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# Comparison of Supraceliac and Infrarenal Aortic Conduits in Liver Transplantation: Is There a Difference in Patency and Postoperative Renal Dysfunction?

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**Background.** Aorto-hepatic conduits can provide arterial inflow for liver transplants in cases where the native hepatic artery is unsuitable for use. **Methods.** Clinical outcomes of all patients undergoing liver transplantation (LT) with an aorto-hepatic conduit between 2000 and 2016 were included. Recipients were divided into 2 groups: those with a supraceliac (SC) aortic conduit (N = 22) and those with an infrarenal (IR) aortic conduit (N = 82). **Results.** There was no difference in calculated model for end-stage liver disease score between the 2 groups. The SC group received grafts with a higher mean donor risk index (1.69 versus 1.48;  $P = 0.02$ ). Early allograft dysfunction was 18.2% in the SC group and 29.3% in the IR group ( $P = 0.30$ ). In the SC group, 10.5% of patients required initiation of postoperative continuous renal replacement therapy compared to 12.1% of patients in the IR group ( $P = 0.69$ ). No difference in the rate of postoperative acute kidney injury was seen between the 2 groups ( $P = 0.54$ ). No significant difference in median creatinine at 1 year was seen between the SC (1.2 mg/dL; IQR 1–1.3) and IR (1.2 mg/dL; IQR 0.9–1.5) groups ( $P = 0.85$ ). At a median follow-up of 5.3 years, thrombosis of the aortic conduit occurred in 0% of patients in the SC group and 6.1% of patients in the IR group ( $P = 0.24$ ). Graft survival was not significantly different between the 2 groups ( $P = 0.47$ ). **Conclusions.** No difference in renal dysfunction as demonstrated by need for post-LT continuous renal replacement therapy, acute kidney injury, or creatinine at 1 year post-LT was seen between SC and IR aortic conduits. A slight trend of higher conduit thrombosis rate was seen with IR compared to SC aortic conduits; however, this did not reach statistical significance. Both SC and IR aortic conduits represent reasonable options when the native hepatic artery is unsuitable for use.

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## INTRODUCTION

In liver transplantation (LT), aorto-hepatic conduits are an alternative technique for hepatic artery revascularization in cases where the native hepatic artery is thrombosed or unsuitable for use. Previous publications reporting on the use of aorto-hepatic conduits have demonstrated mixed results.<sup>1–3</sup> Several studies have demonstrated higher hepatic arterial thrombosis rates compared to nonconduit patients,<sup>3–6</sup> while other studies have demonstrated no difference.<sup>2,7</sup> The heterogeneity of results is likely related to a multitude of factors including variable indications for use, era effects, as well as variation in technique. The majority

of previous publications describe utilization of the infrarenal (IR) aorta for creation of aorto-hepatic conduits<sup>1–6</sup>; however, the supraceliac (SC) aorta can also be used. A small historical study demonstrated lower thrombosis rate with SC (0%) compared to IR (23%) aortic conduit.<sup>8</sup> Potential concern-related SC aortic clamping includes interruption of arterial flow to both the lumbar and renal arteries and subsequent ischemic injury to both the spinal cord and the kidneys. Whether these same concerns exist if the SC aorta is only partially clamped remains unknown.

To date, no studies have compared the perioperative and long-term renal and neurologic outcomes of SC and IR aortic

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conduits. The present study aimed to compare the perioperative and long-term outcomes of SC versus IR aortic-conduits. Primary end-points were postoperative renal dysfunction and aortic-conduits patency.

## MATERIALS AND METHODS

This study was performed with the approval of the Mayo Clinic Institutional Review Board. Data were acquired from patients' medical records, outside medical records, and a prospectively maintained transplant database on all patients who underwent LT at our program. All patients undergoing LT at Mayo Clinic Florida between the dates of January 1, 2000, and December 31, 2016 were identified. Patients who received an aortic conduit for arterial reconstruction were identified. Patients were divided into 2 groups: those with an SC aortic conduit and those with an IR aortic conduit. Patients undergoing simultaneous liver–kidney transplant or on continuous renal replacement therapy (CRRT) before LT were excluded.

Recipient factors were examined including recipient age, body mass index (BMI), gender, etiology of liver disease, secondary diagnosis such as hepatocellular cancer, medical status at transplant, calculated model for end stage liver disease (MELD) at the time of transplant and allocation MELD scores. Donor factors examined included donor gender, donor BMI, and all components of the donor risk index (DRI).<sup>9</sup> Early allograft dysfunction (EAD) was determined based on the previously validated definition of the presence of 1 or more of the following: bilirubin 10 mg/dL on day 7; international normalized ratio 1.6 on day 7; and alanine aminotransferase or aspartate aminotransferase >2000 IU/L within the first 7 days.<sup>10,11</sup> The RIFLE (risk, injury, failure, loss of kidney function, and end-stage kidney disease) classification was utilized to stratify the severity of acute kidney injury (AKI).<sup>12</sup> For the RIFLE classification, the following definitions were used: Risk =  $\uparrow$  SCr  $\times$  1.5 or  $\downarrow$  glomerular filtration rate (GFR) >25%, Injury =  $\uparrow$  SCr  $\times$  2 or  $\downarrow$  GFR >50% and Failure =  $\uparrow$  SCr  $\times$  3 or  $\downarrow$  GFR >75% or requirement of post-LT CRRT. Graft survival was calculated from the time of LT until death, graft loss, or date of last follow-up. Patient survival was calculated from the date of LT to death or last known follow-up.

Routinely, we utilize the native hepatic artery for arterial inflow for liver transplants performed at our center. Aortohepatic conduits were utilized in cases of hilar cholangiocarcinoma and cases where the native hepatic artery was determined to be unsuitable for use. Use of SC versus IR aortic conduit was based on surgeon preference, with 2 surgeons routinely performing SC and 4 surgeons routinely performing IR. Both SC and IR grafts were placed after the liver allograft was reperfused off the portal vein. For SC aortic conduits, the crural fibers just above the celiac artery were divided. An umbilical tape was then passed behind the aorta. A partial vascular clamp was then applied to the anterior aortic wall so that distal flow was maintained. An aortotomy was then made with an 11 blade and an opening created using an aortic punch. The donor common iliac artery was then anastomosed to the SC aorta in an end-to-side fashion using running Prolene suture. The external iliac artery from the aortic conduit was then used to anastomose to the donor hepatic artery. For IR aortic conduits, a partial vascular clamp was applied on the aorta distal to the renal arteries and the anastomosis

performed in a similar fashion to that described with SC conduits. The conduit was then tunneled through the transverse mesocolon and brought up to the liver hilum in a retro-gastric fashion anterior to the pancreas. Routine Doppler ultrasound was performed on all patients on postoperative day 1 and 7.

All statistical analyses were performed using STATA 12 software (Stata Corp., College Station, TX). Results were presented as mean  $\pm$  SD except in situations where results were not normally distributed in which they were presented as median (range). Differences between groups were analyzed using the unpaired *t* test for continuous variables and by the  $\chi^2$  test or continuity correction method for categorical variables. Wilcoxon rank-sum was used for variables that did not display a normal distribution. Survival curves for patient or graft survival were generated using the Kaplan-Meier method and compared by the log-rank test. All statistical tests were two-sided and differences were considered significant when  $P < 0.05$ .

## RESULTS

During the study period, a total of 3125 LTs were performed at our program. SC aortic conduit was performed in 22 recipients and IR aortic conduit was performed in 82 recipients that met inclusion criteria. Follow-up of at least 1 year was complete in all patients included in the study. Median follow-up was 52.8 months. Recipient characteristics for the groups can be seen in Table 1. No difference in recipient characteristics was seen between the SC and IR aortic conduit groups. No difference in creatinine at the time of LT was seen between the SC (1.15  $\pm$  0.71) and IR groups (1.20  $\pm$  0.72) ( $P = 0.77$ ). No difference in GFR at the time of transplant was seen between the SC and IR groups. Donor and graft characteristics for the groups can be seen in Table 2. Donor age was significantly higher in the SC aortic conduit group (49.5  $\pm$  20.1 y) compared to the IR aortic conduit group (38.6  $\pm$  18.1 y) ( $P = 0.02$ ). Accordingly, DRI was significantly higher in the SC aortic conduit group (1.69  $\pm$  0.44) compared to the IR aortic conduit group (1.48  $\pm$  0.36) ( $P = 0.02$ ). None of the other donor variables were statistically different between the SC and IR aortic conduit groups. No difference in aortic clamp time was seen between the SC (23.9  $\pm$  15.1 min) and IR groups (29.7  $\pm$  14.2 min) ( $P = 0.09$ ).

Perioperative outcomes for the 2 groups can be seen in Table 3. EAD was 18.2% in the SC group and 29.3% in the IR group ( $P = 0.30$ ). In the SC group, 10.5% of patients required postoperative CRRT compared to 12.2% of patients in the IR group ( $P = 0.69$ ). Using the RIFLE classification for AKI, there was no difference in the proportion of patients classified as risk (10.5% versus 12.2%;  $P = 0.69$ ), injury (10.5% versus 9.8%;  $P = 0.85$ ), and failure (10.5% versus 12.1%;  $P = 0.69$ ) in the SC compared to the IR groups, respectively. No significant difference in median serum creatinine at 1 year was seen between the SC (1.2 mg/dL; IQR 1–1.3) and IR (1.2 mg/dL; IQR 0.9–1.5) groups ( $P = 0.85$ ). None of the patients who received post-LT CRRT were dialysis-dependent at 1 year following LT. Median follow-up was 5.3 years. Median serum creatinine at last follow-up was 1.1 mg/dL (IQR 0.9–1.5 mg/dL) in the SC group and 1.3 mg/dL (IQR 1.0–1.6 mg/dL) ( $P = 0.24$ ). At last follow-up thrombosis of the aortic conduit occurred in 0% of patients in the SC group and 6.1% of patients in the IR group ( $P = 0.24$ ). A multivariate logistic

**TABLE 1.****Recipient characteristics in the supraceliac and aortic infrarenal aortic conduit groups**

Recipient characteristics	Supraceliac N = 22	Infrarenal N = 82	P
Age at transplant, y	51.5 ± 13.3	52.7 ± 10.7	0.67
Body mass index	25.7 ± 5.5	26.3 ± 5.2	0.61
Gender (male)	14 (63.6%)	57 (69.5%)	0.60
HCC exception	2 (9.1%)	6 (7.3%)	0.78
Calculated MELD score	19.6 ± 9.7	19.0 ± 10.4	0.81
Match MELD score	27.3 ± 7.3	24.9 ± 8.5	0.22
Creatinine at LT, mg/dL	1.15 ± 0.71	1.20 ± 0.72	0.77
GFR at the time of LT, mL/min			
≥60	18 (8.2%)	65 (79.3%)	0.79
45–59	0 (0%)	4 (4.9%)	0.29
30–44	2 (9.1%)	13 (15.8%)	0.42
15–29	2 (9.1%)	4 (4.9%)	0.45
Retransplant	10 (45.5%)	45 (54.9%)	0.43
Mechanical, ventilated, or organ perfusion support at transplant	2 (9.0%)	6 (7.3%)	0.78
Medical condition			
At home	16 (72.7%)	55 (67.1%)	0.61
In hospital (not ICU)	4 (18.1%)	18 (22.0%)	0.70
In ICU	2 (9.1%)	9 (11.0%)	0.80

GFR, glomerular filtration rate; HCC, hepatocellular carcinoma; LT, liver transplantation; MELD, model for end stage liver disease.

**TABLE 2.****Donor characteristics in the supraceliac and aortic infrarenal aortic conduit groups**

Donor characteristics	Supraceliac N = 22	Infrarenal N = 82	P
Age	49.5 ± 20.1	38.6 ± 18.1	0.02
DRI	1.69 ± 0.44	1.48 ± 0.36	0.02
Cold ischemia time, h	8.9 ± 7.3	7.2 ± 1.9	0.06
Sex (male)	9 (40.9%)	47 (57.3%)	0.17
BMI	25.7 ± 7.2	27.9 ± 7.1	0.19
Race/ethnicity			
White	15 (68.2%)	48 (58.5%)	0.41
Black	2 (9.1%)	18 (22.0%)	0.17
Other	5 (22.7%)	16 (19.5%)	0.74
Cause of death			
Anoxia	5 (22.7%)	8 (9.8%)	0.10
Stroke	10 (45.5%)	32 (39.0%)	0.59
Trauma	6 (27.3%)	41 (50.0%)	0.06
Other	1 (4.6%)	1 (1.2%)	0.31
Share type			
Local	5 (22.7%)	25 (30.5%)	0.48
Regional	16 (72.7%)	51 (62.2%)	0.36
National	1 (4.6%)	6 (7.3%)	0.65

BMI, body mass index; DRI, donor risk index.

regression predicting the odds of AKI based on RIFLE classification was performed (Table 4). Adjusting for recipient age, MELD score and DRI, location of aorto-hepatic conduit was not associated with odds of AKI.

Patient survival for the 2 groups can be seen in Figure 1. Patient survival was not statistically different between the SC aortic conduit and IR aortic conduit groups ( $P = 0.47$ ). Patient survival at 1, 3, and 5 years was 85.1%, 67.8%, and

**TABLE 3.****Perioperative outcomes in the supraceliac and aortic infrarenal aortic conduit**

	Supraceliac N = 22	Infrarenal N = 82	P
EAD	4 (18.2%)	24 (29.3%)	0.3
LOS, days <sup>a</sup>	10 (7–18)	10 (7–21)	0.84
CRRT post-LT <sup>b</sup>	2 (10.5%)	10 (12.2%)	0.69
RIFLE classification for AKI			
Risk	2 (10.5%)	10 (12.2%)	0.69
Injury	2 (10.5%)	8 (9.8%)	0.85
Failure	2 (10.5%)	10 (12.2%)	0.69
Creatinine 1-y post-LT, mg/dL <sup>a</sup>	1.2 (1–1.3)	1.2 (0.9–1.5)	0.85
Creatinine at maximal follow-up, mg/dL <sup>a</sup>	1.1 (0.9–1.5)	1.3 (1.0–1.6)	0.24
Neurologic impairment	0 (0%)	0 (0%)	NA
Conduit thrombosis	0 (0%)	5 (6.1%)	0.24

<sup>a</sup>Median (range).

<sup>b</sup>Included 21 patients with supraceliac aortic conduit and 82 patients with infrarenal aortic conduit.

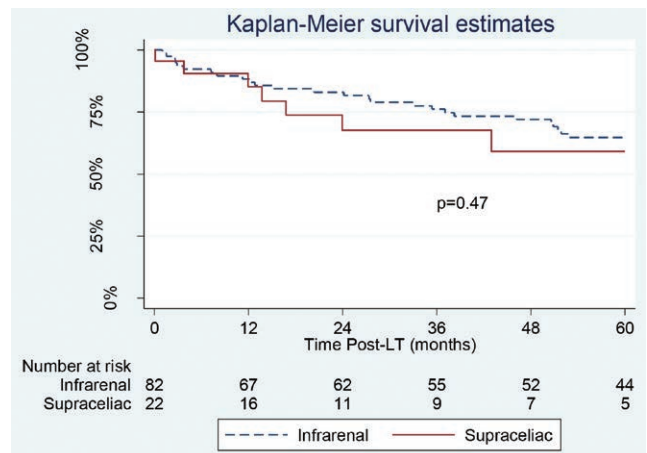
AKI, acute kidney injury; CRRT, continuous renal replacement therapy; EAD, early allograft dysfunction; LOS, length of stay; LT, liver transplant.

**TABLE 4.****Multivariate logistic regression predicting odds of AKI**

Variable	OR	CI	P
Supraceliac (ref IR)	0.6	0.19–1.9	0.39
Age (per y)	1.01	0.97–1.06	0.58
MELD (per unit)	1.09	1.04–1.14	0.001
DRI (per unit)	1.56	0.45–5.37	0.48

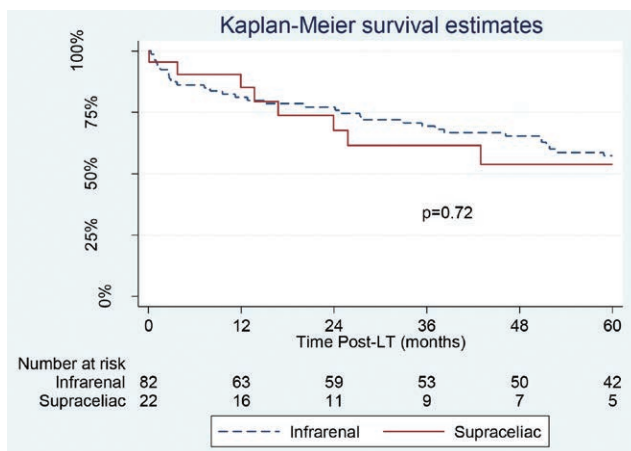
AKI defined as risk, injury or failure using RIFLE classification.

AKI, acute kidney injury; CI, confidence interval; DRI, Donor Risk Index; IR, infrarenal; MELD, model for end-stage liver disease; OR, odds ratio.



**FIGURE 1.** Patient survival in the supraceliac and aortic infrarenal aortic conduit groups. LT, liver transplantation.

59.3% in the SC aortic conduit group and 88.3%, 76.1%, and 64.9% in the IR aortic conduit group. Graft survival for the 2 groups can be seen in Figure 2. Graft survival was not statistically different between the SC aortic conduit and IR aortic conduit groups ( $P = 0.72$ ). Graft survival at 1, 3, and 5 years was 85.1%, 65.3%, and 53.9% in the SC aortic conduit group and 79.1%, 67.7%, and 56.0% in the IR aortic conduit group.



**FIGURE 2.** Graft survival in the supraceliac and aortic infrarenal aortic conduit groups. LT, liver transplantation.

## DISCUSSION

In cases where the native hepatic artery is thrombosed or unsuitable for use, aorto-hepatic conduits provide a vital alternative for hepatic artery revascularization. The majority of previous publications describe utilization of the IR aorta for creation of aorto-hepatic conduits. Limited data exist describing the outcomes with SC aorto-hepatic conduits.

A study published in 1991 is the only publication describing the outcomes with SC aorto-hepatic conduits.<sup>8</sup> This study demonstrated a 0% thrombosis rate in 45 patients undergoing LT with this arterial reconstruction technique. The thrombosis rate of IR conduits in the literature ranges from 4.1% to 12.9%.<sup>1-7,13,14</sup> In the present study, we demonstrated a 0% thrombosis rate compared for patients in the SC group compared to 6.1% for those patients in the IR group.

Potential concerns with SC aorto-hepatic conduits include interruption of blood flow to both the lumbar and renal arteries and subsequent ischemic injury to both the spinal cord and kidneys. In the present study, using a partial clamp technique, we did not observe any cases of neurologic impairment secondary to spinal cord ischemia. From a renal perspective, no difference in the rate of CRRT following LT (10.5% versus 12.1%) or risk of AKI following LT was seen between the SC and IR groups, respectively. Mean serum creatinine levels at 1 year following LT (1.18 mg/dL versus 1.22 mg/dL) and at maximal follow-up from LT (1.1 mg/dL versus 1.3 mg/dL) were also not significantly different seen between the SC and IR groups, respectively. There was also no significant difference in development of EAD or median post-LT hospital length of stay between the groups.

Patient and graft survival in the present study were lower for both groups of patients receiving aortic conduits compared to our previously published survival rates for patients in which the native hepatic artery is used.<sup>15</sup> This inferior survival can likely be attributed to the indications for LT in the present cohort, with a larger proportion of retransplants or patients being transplanted following our center's hilar cholangiocarcinoma protocol. Previous studies investigating outcomes of aortic conduits compared to the use of native hepatic artery have had similar findings.<sup>3,5</sup>

Data on surveillance for patency of aorto-hepatic conduits and benefits of prophylactic anticoagulation are lacking. A large study describing good outcomes with aorto-hepatic conduits advocated their protocol of placing all such patients on salicylic acid (80 mg once daily).<sup>7</sup> In the present study, we did

not routinely utilize any form of anticoagulation for patients receiving an aorto-hepatic conduit.

Limitations of the present study include its retrospective nature as well as the moderate sample size, limiting statistical power to detect small differences between groups. Also, despite the apparent similarities between the groups, decision to perform a SC or IR conduit was based on surgeon preference and so unmeasurable biases cannot be completely ruled out.

In conclusion, the present study suggests that concerns over spinal or renal ischemia with SC conduits do not appear to be founded when a partial aortic clamping technique is used. No difference in renal impairment was seen between the SC and IR aortic conduit groups. The present study does not provide data to suggest that SC conduits are superior to IR conduits. There may be situations where a SC conduit is not a viable alternative such as in the case of extensive upper abdominal varices or some cases of liver retransplantation where access to the SC aorta is prohibited by dense adhesions. In these cases, an IR conduit would likely be a more favorable option. Both SC and IR aorto-hepatic conduits represent reasonable options when the native hepatic artery is unsuitable for use.

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