The Predictors for Continuous Renal Replacement Therapy in Liver Transplant Recipients

J.M. Kim, Y.Y. Jo, S.W. Na, S.I. Kim, Y.S. Choi, N.O. Kim, J.E. Park, and S.O. Koh

ABSTRACT

Background. Acute renal failure (ARF) after liver transplantation requiring continuous renal replacement therapy (CRRT) adversely affects patient survival. We suggested that postoperative renal failure can be predicted if a clinically simple nomogram can be developed, thus selecting potential risk factors for preventive strategy.

Methods. We retrospectively reviewed the medical records of 153 liver transplant recipients from January 2008 to December 2011 at Severance Hospital, Yonsei University Health System, in Seoul, Korea. There were 42 patients treated with CRRT (20 and 22 patients received transplants from living and deceased donors, respectively) and 111 were not. Univariate and stepwise logistic multivariate analyses were performed. A clinical nomogram to predict postoperative CRRT application was constructed and validated internally.

Results. Hepatic encephalopathy (HEP; odds ratio OR, 5.47), deceased donor liver donations (OR, 3.47), Model for End-Stage Liver Disease (MELD) score (OR, 1.09), intraoperative blood loss (L; OR, 1.16), and tumor (hepatocellular carcinoma) as the indication for liver transplantation (OR, 0.11) were identified as independent predictive factors for postoperative CRRT on multivariate analysis. A clinical prediction model constructed for calculating the probability of CRRT post-transplantation was 1.7000 + HEP + [−4.5427 + 1.2440 × (deceased donor) + 0.0830 × (MELD score) + 0.000149 × the amount of intraoperative bleeding (L) − 2.1785 × tumor]. The validation set discriminated well with an area under the curve (AUC) of 0.90 (95% confidence interval, 0.85–0.95). The predicted and the actual probabilities were calibrated with the clinical nomogram.

Conclusions. We developed a predictive model of postoperative CRRT in liver transplantation patients. Perioperative strategies to modify these factors are needed.

Acute renal failure (ARF) requiring renal replacement therapy after liver transplantation is a common complication associated with increased mortality [1]. For end-stage liver failure patients, preoperative renal function is compromised by unstable clinical conditions, deficiency of effective intravascular volume, chronic renal vascular contraction, renal hypo-perfusion, infection, and multiorgan failure. Also, graft failure imposes a significant risk of ARF after liver transplantation because the metabolism of nephrotoxic immunosuppressive agents, such as cyclosporine or Tacrolimus, is impaired with malfunction of graft [2]. ARF that develops postoperatively leads to chronic renal failure and high mortality [3]. The incidences of ARF after liver transplantation range from 5% to 20% in the
literature [4,5]. Sanchez et al previously reported that risk factors for required renal replacement therapy after orthotopic liver transplantation are preoperative creatinine level, blood urea nitrogen (BUN) level, Model for End-Stage Liver Disease (MELD) score, and duration of intensive care unit (ICU) stay after operation.

They constructed a clinical prediction model based on these risk factors [6]. However, they did not consider preoperative renal function. Therefore, it is possible that impaired renal function at baseline could lead to the development of postoperative ARF.

We undertook this study to indentify preoperative and intraoperative factors that would identify patients at risk of needing postoperative continuous renal replacement therapy (CRRT) in spite of preserved preoperative renal function. Moreover, we aimed to construct a clinical predictive model for ARF after liver transplantation.

MATERIAL AND METHODS

This study was retrospectively performed on 173 patients who underwent liver transplantation from January 2008 to December 2011 at Severance Hospital, Yonsei University Health System, in Seoul, Korea. Institutional review board approval was obtained (IRB number, 1-2013-0001) and this study was registered at www.ClinicalTrials.gov (reference number, NCT01457534).

Patients were excluded from the study if they had undergone renal dialysis treatment, had been diagnosed with chronic renal failure before the liver transplantation, or if they had received a combined liver-kidney transplant. Pediatric patients were excluded. A total of 157 patients were included in the analysis with 110 and 47 undergoing living and deceased donor liver transplantation, respectively. A total of 42 patients required postoperative CRRT, 20 of whom were living donor liver recipients.

We assessed the patients’ demographics. Preoperative data included cause of liver disease, levels of serum BUN and creatinine, prothrombin time, hemoglobin, total bilirubin, and MELD score. Intraoperative data included duration of bypass, duration of anesthesia, number of packed red blood cell (PRBC) units transfused, intraoperative blood loss, and intraoperative urine output. Postoperatively, length of ICU stay, length of hospital stay (HOD), Acute Physiologic and Chronic Health Evaluation (APACHE) score, use of vasopressor, postoperative laboratory data, including aspartate transaminase (AST) levels, total bilirubin levels, and prothrombin time (PT) observed during the first postoperative week, and in-hospital mortality were reviewed. Peak AST levels observed the first postoperative week were used to classify the degree of ischemia reperfusion injury. Neil et al reported that elevated postoperative AST levels were correlated with the degree of ischemia reperfusion injury [7]. Because this was a retrospective study, initial ischemia reperfusion injury was categorized into 4 groups based on postoperative maximum AST levels over the first postoperative week: (I) AST maximum <400 U/L; (II) AST 401–1000 U/L; (III) AST 1001–4000 U/L; and (IV) AST >4000 U/L. Primary non-function (retransplantation required within 7 days) was not observed in this study.

All statistical analyses were performed using SAS version 9.1.3 (SAS Institute Inc., Cary, NC, United States). Categorical variables were compared between groups using 2-tailed Fisher exact tests for two by two tables with likelihood ratio chi-square tests for larger tables. Continuous variables were inspected visually and tested for normal distribution using Kolmogorov-Smirnov tests. If they were normally distributed, a 2-sample test was used to compare 2 groups’ means, and, if not, we used a Mann-Whitney U test. Actual survival was estimated using Kaplan-Meier methods. For analysis of postoperative initial graft function, we used a linear mixed model for postoperative repeated measured laboratory data. Risk factors with a statistically significant relationship to postoperative renal failure needed for CRRT were integrated into a final logistic regression model. To assess the predictive power of the logistic regression model, a receiver operating characteristic (ROC) curve was used. We calculated the area under the curve and decided on a cut point using the Youden method. Significance was established at \( P < .05 \).

The nomogram performance was quantified with regard to discrimination and calibration [8]. In addition, the bootstrapping method (200 repetitions) was used to obtain relatively unbiased estimates of the model’s performance. Discrimination (ie, whether the relative ranking of individual predictions of subsequent postoperative CRRT application was in the correct order) was quantified with the AUC. A 95% confidence interval (CI) was calculated for the AUC. We performed the graphic calibrations of the relationship between the observed outcome and the expected probabilities. The clinical significance of calibration represents the accuracy of individual predictions of postoperative CRRT application in liver transplantation patients.

RESULTS

There were 173 patients who underwent transplantation during the study period. One patient who underwent combined liver-kidney transplantation and 15 patients who underwent renal replacement therapy before liver transplantation were excluded from the multivariate analysis. A total of 157 patients were included in the analysis and 42 patients were supported by postoperative CRRT.

Kaplan-Meier survival estimates demonstrated significant survival differences between the CRRT group compared with the non-CRRT group \( (P < .001) \). The mortality of the CRRT group was higher than that of the non-CRRT group despite preoperative renal function preservation (90-day predictive mortality rate, 43.18% vs 0.96%; 1-year predictive mortality rate, 50.00% vs 0.096%; \( P < .001 \), respectively; Fig 1).

The baseline patient characteristics are summarized in Table 1. The amount of intraoperative blood loss and units of transfused PRBCs were significantly higher in the CRRT group than in the non-CRRT group \( (12.5 \pm 11.7 \text{ L} \text{ vs } 5.7 \pm 4.1 \text{ L}; P < .001) \) and in-hospital mortality were reviewed. The use of postoperative vasopressor and duration of vasopressor use were compared between the 2 groups. The use of vasopressor was more frequent in the CRRT groups and the duration of vasopressor use was longer in the CRRT groups \( (37 \pm 90.2\% \text{ vs } 84 \pm 73.0\%; P = .028; 4.49 \pm 0.08 \text{ days vs } 1.41 \pm 1.35 \text{ days}; P < .0001, \text{ respectively; Table 1}) \). Postoperative laboratory data were compared between the 2 groups. There were significant differences between the 2 groups (Fig 2).
There were more deceased donor liver transplantsations in the CRRT group than in the non-CRRT group (52.4% vs 21.7%, respectively). In the CRRT group, pretransplantation hemoglobin (gram/deciliter) and hematocrit (%) were significantly lower than that in the non-CRRT group. However, estimated glomerular filtration rate (eGFR) (mL/min/1.732m²) = 186 × (creatinine/88.4) − 1.154 × (age) − 0.203 × (0.742 if female) × (1.210 if black) [9] was not different between the 2 groups.

In addition, the incidence of hepatic encephalopathy was significantly higher in the CRRT group compared with the non-CRRT group (54.76% vs 12.17%, respectively; P < .0001; Table 2). Chronic hepatitis B was the most common indication in both groups (CRRT vs non-CRRT: 57.1% vs 66.9%, respectively; P = .158). Tumor as the indication for transplantation was far less common in the CRRT group than in the non-CRRT group (4.76% vs 33.04%, respectively; P < .001; Table 3).

Table 4 shows the results of the multivariate logistic regression analyses. Stepwise multivariate analysis demonstrated that the following factors were appropriate for our renal replacement predictive model: type of organ donation (deceased donor, OR, 3.47; P = .019), preoperative hepatic encephalopathy (OR, 5.47; P = .001), MELD score (OR, 1.09; P = .002), tumor as the indication for transplantation (OR, 0.11; P = .033), and the amount of intraoperative blood loss (1000 L; OR, 1.16; P = .001; Table 4).

The formula developed for postoperative continuous renal replacement risk score was 1.7000 × HEP + [−4.5427 + 1.2440 × (deceased donor) + 0.0830 × (MELD score) + 0.000149 × the amount of intraoperative bleeding (L) − 2.1785 × tumor].

The performance of the regression model was evaluated using the AUC. The model discriminated well high-risk group who needed CRRT. The AUC was 0.90 (95% CI, 0.85–0.95; P < .001; Fig 4A).

On the basis of the variables independently associated with postoperative CRRT application, we constructed a nomogram (Fig 3). In the validation set, we compared the nomogram-predicted postoperative CRRT application with the observed rates. The nomogram strongly predicted the application of postoperative CRRT (Fig 4B).

**DISCUSSION**

Hepatic function and renal function are closely associated in patients with end-stage liver disease (ESLD) due to hemodynamic mechanisms related to advanced decompensated cirrhosis. ARF is a not uncommon complication that occurs immediately after orthotopic liver transplantation (OLT). Umbro et al recently reported that a greater severity of hepatic dysfunction before OLT resulted in a greater chance of ARF that can adversely affect long-term survival [10].

The Risk, Injury, Failure, Loss and End-Stage Renal Disease (RIFLE) classification system developed in 2004 by the Acute Dialysis Quality Initiative (ADQI) [11] is a consensus definition and has been widely validated worldwide. The severity grades of risk, injury, and failure are
defined on the basis of changes in serum creatinine level or urine output where the worst value for each criterion is used. Several previous studies used the RIFLE classification as means of diagnosing ARF in liver transplant recipients [12,13]. However, due to the retrospective nature of the data, the postoperative hourly urine output record was not always evident and the serum creatinine level of ESLD patients was less reliable in estimated renal function than normal adults. Therefore, we defined postoperative CRRT application within a week after transplantation as the onset of ARF in liver transplant recipients. The decision to initiate CRRT in each patient was a collaborative effort by nephrology, transplantation surgeon, and critical care teams. It took an average of 4.6 days postoperatively to initiate CRRT in liver transplant recipients (data not shown). The usual indications included the following: anuria, oliguria >500 mL/24 hours in combination with increased creatinine concentration >2 μmol/dL, and/or uncorrectable electrolyte imbalance in combination with severe bleeding tendency. CRRT was continuous veno-venous hemodiafiltration in all patents. We preferred CRRT rather than conventional intermittent hemodialysis for liver transplant recipients who developed ARF after operation. CRRT results in greater cardiovascular stability, less change in intracranial pressure, and less cerebral edema compared with standard conventional hemodialysis. In addition, postoperative inflammatory cytokine removal was more efficient with CRRT; and, therefore, CRRT was beneficial for end-stage hepatic failure patients [14,15].

We demonstrated that even in patients with preserved preoperative renal function, postoperative ARF requiring CRRT was associated with a higher mortality rate (90-day mortality rate, 43% vs 1%, and 1-year mortality rate, 50% vs 0.1%; P < .001 for both). Kaplan-Meier was used to graphically depict the difference between the 2 groups (Fig 1). As expected, the CRRT group showed postoperatively higher AST levels compared with the non-CRRT group (Fig 2). A previous study reported that ischemia reperfusion injury may be associated with initial hepatocyte destruction during the ischemia period and further injury ensuing on reperfusion. Postoperative AST correlated with the severity of IRI on postreperfusion liver biopsy [7,16]. In an animal model, renal cells undergo apoptosis during ischemia reperfusion injury like hepatic cells after OLT [17]. In our study, postoperative peak AST levels in the CRRT group were significantly higher than in the non-CRRT group (P < .001). Early liver dysfunction related to ischemia reperfusion injury has been associated with more frequent graft failure and postoperative multiorgan failure, leading to higher morbidity and mortality.

**Table 2. Preoperative Variables and Significance in Each Group**

<table>
<thead>
<tr>
<th>Variable</th>
<th>CRRT Group</th>
<th>Non-CRRT Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>42</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>Cadaver (%)</td>
<td>22 (52.38%)</td>
<td>25 (21.74%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hb (mg/dL)</td>
<td>10.21 ± 1.78</td>
<td>12.25 ± 8.56</td>
<td>.017</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>30.18 ± 5.32</td>
<td>33.84 ± 5.86</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Platelet (10³/μL)</td>
<td>93.38 ± 77.53</td>
<td>95.88 ± 86.43</td>
<td>.870</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>1.36 ± 1.57</td>
<td>0.90 ± 0.38</td>
<td>.064</td>
</tr>
<tr>
<td>BUN (mg/dL)</td>
<td>25.93 ± 19.94</td>
<td>15.14 ± 7.05</td>
<td>.001</td>
</tr>
<tr>
<td>eGFR* (ml/min/1.73 m²)</td>
<td>94.20 ± 80.34</td>
<td>94.95 ± 35.95</td>
<td>.955</td>
</tr>
<tr>
<td>Albumin</td>
<td>2.34 ± 0.82</td>
<td>2.23 ± 0.89</td>
<td>.472</td>
</tr>
<tr>
<td>INR</td>
<td>2.06 ± 0.96</td>
<td>1.44 ± 0.59</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total bilirubin (mg/dL)</td>
<td>13.35 ± 12.72</td>
<td>4.85 ± 8.27</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MELD score*</td>
<td>24.97 ± 9.49</td>
<td>13.58 ± 7.57</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>HEP</td>
<td>23 (54.76%)</td>
<td>14 (12.17%)</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**Table 3. Indications for Transplantation**

<table>
<thead>
<tr>
<th>Indication</th>
<th>CRRT Group</th>
<th>Non-CRRT Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAH (HBV)</td>
<td>24 (57.14%)</td>
<td>77 (66.96%)</td>
<td>.158</td>
</tr>
<tr>
<td>CAH (HCV)</td>
<td>3 (7.14%)</td>
<td>11 (9.57%)</td>
<td>.761</td>
</tr>
<tr>
<td>Cirrhosis not otherwise specified</td>
<td>9 (21.43%)</td>
<td>16 (14.04%)</td>
<td>.264</td>
</tr>
<tr>
<td>Cirrhosis of alcoholic</td>
<td>7 (16.67%)</td>
<td>7 (6.09%)</td>
<td>.056</td>
</tr>
<tr>
<td>Others</td>
<td>1 (2.38%)</td>
<td>14 (12.17%)</td>
<td>.072</td>
</tr>
<tr>
<td>Tumor</td>
<td>2 (4.76%)</td>
<td>38 (33.04%)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: CAH, chronic active hepatitis; Cirrhosis not otherwise specified or cryptogenic cirrhosis; FHF, fulminant hepatic failure.

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**Fig 2.** Postoperative sequential comparison of the changes in the levels of AST, PT, and total bilirubin between the 2 groups.
Among other laboratory values, postoperative PT is commonly monitored in patients with hepatic failure because it is inexpensive, readily available, and commonly perceived to reflect the risk of bleeding. The extent of coagulation abnormalities, reflected most sensitively by the PT, correlates well with the severity of hepatocellular damage, as well as the overall prognosis [18]. The PT in group CRRT was higher than that of the non-CRRT group at any point during the postoperative first week (P < .001). Another laboratory value, postoperative total bilirubin showed a similar pattern as PT. Wagener et al reported that total bilirubin could be a useful predictor of early allograft failure not only for pretransplantation graft allocation but also for postoperative risk stratification [19]. There was also a statistically significant difference in the level of total bilirubin of the 2 groups (P < .001).

Multivariate analysis demonstrated that the following factors proved to have the best fit in our predictive model:

\[
\text{Points} = 4.5427 \times \frac{1}{\text{CRI}} + 1.09 \times (1.03 - 1.15) + 1.16 \times (1.06 - 1.27) + 0.11 \times (0.02 - 0.84) \]

\[
\text{Odds Ratio (95\% CI)} = 5.47 (1.93 - 15.52), 3.47 (1.23 - 9.80), 1.09 (1.03 - 1.15), 1.16 (1.06 - 1.27), 0.11 (0.02 - 0.84)
\]

**Table 4. Multivariate Analysis**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEP</td>
<td>5.47 (1.93–15.52)</td>
<td>.001</td>
</tr>
<tr>
<td>Deceased donor</td>
<td>3.47 (1.23–9.80)</td>
<td>.019</td>
</tr>
<tr>
<td>MELD score*</td>
<td>1.09 (1.03–1.15)</td>
<td>.002</td>
</tr>
<tr>
<td>Intraoperative blood loss (L)</td>
<td>1.16 (1.06–1.27)</td>
<td>.001</td>
</tr>
<tr>
<td>Tumor†</td>
<td>0.11 (0.02–0.84)</td>
<td>.033</td>
</tr>
</tbody>
</table>

Abbreviation: HEP, hepatic encephalopathy.

*10 (0.957 Ln[Scr] + 0.378 Ln[Tbil] + 1.12 Ln[NAL] + 0.643) [29].
†Hepatocellular carcinoma: indication for liver transplantation.

Hepatic encephalopathy (HEP) (OR, 5.47; P = .001), type of organ donation (deceased donor OR, 3.47; P = .019), MELD score (OR, 1.09; P = .002), intraoperative blood loss (L, OR, 1.16; P = .001), and tumor as the indication for transplantation (OR, 0.11; P = .033; Table 4). The formula developed was postoperative continuous renal replacement risk score = 1.7000 × HEP + [-4.5427 + 1.2440 × (deceased donor) + 0.0830 × (MELD score) + 0.000149 × the amount of intraoperative bleeding (L) – 2.1785 × tumor].

The formula could be compared with a previous study in which Sanchez et al reported a clinical prediction model for renal replacement therapy after liver transplantation [6]. However, there are a few apparent differences between this previous study and our study. First, they did not consider preoperative renal function and renal replacement therapies and included both intermittent conventional hemodialysis and CRRT. In contrast, we included only CRRT, which we typically applied for severely hemodynamically unstable patients. Second, they assessed the preoperative creatinine value and MELD score simultaneously. However, this may result in multi-collinearity of the 2 independent variables in a regression equation. Moreover, reduced muscle mass, poor protein intake, severe hyperbilirubinemia, volume expansion, and reduced liver synthesis of creatinine all contributed to serum creatinine level being a poor marker for renal function in liver disease. Third, they arbitrarily changed continuous variables, such as creatinine, BUN, and MELD score, to categorical. This would attenuate the predictive power of the clinical prediction model.

In our study, HEP had the highest OR as a predictor for CRRT intervention. The severity of hepatic encephalopathy suggests that manifestation of encephalopathy accounts for brain exposure to excess levels of neuro-toxic substances [20,21]. Kalaitzakis et al reported that renal dysfunction was related to cognitive impairment in patients with liver cirrhosis and might be implicated in the pathogenesis of HEP [22]. Renal function in end-stage hepatic failure patients might play an important role in the metabolism of ammonia or renal failure influenced by the synthesis of urea, in other words, the detoxification of ammonia [23]. Riggio et al reported that serum creatinine level was a risk factor for HEP in patients undergoing transjugular intrahepatic porto-systemic shunting [24]. Although we did not clarify the sequence underlying the incidents of renal failure and HEP, we can say that preoperative HEP was related to postoperative renal function impairment.

Our study is the first trial to reveal a relationship between postoperative renal function impairment and the type of organ donation. There are some factors that may explain why adult living donor liver transplant (LDLT) recipients developed ARF less frequently than deceased donor liver transplant (DDLT) recipients. Living donation recipients had a relatively lower MELD score and LDLT recipients were generally less ill than their DDLT counterparts at the time of transplantation. Cold ischemic time (CIT) is a known risk factor for postoperative acute cellular rejection [25,26]. In addition, LDLT could decrease the incidence of
acute cellular rejection by shortening the waiting time and CIT, and, furthermore, it could help with recovery of hepatic function. In the setting of LDLT, we were able to provide planned preoperative nutritional support to both the recipients and donors. Protein-energy malnutrition is a known risk factor for postoperative morbidity and mortality in end-stage hepatic failure patients awaiting transplantations [27]. The European Society for Enteral Nutrition recommends that those undergoing major abdominal surgery, including liver transplantation, should receive at least 5 to 7 days of enteral nutritional support with immune-modulating substances [28].

In our study, the MELD score was one predictor of CRRT therapy. MELD score predicted 3-month mortality in patients with chronic liver disease on the liver waiting list and could be applied for allocation of donor livers. Mortality rate was 1.9% in patients with a MELD score <9, whereas patients with a MELD score >40 had a mortality rate of 71.3% [29]. MELD scores predicted liver disease severity, and it is associated with postoperative renal impairment.

Intraoperative blood loss is a known risk factor for the postoperative renal failure. Our results correspond with those of previous studies [13,30]. Hypotension from massive bleeding provides a clinical environment for ischemic renal injury.

Hepatocellular carcinoma (HCC) is 1 of the 5 most common malignancies in Koreans [31] and its incidence is increasing worldwide [32]. In our study, 40 patients (25%) had HCC as the indication for transplantation. Liver transplantation represents the treatment of choice for patients with HCC and cirrhosis, and provides excellent oncological results and a cure for cirrhosis. During the preoperative evaluation, Milan criteria (1 tumor between 2 and 5 cm, or up to 3 tumors all <3 cm) [33–35] are applied as a basis for selecting patients with cirrhosis and HCC for liver transplantation. Therefore, patients with HCC have generally preserved liver function and a lower MELD score than ESLD patients. It is not surprising that preoperative preserved liver function could explain the favorable postoperative renal function.

We developed a nomogram to predict the application of CRRT in patients undergoing liver transplantation. The discriminative ability of the regression model was evaluated using AUC. The model discriminated well between patients who needed CRRT and those who did not. The AUC for our nomogram was 0.90 (95% CI, 0.85–0.95; P < .001; Fig 4A). We compared the nomogram-predicted postoperative CRRT application to the observed frequency of patients requiring CRRT in the validation set. The calibration was satisfactory for the validation set (Fig 4B). These results show that the individual probability of postoperative CRRT application can be predicted accurately by combining preoperative and intraoperative data. Our nomogram was designed to use clinical covariates to identify patients who may develop postoperative ARF and require postoperative CRRT.

Our findings have several limitations. First, this study was done at a single institution, and it included a mix of living and deceased donor recipients (LDLT vs DDLT, 70.1% vs 29.9%, respectively). In addition, the number of LDLTs was greater than that of DDLTs, including when compared with other studies performed in Western countries. In Asia, where the supply of cadaveric grafts remains scarce and the necessity for liver transplantation has increased, the demand for adult LDLTs has increased. According to the Korean Network of Organ Sharing (KNOS), the number of adult LDLTs (patients aged older than 18 years) increases annually with 502 transplantations performed in Korea in 2006, while there were only 383 in Japan and 223 in the United States [36,37]. LDLTs accounted for less than 5% of all liver transplantations in the United States, compared with more than 90% in Asia [37]. For this study, we did not consider the difference between surgical procedures and donor selection for the 2 types of donation. Second, we could not externally validate the predictive model for this study period, and we need to validate this model in at least one other institution. We should use deviance statistics to
assess the model’s goodness of fit. Third, the time point of application of CRRT was not analyzed. Postoperative renal function recovery might be affected by the time point of CRRT application. Finally, other risk factors, which might be involved in the development of ARF in liver transplant recipients, including infection/sepsis, intolerance of calcineurin inhibitor therapy, and postoperative shock, were not analyzed.

In conclusion, we evaluated perioperative factors that may predict ARF requiring CRRT after liver transplantation. The associated risk factors were HEP, DDLT, preoperative MELD score, and intraoperative blood loss. In cases for which tumor was the indication for transplantation, it was revealed that these patients had a more favorable outcome in terms of postoperative renal function. With this clinical, simple nomogram, we could calculate the probability of postoperative application of CRRT and could thoroughly prepare postoperative application of CRRT in advance. Moreover, we should try to develop preventive strategies to preserve renal function and to decrease morbidity and mortality.

ACKNOWLEDGMENTS

We would like to thank statistical assistant, Ms Lee Hye Sun, for her help with the data analysis.

REFERENCES


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