INTRODUCTION

The number of cadaveric organ donors has markedly increased since the revision of the “Internal organs, etc. transplant act” in 2011. However, the gap between the number of patients on the waiting list and the number of donors has only grown wider. In the year 2019, the number of patients on the waiting list for organ transplantation was 32,560, while the number of transplants performed was only 1,612 from 450 cadaveric donors. According to Korean Network for Organ Sharing data, there were 5,804 potential recipients on the waiting list; however, only 1,579 patients underwent liver transplant in 2019 [1].

This shortage of organs has compelled transplant centers to use organs from non-standard donors. Reuse of a graft that has been previously transplanted to other recipients could be an option in this situation. However, because the liver is generally more susceptible to ischemic damage than the kidney, reusing hepatic grafts without careful consideration can be dangerous [2,3].

Reports on hepatic graft reuse have been published in other countries; however, with the exception of two case reports, there are no national reports on the same in Korea [4-7]. Since the year 2000, there have been 24 cases of graft reuse across all transplant centers in Korea, wherein grafts were sourced from brain-dead organ donors who...
had previously received the same graft themselves. Among
them, we focused on six transplants that reused a hepatic
graft. All data were collected retrospectively through elec-
tronic medical records after obtaining permission from the
Institutional Review Board (IRB) of each transplant center
(Seoul National University Bundang Hospital: No. B-2004-
604-110, Pusan National University Yangsan Hospital: No.
05-2020-045, Asan Medical Center: No. S2021-0010-0001,
The Catholic University of Korea, Seoul St. Mary’s Hospital:
No. KC21RIDI0146). Informed consent was waived given
the retrospective design of the study. Transplant surgeons
who plan to reuse hepatic grafts for their patients may
benefit from our nation-wide data.

### CASE REPORT

Six recipients underwent liver transplantation with reused hepatic grafts; one underwent living-donor transplantation, while the others underwent deceased-donor transplantation. Data on the warm ischemic time were unavailable for all patients; therefore, we have only shown the cold ischemic times of the first and second transplantations (Table 1). The model for end-stage liver disease (MELD) scores in the failed graft groups were higher than those in the successful graft groups, even though the absolute values were not high.

#### Case 1

The first recipient was a 32-year-old woman with fulmi-
nant hepatitis A. The donor was a 30-year-old woman, the
younger sister of the recipient. A modified right lobe graft
was used for living donor transplantation. However, the
next day, the recipient developed brain edema as observed
on a computed tomography (CT) scan, and brain death oc-
curred after one day. Even though the abrupt huge tragedy
occurred to the family, they agreed to donation of the first
recipient as a deceased donor.

Eight days after the first transplant procedure, the graft
was re-transplanted to a 43-year-old man with liver cirrho-
sis secondary to hepatitis B virus (HBV) infection. He was
on the waiting list for deceased donor liver transplantation
for intractable ascites. There were mild adhesions around
the liver graft, and mobilization of the liver was uneventful.
The bile duct, portal vein, hepatic artery, and reconstructed
hepatic vein were clearly identified and procured from the
former anastomotic site and confirmed to be in a good
condition for subsequent anastomosis. The graft weight
had increased from 590 g at the first transplantation to
1,120 g at the second transplantation. The graft-recipient
weight ratio was 1.66%. He has been doing well for more
than 10 years after the transplant. This case has been pre-
viously reported [5] (Fig. 1A).

#### Case 2

The first recipient was a 42-year-old man with toxic hepa-
titis. The donor was a 37-year-old man who had suffered
brain death due to subarachnoid hemorrhage (SAH).
However, hepatic encephalopathy developed after the
transplant, and brain necrosis was observed on a CT scan
seven days after the transplant.

The graft was then retransplanted to a 45-year-old
man with liver cirrhosis and variceal bleeding due to HBV
infection. A duct-to-duct anastomosis was performed and
an internal stent was inserted; no problems were noted in
the duct anastomosis during the graft-reuse surgery. Fur-
thermore, there were no major problems, such as thinning
of the portal vein on the graft side; therefore, there was no
risk of bleeding. The anastomosis was created using the
branch-patch technique, which involved the gastroduode-
nal and common hepatic arteries; no additional vessel was
obtained from the donor during the anastomosis. A pig-
gyback cavocaval anastomosis was performed; unlike in
the original transplantation, the anastomosis was excised
proximally. The graft function did not recover after the sec-
ond transplant. The recipient then underwent transplant
from a different brain-dead donor three days after the ear-
lier transplant with the reused hepatic graft (Fig. 2A).

#### Case 3

The first recipient was a 48-year-old woman with idiopath-
ic hepatic failure and hepatic encephalopathy. The donor
was a 31-year-old woman who had been declared brain
dead due to SAH. However, the recipient’s encephalopathy
did not recover despite the transplant. The patient deteri-
| Variable                          | Case 1       | Case 2       | Case 3       | Case 4       | Case 5       | Case 6       |
|----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Year                             | 2008         | 2015         | 2015         | 2016         | 2017         | 2019         |
| Donor                            |              |              |              |              |              |              |
| Age                              | 30           | 37           | 31           | 55           | 58           | 48           |
| Sex                              | F            | F            | F            | M            | M            | M            |
| Type                             | Living       | Deceased     | Deceased     | Deceased     | Deceased     | Deceased     |
| Day from first transplant to     | 7            | 7            | 4            | 11           | 10           | 2,196        |
| donation                         |              |              |              |              |              |              |
| Cold ischemic time (min)         |              |              |              |              |              |              |
| 1st                              | 90           | 281          | 349          | 152          | 315          | 290          |
| 2nd                              | 67           | 235          | Unknown      | 311          | 229          | 350          |
| MELD score                       |              |              |              |              |              |              |
| 1st recipient                    | 38           | 32           | 35           | 38           | 40           | 19           |
| 2nd recipient                    | 11           | 24           | 40           | 22           | 32           | 12           |
| Result of graft biopsy           |              |              |              |              |              |              |
| 1st (%)                          |              |              |              |              |              |              |
| Fatty change                     | -            | -            | -            | -            | -            | -            |
| Rt                               | -            | -            | -            | -            | -            | -            |
| Lt                               | -            | -            | -            | -            | -            | -            |
| Portal inflammation              | -            | Mild         | Moderate     | Mild         | Mild         | -            |
| 2nd (%)                          |              |              |              |              |              |              |
| Fatty change                     | <5           | <5           | <5           | <5           | <5           | 5–10         |
| Portal inflammation              | -            | Mild         | Micro 20–30  | Mild to moderate | Mild to moderate | -          |
| Portal Fibrosis                  | -            | -            | -            | -            | -            | -            |
| Periportal inflammation          | -            | -            | -            | -            | -            | Yes          |
| Necrotic change                  | -            | -            | -            | -            | -            | 20           |
| Cause of death of the 1st        | -            | Hepatic encephalopathy | Hepatic encephalopathy | Cerebral infarction | Subarachnoid hemorrhage | Pontine hemorrhage |
| recipient                        |              |              |              |              |              |              |
| Graft status in the 2nd recipient| Functioning  | Failed       | Failed       | Failed       | Functioning  | Functioning  |

MELD, model for end-stage liver disease; Rt, right; Lt, left.
orated and was ultimately declared brain dead three days after transplant.

The second recipient was a patient with alcoholic liver cirrhosis. Hepatic vein anastomosis was performed using the piggyback technique, and the donor hepatic artery was easily anastomosed with the recipient common hepatic artery. An end-to-end bile duct anastomosis was performed as well. However, postoperative bleeding occurred and necrosis of segments 6 and 7 was observed during re-exploration. The reused hepatic graft did not recover its function after transplant. The recipient died on the 6th day posttransplant due to primary non-function and septic shock (Fig. 2B).

**Case 4**

The first recipient was a 37-year-old man with toxic hepatitis secondary to HAV. The donor was a 55-year-old man who had been brain dead due to intracranial hemorrhage. After the transplant, brain infarction and edema developed, ending in brain death 11 days after transplant.

The second recipient was a 53-year-old man with HBV and liver cirrhosis. In case of the first recipient, hepatecto-
my was performed in the usual manner without any difficulties. The second recipient had already undergone living donor liver transplantation (LDLT) 4 years ago. Therefore, the individual dissection of the hepatic hilum was very difficult due to adhesion. Furthermore, the patient had a cavernous malformation of the portal vein before the LDLT, and a portal vein stent had been inserted after the LDLT. Therefore, the portal vein flow was very weak, and the surgeon anastomosed the left renal vein to the graft portal vein by using the cadaveric iliac vein (reno-portal anastomosis). Postoperative CT and Doppler ultrasound revealed a decreased flow in the hepatic artery and portal vein. and the reused hepatic graft did not recover its function after transplant, and the recipient died on the 7th day posttransplant due to primary non-function and septic shock (Fig. 2C).

### Case 5

The first recipient was a 42-year-old man with alcoholic liver cirrhosis undergoing hemodialysis for end-stage kidney disease. The donor was a 58-year-old man who had been brain dead due to SAH. On the 8th day after transplant, subdural hemorrhage occurred and the recipient experienced a decreased flow in the hepatic artery and portal vein. and the reused hepatic graft did not recover its function after transplant, and the recipient died on the 7th day posttransplant due to primary non-function and septic shock (Fig. 2C).

### Change in Biochemical Parameters

| Day | PT/INR | AST (IU/L) | ALT (IU/L) | T.bil (mg/dL) |
|-----|--------|------------|------------|--------------|
| 0   | 2.11   | 1.14       | 1.01       | 1.2          |
| 1   | 1.14   | 1.01       | 1.2        | 2.03         |
| 2   | 1.01   | 1.2        | 2.03       | 4.57         |
| 3   | 1.2    | 2.03       | 4.57       | 6.38         |
| 4   | 2.03   | 4.57       | 6.38       | 8.22         |
| 5   | 4.57   | 6.38       | 8.22       | 10.54        |
| 6   | 6.38   | 8.22       | 10.54      | 12.8           |
| 7   | 8.22   | 10.54      | 12.8       | 15.12         |
| 8   | 10.54  | 12.8       | 15.12      | 17.44         |
| 9   | 12.8   | 15.12      | 17.44      | 19.66         |
| 10  | 15.12  | 17.44      | 19.66      | 21.98         |

Fig. 2. Change in biochemical parameters of the first and second recipient in case 2 (A), case 3 (B), and case 4 (C, the unsuccessful group). PT, prothrombin time; INR, international normalized ratio; AST, aspartate aminotransferase; ALT, alanine aminotransferase; T. bil, total bilirubin.
enced brain death.

The second recipient was a 40-year-old woman with hepatic failure caused by toxic hepatitis. Because the liver graft was reconstructed by using the piggyback technique in the first recipient, the recipient retrohepatic inferior vena cava (IVC) was completely preserved for application of the modified piggyback technique. The weight of the liver graft was 1,430 g. The redundant portion of the hepatic artery, which was derived from the first recipient, was resected and the graft’s own hepatic artery was anastomosed to the hepatic artery stump of the second recipient. Biliary reconstruction was performed in duct-to-duct anastomosis of the common bile duct with a T-tube insertion. The recipient recovered well and has been doing well since. This case also has been reported previously (Fig. 1B) [4].

**Case 6**
The first recipient was a 65-year-old man with hepatitis C, liver cirrhosis, and alcoholic liver disease. The donor was a 48-year-old man with SAH. The recipient recovered well after transplant. However, 6 years later, pontine hemorrhage occurred, abruptly leading to brain death. The second recipient, who had underlying hepatocellular carcinoma as the indication for transplant. No complicated procedures, except for adhesiolysis, were performed during the transplantation. Duct-to-duct anastomosis was performed in an end-to-end manner. The surgeon used the retrohepatic IVC, which included the liver graft, and performed hepatic vein anastomosis with the piggyback cavocaval technique. The recipient recovered well and has been doing well since the procedure (Fig. 1C).

**DISCUSSION**

Reusing organs in an organ shortage can be a good option in terms of increasing the donor pool. However, the reuse of a liver graft can be risky for patients, unlike reuse of the kidney [3]. In this study, the first case received a graft that was relatively less ischemic due to living donor transplant; in the last case, there was virtually no ischemic damage because the second transplant occurred 6 years after the first. Except for the last case, one of the remaining four livers from deceased donors was liver transplanted successfully.

In a recent study of reused hepatic grafts, there was a proposal to consider routine biopsy before the second transplant to predict primary non-functional graft status [8]. However, according to our study, non-functional status seems quite non-predictable (cases 2 and 3). Laboratory findings are likely more important than biopsy findings. If the total bilirubin level is 3 mg/dL or higher in the donor, the graft can be considered unsuitable for transplant. Since June 2016, the distribution of liver grafts has changed according to the MELD system; a higher MELD score reflects poorer patient condition before transplant, meaning the hepatic graft would experience a greater burden despite the transplant. In such situations, reusing the hepatic graft would necessitate more caution.

Hepatic ischemia-reperfusion injury (IRI) is a major risk factor of liver transplant failure [2]. In cases 2 and 3, the reused graft experienced two consecutive IRIs during a relatively short period. Furthermore, in case 3, the MELD score of the second recipient was very high (40) and the international normalized ratio and total bilirubin level had already increased in the first recipient before the second transplant.

In case 4, the recipient had a cavernous malformation of the portal vein and the portal vein stent had already been inserted before the second transplant. Unfortunately, reno-portal bypass was unsuccessful. In this case, the graft condition might have not been the primary cause of graft failure; careful recipient selection appears to be crucial in the transplantation of reused grafts.

This study has some limitations. We could not obtain data of good quality due to the study’s retrospective and multi-center design. The data were somewhat old and had different available ranges according to the IRB policies of the respective institutions. However, we hope that our report helps other liver transplant surgeons who are planning to reuse hepatic grafts. In conclusion, to date, the outcome of reusing hepatic grafts in Korea has not been ideal. However, in patients with limited options, reuse can be carefully considered after thoroughly assessing the graft for ischemic damage and status of the recipient.

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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Author Contributions
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