 (SDC, http://links.lww.com/TXD/A583).

Comparison Between the Congestion and Small Noncongestion Groups

Next, we evaluated the impact of adding congested areas to a graft on postoperative outcomes. To investigate the

effects of adding congested areas, groups with similar ncGRWRs were compared. The ncGRWR in the congestion group was 1.08% (0.82–1.50%). Hence, recipients with a GRWR of <1.5% were selected from the noncongestion group; this group was designated as the small noncongestion group (Figure 1). Patient characteristics of the 2 groups are summarized in Table 3. The ncGRWR of the small noncongestion group was 1.04% (0.96–1.29%), which was comparable to that of the congestion group.

The GRWR of the congestion group was 1.36% (1.24%–1.91%), whereas that of the small noncongestion group was 1.11% (0.96%–1.29%), demonstrating a significantly greater GRWR in the congestion group than in the small noncongestion group ($P = 0.016$). Additionally, background characteristics such as age, height, and weight were significantly higher in the small noncongestion group than in the congestion group (9.8 versus 6.1 y, $P = 0.0087$; 128 versus 111 cm, $P = 0.010$; and 27.0 versus 20.6 kg, $P = 0.0044$, respectively). There were no significant differences between the 2 groups in terms of surgical factors such as operation times, warm and cold ischemic times, and volumes of blood transfusion.

The prothrombin time-INR were significantly worse in the congestion group than in the small noncongestion group on postoperative d 14 ($P = 0.020$) (Figure 4). The volumes of daily ascites per body weight were significantly higher in the congestion group for up to 2 mo after transplantation ($P < 0.05$, consistently) (Figure 4). The duration of hospitalization was significantly longer in the congestion group than in the small noncongestion group (90 [53–108] d versus 53 [38–76] d; $P = 0.045$; Figure 4), and the volumes of albumin infusion, total γ-globulin, and AT III per body weight required during hospitalization were significantly higher in the congestion group than in the small noncongestion group ($P = 0.027$, $P = 0.0083$, $P = 0.043$, respectively) (Figure 4). Reoperations because of wound dehiscence were significantly more frequent in the congestion group than in the small noncongestion group (15% versus 0%; $P = 0.048$; Table 4). Other data are presented in Figure S1 (SDC, http://links.lww.com/TXD/A583).

DISCUSSION

The present study demonstrated that the addition of congested segment IV (H4) to the left lateral segment graft (H23) may have a negative effect on postoperative outcomes of pediatric living-donor liver-transplant recipients. In this study, although ncGRWRs were similar between groups, the congestion group, which had a significantly larger GRWR, had poorer postoperative outcomes than the small noncongestion group. Although 1 previous study reported that congested areas of the graft have no positive effects early in the transplantation process,[5] ours is the first report demonstrating that congested areas of the graft might have a negative effect on transplant outcomes.

The finding that the addition of a congested area to a graft might have a negative impact on outcomes is noteworthy. Liver function in congested areas is considered inferior to that in noncongested areas.[12] The comparison between the congestion and noncongestion groups in our study demonstrated that pediatric living-donor liver-transplant recipients with

TABLE 2.

Surgical factors and postoperative outcomes of patients in the noncongestion and congestion groups

Variables	Total n = 53	Noncongestion group n = 40	Congestion group n = 13	*P*
Surgical factors				
Operation time, min	757 (660–885)	760 (659–938)	726 (678–864)	0.58
CIT, min	88 (59–151)	84 (57–151)	106 (60–142)	0.68
WIT, min	37 (33–42)	38 (33–42)	36 (33–38)	0.43
Blood loss, mL	1585 (1050–2341)	1525 (1020–2340)	1770 (1415–2920)	0.43
Transfused red blood cells, U	4 (2–6)	4 (2–6)	3 (1–4)	0.52
Transfused platelets, U	0 (0–20)	0 (0–20)	0 (0–20)	0.83
Transfused fresh-frozen plasma, U	2 (2–4)	3 (2–4)	2 (1–4)	0.16
Splenectomy, n (%)	7 (13)	6 (15)	1 (8)	0.50
Postoperative outcomes				
Acute rejection, n (%)	31 (58)	22 (55)	9 (69)	0.37
Bacteremia, n (%)	5 (9)	2 (5)	3 (23)	0.053
Virus infection, n (%)	28 (53)	21 (53)	7 (54)	0.93
Binary early allograft dysfunction, n (%)	24 (45)	16 (40%)	8 (62%)	0.18
Early graft loss, n (%)	1 (2)	0 (0)	1 (8)	0.077
Reoperation, n (%)	6 (11)	2 (5)	4 (31)	**0.011**
Hemorrhage, n (%)	3 (6)	1 (3)	2 (15)	0.081
Bile leakage, n (%)	2 (4)	2 (5)	0 (0)	0.41
Wound dehiscence, n (%)	2 (4)	0 (0)	2 (15)	**0.011**
Others, n (%)	1 (2)	0 (0)	1 (8)	0.077
Hospital stays, d	53 (39–85)	49 (38–71)	90 (53–108)	**0.025**
Follow-up, mo	7.5 (4.6–11.2)	8.1 (4.0–11.4)	6.8 (5.8–10.6)	0.91
Graft survival, n (%)	52 (98)	40 (100)	12 (92)	0.077
Alive, n (%)	52 (98)	40 (100)	12 (92)	0.077

P values <0.05 are highlighted in bold.
CIT, cold ischemic time; WIT, warm ischemic time.

TABLE 4.

Surgical factors and postoperative outcomes of patients in the small noncongestion and congestion groups

Variables	Total n = 37	Small noncongestion group n = 24	Congestion group n = 13	*P*
Surgical factors				
Operation time, min	762 (703–937)	811 (710–954)	726 (678–864)	0.14
CIT, min	116 (61–160)	126 (70–161)	106 (60–142)	0.42
WIT, min	37 (33–42)	38 (35–42)	36 (33–38)	0.40
Blood loss, mLI	1920 (1365–2970)	2060 (1340–2976)	1770 (1415–2920)	0.71
Transfused red blood cells, U	4 (1–6)	4 (2–6)	3 (1–4)	0.34
Transfused platelets, U	0 (0–20)	10 (0–20)	0 (0–20)	0.42
Transfused fresh-frozen plasma, U	2 (2–4)	4 (2–6)	2 (1–4)	0.14
Splenectomy, n (%)	6 (16)	5 (21)	1 (8)	0.30
Postoperative outcomes				
Acute rejection, n (%)	23 (62)	14 (58)	9 (69)	0.51
Bacteremia, n (%)	5 (14)	2 (8)	3 (23)	0.21
Virus infection, n (%)	19 (51)	12 (50)	7 (54)	0.82
Binary early allograft dysfunction, n (%)	21 (57)	13 (54)	8 (62)	0.67
Early graft loss, n (%)	1 (3)	0 (0)	1 (8)	0.17
Reoperation, n (%)	6 (16)	2 (8)	4 (31)	0.077
Hemorrhage, n (%)	3 (8)	1 (4)	2 (15)	0.23
Bile leakage, n (%)	2 (5)	2 (8)	0 (0)	0.28
Wound dehiscence, n (%)	2 (5)	0 (0)	2 (15)	**0.048**
Others, n (%)	1 (3)	0 (0)	1 (8)	0.17
Hospital stays, d	62 (39–88)	53 (38–76)	90 (53–108)	**0.045**
Follow-up, y	7.5 (5.0–10.6)	8.2 (4.8–10.5)	6.8 (5.8–10.5)	0.94
Graft survival, n (%)	36 (97)	24 (100)	12 (92)	0.17
Alive, n (%)	36 (97)	24 (100)	12 (92)	0.17

P values <0.05 are highlighted in bold.
CIT, cold ischemic time; WIT, warm ischemic time.

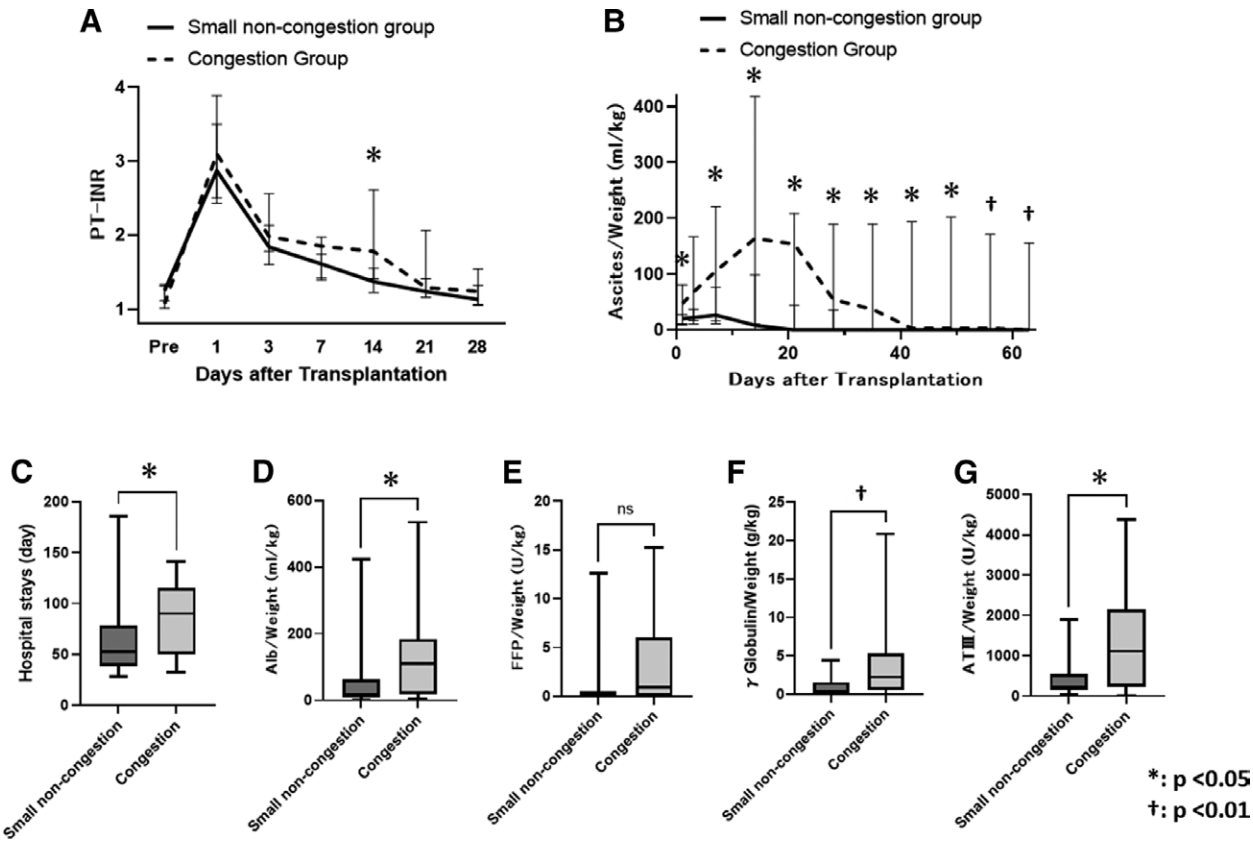

FIGURE 4. Comparison of postoperative results between the small noncongestion and congestion groups. (A) Prothrombin time-INR values. (B) Volume of ascites per body weight. (C) Hospital d ($P = 0.043$). (D) Dose of albumin infusion per body weight ($P = 0.027$). (E) Dose of fresh-frozen plasma infusion per body weight ($P = 0.12$). (F) Dose of total γ-globulin infusion per body weight ($P = 0.008$). (G) Dose of AT III infusion per body weight ($P = 0.043$). AT III, antithrombin III; INR, international normalized ratio.

TABLE 3.

Clinical characteristics of recipients and donors in the small noncongestion and congestion groups

Variables	Total n = 37	Small noncongestion group n = 24	Congestion group n = 13	*P*
Recipient factors				
Age, y	8.4 (6.1–10.2)	9.8 (7.2–10.6)	6.1 (5.1–8.1)	**0.009**
Female, n (%)	26 (70)	16 (67)	10 (77)	0.51
Height, cm	124 (110–134)	128 (120–145)	111 (106–122)	**0.010**
Weight, kg	24.7 (19.5–30.6)	27.0 (21.3–33.9)	20.6 (16.7–24.3)	**0.004**
Graft, n (%)	17 (46)/15 (41)/5 (14)	17 (71)/2 (8)/5 (21)	0 (0)/13 (100)/0 (0)	**<0.001**
Left lobe with MHV/left lobe without MHV/left lateral segment				
Causes, n (%)	9 (24)/8 (22)/13 (35)/7 (19)	5 (21)/6 (25)/8 (33)/5 (21)	4 (31)/2 (15)/5 (38)/2 (15)	0.83
Liver failure/hepatopulmonary syndrome/hemorrhage/cholangitis				
PELD score, n (%) –5/6–9/10–19/20–	27 (73)/6 (16)/3 (8)/1 (3)	18 (75)/4 (17)/1 (4)/1 (4)	9 (69)/2 (15)/2 (15)/0 (0)	0.59
Ascites (+), n (%)	6 (16)	3 (13)	3 (23)	0.40
Donor factors				
Age, y	41.1 (36.6–44.9)	41.3 (35.9–44.9)	40.6 (38.3–44.9)	0.94
Graft weight, g	280 (245–350)	299 (245–390)	280 (255–320)	0.30
GRWR, %	1.24 (0.97–1.41)	1.11 (0.96–1.29)	1.36 (1.24–1.91)	**0.016**
ncGRWR, %	1.05 (0.90–1.29)	1.04 (0.96–1.29)	1.08 (0.82–1.50)	0.94
ABO incompatibility, n (%)	3 (8)	1 (4)	2 (15)	0.23

P values <0.05 are highlighted in bold. ncGRWR, non-congestive graft-to-recipient weight ratio.
GRWR, graft-to-recipient weight ratios; MHV, middle hepatic vein; PELD, pediatric end-stage liver disease.

similar GRWRs who received grafts containing congested regions had poorer short-term outcomes. This finding is similar to that reported in a previous study and venous reconstruction is advisable to avoid congestion if the congested area is large.[13] Nevertheless, even congested areas are considered to maintain some liver function.[12] Thus, the negative impact on outcomes of adding a congested area to a graft is unexpected but meaningful. In this study, postoperative ascites volume was particularly higher in the congestion group, which may have resulted in increased abdominal pressure, leakage of necessary proteins, increased frequency of wound dehiscence, and a longer hospitalization.

The following hypotheses may help explain why congested areas may have a deleterious effect on liver transplantation outcomes:

(1) In congested areas, portal venous blood flows back as an outflow of arterial blood. Thus, portal pressure is elevated when congested regions are included in grafts. Elevated portal vein pressure may impart shear stress on noncongested areas of the liver as well, leading to decreased liver function in these areas.[14–16]
(2) The deleterious effect of congested areas can also be explained by the effect of cold storage and ischemia–reperfusion injury. Most evaluations of liver function and regeneration of congested areas have been conducted and reported in the context of liver resection procedures, including donor surgery.[17–20] Few studies have evaluated the function and regeneration of congested areas following liver transplantation, i.e., their function and regeneration in recipient livers. The effects of cold storage and ischemia–reperfusion injury can be more profound in congested areas because shear stress can be more harmful as arterial blood with higher pressure flows into the portal vein in congested areas, while there is insufficient blood flow, especially in zone 3, because of venous obstruction. This can result in severe hepatic injury or prominent impairment of hepatic function in congested areas after liver transplantation, unlike after liver resection without cold storage and ischemia–reperfusion injury. While necrosis of congested areas has rarely been reported following liver resection procedures, it has been frequently documented following liver transplantation.[21,22]
(3) Adverse effects may result from inadequate reflux and preservation methods in congested areas. When the medial liver area (segment IV, H4) without MHV is added to the graft, as performed in the present study, congested areas are often cold-stored and reperfused without being filled with organ preservation solutions, which may also have a negative effect.

The results of this study provide 1 criterion for graft selection. In pediatric liver transplantation, there has been no clear consensus regarding the appropriate or minimum weight of the graft liver required for each age group. In adults, the small-for-size syndrome is a major concern. A GRWR of approximately 0.6%–0.8% is considered necessary to prevent small-for-size syndrome.[23,24] However, in pediatric recipients, the large-for-size syndrome is more common,[25–28] and there have only been a few reports of small-for-size syndrome in children.[29] The weight of the graft liver required by the recipient varies with age; this contributes to the difficulty in determining the criteria for the minimum required GRWR in children.[30] Therefore, although it is not possible to state a clear criterion, it may be desirable to not add congested areas if a sufficient GRWR can be secured. In contrast, if the small-for-size syndrome is a concern with the use of a left lateral segment graft, it is advisable to use a larger graft without congested areas—that is, a left lobe graft with MHV (H234-MHV).

Furthermore, segment IV (H4) becomes obsolete in donors because of the presence of an ischemic area.[31] Previous studies have demonstrated that retaining segment IV in the donor can result in abscesses and biliary fistula formation.[7–9] Similarly, as

this study showed, if segment IV (H4) is also unnecessary for the recipient, exclusion of segment IV (H4) may be appropriate for both donors and recipients.

The results of the present study may have useful implications for split-liver transplantation from deceased donors, which is an extremely useful technique that could help reduce the mortality rate in pediatric patients on the waiting list to receive liver transplants.[32–34] In split-liver transplantation from deceased donors, grafts contain congested areas in nearly all cases, but there is no established consensus on how to manage these areas. Based on the findings of this study, congested areas should be reduced as much as possible; it may be better excluded in some cases.

One limitation of this study is its single-center retrospective design; thus, the characteristics of patients and preoperative conditions might have influenced the results. Additionally, the congested area was calculated based on CT images and not actual liver weight; therefore, there might have been slight deviations from the actual results. Liver regeneration could not be evaluated because postoperative CT imaging was not performed in most patients to avoid radiograph exposure. There were significant differences in length of hospitalization; however, the overall length of hospitalization was long as almost all patients stayed in the hospital until full recovery.

In pediatric liver-transplant recipients, addition of the congested segment IV (H4) to the left lateral segment graft (H23) to obtain a larger graft volume may have a negative impact on short-term postoperative outcomes. Therefore, left lobe grafts with MHV (H234-MHV) should be selected in cases wherein small-for-size syndrome is a concern with left lateral segment grafts (H23).

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