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Histidine-tryptophan-ketoglutarate solution versus University of Wisconsin solution in adult-to-adult living donor liver transplantation

A propensity score matching analysis from mainland China

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Abstract

To compare the difference between University of Wisconsin (UW) solution and histidine-tryptophan-ketoglutarate (HTK) solution in adult living donor liver transplantation (LDLT).

This study included LDLT patients at the Liver Transplantation Center of West China Hospital of Sichuan University from November 2001 to June 2018. These patients were classified into 2 groups depending on the use of the different preservation solutions, and the confounding factors between the 2 groups were eliminated by propensity score matching. Finally, the incidence of complications; serum examination at postoperative days 1, 3, 5, 7, 14, 21, and 30; and the overall survival rate of the 2 groups were compared to observe whether there were any differences between the 2 preservation solutions.

Of the 298 patients we screened, 170 were treated with UW solution and 128 with HTK solution. After propensity score matching, 106 pairs of patients were selected. In the comparison of the 2 groups, the length of intensive care unit stay in the UW group was significantly longer than that in the HTK group ($P = .022$), but there was no difference in the total length of hospital stay between the 2 groups ($P = .277$). No statistically significant difference was observed in the 2 groups in terms of the incidence of complications or postoperative examinations. However, the incidence of early allograft dysfunction in the HTK group was slightly lower than that in the UW group (HTK: UW = 14.1%: 20.7%), although the difference was not statistically significant. In terms of the overall survival rate, the 1, 3, and 5-year survival rates of the HTK group were 85.5%, 70.2%, and 65.1%, respectively, while the 1, 3, and 5-year survival rates of the UW group were 83.1%, 67.2%, and 59.8%, respectively, and there was no significant difference between the 2 groups.

In conclusion, our study shows that UW solution and HTK solution are equivalent in perioperative safety, the recovery of transplanted liver function, the occurrence of postoperative complications and overall survival and can be safely and effectively applied in adult LDLT. If economic factors are taken into account, HTK can save costs to a certain extent.

Abbreviations: BMI = body mass index, CIT = cold ischemia time, DCD = donated after cardiac death, DDLT = deceased donor liver transplantation, HTK = histidine-tryptophan-ketoglutarate, ICU = intensive care unit, INR = international normalized ratio, LDLT = living donor liver transplantation, PSM = propensity score matching, TB = total bilirubin, UW = University of Wisconsin.

Keywords: histidine-tryptophan-ketoglutarate solution, living donor liver transplantation, organ preservation, University of Wisconsin solution

1. Introduction

Due to the growing waiting list for liver transplantation and the Asian region's religious, cultural, political, and traditional factors, the shortage of organs has become increasingly apparent.[1,2] Therefore, living donor liver transplantation (LDLT) is booming in Asia.

Editor: Kelvin Ng.

This study was supported by grants from the 1.3.5 project for discipline of excellence, West China Hospital, Sichuan University (ZY2017308).

The Ethics Committee of West China Hospital, Sichuan University approved this study.

Written informed consent was waived because this was a retrospective study, and all participants were anonymous.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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How to cite this article: Xu X, Zhu Y-F, Lv T, Zheng J-L, Li Y-k, Zhang B-H, Jiang L, Yang J-y. Histidine-tryptophan-ketoglutarate solution versus University of Wisconsin solution in adult-to-adult living donor liver transplantation: a propensity score matching analysis from mainland China. Medicine 2020;99:51(e23584).

Received: 26 February 2020 / Received in final form: 17 July 2020 / Accepted: 16 August 2020

http://dx.doi.org/10.1097/MD.0000000000023584

Organ preservation is indispensable for both deceased donor liver transplantation (DDLT) and LDLT, plays an important role in graft ischemia reperfusion injury and graft function and is a prerequisite for long-term survival of the recipient and graft.[3] Despite the current thrive of machine perfusion, static cold perfusion still used as main technique for graft preservation in most liver transplantation centers at present and may not be fully replaced by machine perfusion for a long time. For static cold perfusion, the effectiveness between different preservation solutions is not yet fully elucidated.

The University of Wisconsin (UW) solution and histidine-tryptophan-ketoglutarate (HTK) solution are 2 most commonly used organ preservation fluids and their specific components have been described in detail in previous articles.[4] The comparison between UW solution and HTK solution has been ongoing for decades. Earlier studies found that HTK solution and UW solution had similar results and were equally safe and effective.[5–12] Beyond that, there is no clear evidence that 1 preservation solution is superior to another. However, according to some reports, the viscosity of UW solution is higher than that of HTK solution. Therefore, it takes more time in the perfusion and flush processes, and uneven perfusion and incomplete flush before reperfusion are more likely to occur. Furthermore, because of the high potassium levels in UW fluid, not rinsing before reperfusion can cause hemodynamic instability.[5,6,9,11] Beyond that, the role of 2 preservation solutions in biliary complications created tremendous controversy. And different studies had different conclusions.[12–14]

With the further development of follow-up studies, Z. A. Stewart et al stated in their report that HTK solution was an independent risk factor for graft loss, especially for grafts donated after cardiac death (DCD) and organs with a long cold ischemia time (CIT).[15] This was reemphasize in a 2014 European multicenter study by R. Adam et al. In this study, they found that the survival rate of the HTK solution group and UW solution group became increasingly different with the extension of total ischemia time.[4] Interestingly, DE Boer et al conducted a stratified study of the region later on, suggesting that the above results were due to regional differences in donor, recipient and transplant characteristics, and they proposed that preservation fluid could be selected according to the experience of surgeons and transplant centers.[16]

LDLT has its unique advantages and disadvantages compared to DDLT. Therefore, the preservation solution requirements of LDLT are different from those of DDLT. However, only a few articles have comprehensively analyzed the application of HTK and UW solutions in LDLT.[5,10] Moreover, the sample sizes were small, and the baseline indicators were not consistent.

In this study, we collected LDLT data of our center and classified them into 2 groups based on the use of the different preservation solutions, and the propensity scores matching method was used to eliminate confounding factors, we compared their short-term and long-term outcomes to get know that whether any difference between 2 preservation solutions.

2. Method

2.1. Patient

We collected data of LDLT patients who underwent LDLT in Liver Transplantation Center of West China Hospital, Sichuan University from November 2001 to June 2018. Patients meet the following criteria were excluded from this study:

1) younger than 18 years old;
2) repeated liver transplantation;
3) dual-grafts transplantation;
4) non-right-lobe grafts LDLT.

UW solution was the only preservation solution in our center at the very beginning and HTK solution were introduced into our center to replace UW solution completely at June 2013. Thus, patients included in this study who underwent LDLT before June 2013 were divided into the UW solution group and the rest were divided into the HTK solution group. Prior to analysis, all our data were prospectively entered into the China Liver Transplantation Register) (http://www.cltr.org/). All procedures in this study were approved by the West China Hospital Ethics Committee and were in line with the Declaration of Helsinki.

2.2. Donor and recipient data

All donor and recipient data were obtained from the China Liver Transplantation Register, including donor and recipient demographic data, surgical data, postoperative recovery, intraoperative, postoperative complication rates, serological examination results at days 1, 3, 5, 7, 14, 21, and 30and annual survival of recipient and graft.

2.3. Surgical procedure

First, multi-row computed tomography and magnetic resonance cholangiopancreatography were performed on the donor to assess liver volume and vascular and bile duct anatomy. Then, intraoperative cholangiography and intraoperative ultrasonography were used for further evaluation. After the evaluation, we used Cavitron ultrasonic surgical aspirator (CUSA System 200; Valleylab Inc., Boulder, CO) to perform donor liver resection with intermittent interruption of blood flow into the liver (15 minutes each time, 5-minute intervals). After the donor liver resection was completed, the donor liver was quickly placed in a 4°C container with preservation fluid and then perfused in the background through the portal vein. Prior to transplantation, portal vein irrigation was routinely performed with albumin in either UW solution or HTK solution. Next, grafts were orthotopically transplanted using a piggyback technique. The entire procedure was described in detail in our previous study.[17]

2.4. PSM

To eliminate the confounding factors between the 2 groups as much as possible, we conducted a PSM analysis. By using logistic regression, recipient information (gender, age, body mass index (BMI), diagnosis, preoperative creatinine, preoperative albumin, preoperative total bilirubin (TB), preoperative International normalized ratio (INR), Model for end-stage liver disease score, Child-Pugh score, ABO compatibility), donor information (gender, age, BMI), Graft-to-recipient weight ratio, and surgical features (anhepatic phase, CIT, recipient operation time) were used to calculate the propensity scores. Two groups were then matched 1:1 using a nearest-neighbour calliper matching algorithm with a calliper width fixed at 0.2.

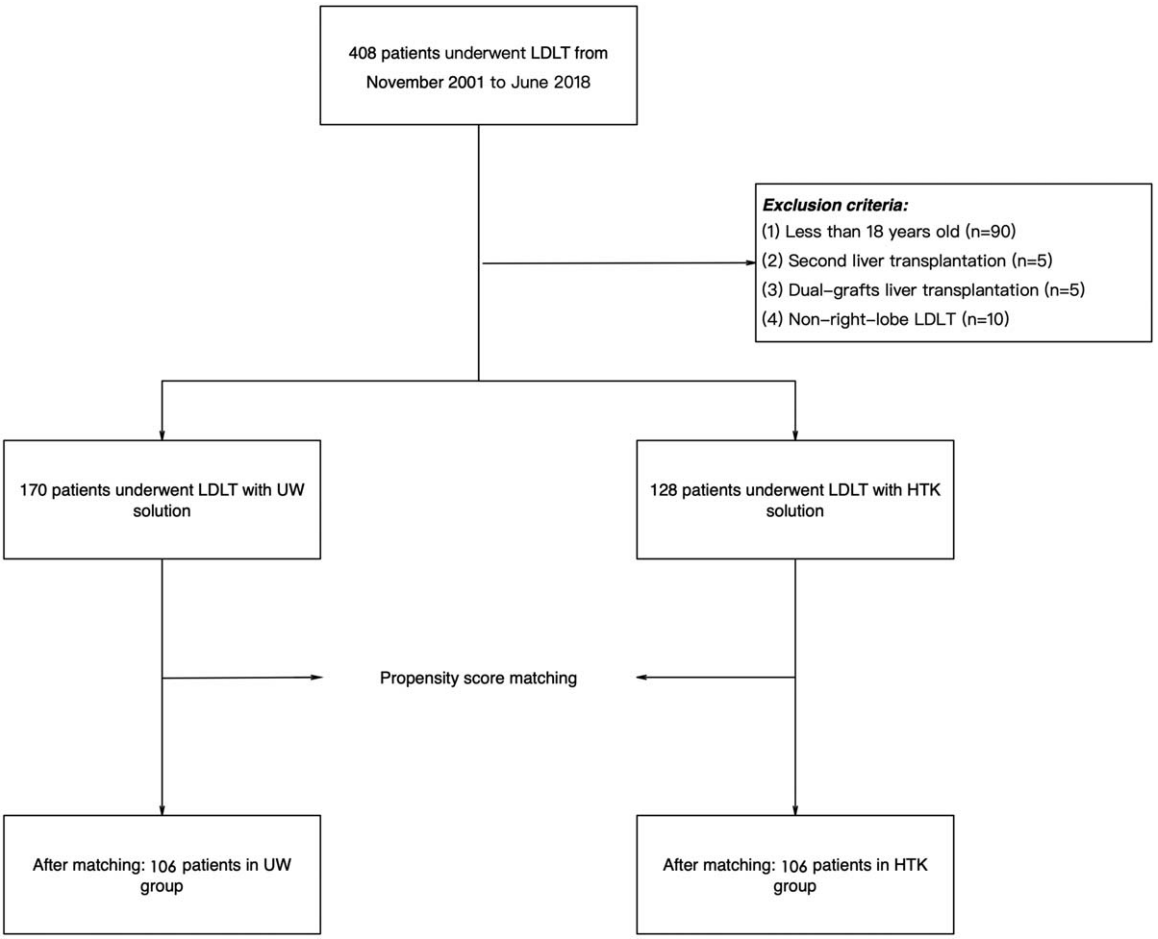

Figure 1. Flow of study participants. HTK = histidine-tryptophan-ketoglutarate, LDLT = living donor liver transplantation, UW = University of Wisconsin.

2.5. Statistical analysis

All continuous variables were represented by the mean ± standard deviation or median (interquartile range) and compared by Student *t* test or Mann–Whitney *U* test. Categorical data were expressed as percentages and compared by the Chi-squared test or Fisher exact test. The survival curves were analyzed by the Kaplan–Meier method and compared by the log-rank test. Two-way repeated-measures ANOVA was used for postoperative laboratory examination. When $P < .05$, the difference was considered statistically significant. Each test was 2 tailed. All statistical analyses were performed using IBM SPSS version 23.0 (SPSS Inc., Chicago, IL).

3. Results

3.1. Recipient demographic characteristics

Flow chart of study participants is shown in Figure 1. Of the 408 patients we screened, 298 patients were included into this study. Among them, 170 were treated with UW solution and 128 were treated with HTK solution. After matching the propensity scores, 106 pairs of patients were selected. All the statistical results are listed in Table 1. There were no statistically significant differences in age, gender, BMI, or diagnostic distribution between the 2 groups of DDLT recipients before the PSM. However, there were statistically significant differences in some indicators of disease severity, such as preoperative TB ($P = .025$) and model for end-stage liver disease scores ($P = .029$). This means that patients in the HTK group were sicker than those in the UW group. It also implies confounding factors between the 2 groups.

3.2. Donor demographic characteristics

All the donors were healthy people who had undergone our rigorous evaluation and were also reviewed by the ethics committee. All results of donor demographic characteristics are shown in Table 2. There was significant difference in the gender distribution between the 2 groups ($P = .004$), the proportion of males in the UW group was much higher than that in the HTK group. After PSM, there was no significant difference between the 2 groups in terms of donor demographics and preoperative examination.

3.3. Surgical features of the recipients

The surgical characteristics are also listed in Table 1. Before PSM, the overall operation time ($P = .008$) between the 2 groups was significantly different. The operation time of the UW group was significantly longer than that of the HTK group, which may have a certain degree of influence on the prognosis. After PSM, there

Table 1

Recipient demographics and surgically related factors before and after propensity score matching.

Variable	Before matching			After matching		
	HTK group (n = 128)	UW group (n = 170)	*P* value	HTK group (n = 106)	UW group (n = 106)	*P* value
Age	43.0 ± 9.5	42.6 ± 8.7	.708	43.3 ± 9.7	42.4 ± 9.1	.494
Sex (male)	105 (82.0%)	144 (84.7%)	.537	85 (80.2%)	88 (83.0%)	.595
BMI (kg/m^2)	22.2 ± 2.8	22.6 ± 3.2	.246	22.3 ± 2.8	22.5 ± 3.2	.647
Creatinine (μmol/L)	65 (50–76.4)	67 (57–84)	.070	65 (53.2–76)	65 (56.4–84)	.335
ALB (g/L)	32.5 (25.2–37.4)	32.9 (26.8–39.0)	.346	33.2 (27.1–38)	31.5 (27.1–37.3)	.400
TB (μmol/L)	37.15 (15.95–93.4)	26.65 (13.9–59.4)	.025*	35.2 (15.6–74.8)	35.7 (17.0–68.6)	.956
INR	1.38 (1.21–1.71)	1.37 (1.15–1.68)	.151	1.32 (1.2–1.6)	1.44 (1.19–1.85)	.183
MELD score	14 (9.5–21.5)	12 (8–17)	.029*	13 (9–18)	13.5 (10–18)	.506
Child-Pugh score	8 (7–10)	8 (7–9)	.218	8 (7–10)	8 (7–10)	.957
Diagnosis			.882			.882
Liver cirrhosis	55 (42.9%)	66 (38.9%)		43 (40.6%)	49 (46.2%)	
Primary liver cancer	50 (39.1%)	77 (45.3%)		46 (43.4%)	41 (38.7%)	
Alcoholic cirrhosis	4 (3.1%)	5 (2.9%)		3 (2.8%)	4 (3.8%)	
Liver failure	13 (10.2%)	15 (8.8%)		9 (8.5%)	9 (8.5%)	
Others	6 (4.7%)	7 (4.1%)		5 (4.7%)	3 (2.8%)	
Anhepatic phase (min)	89 (73–102)	87 (70–105)	.949	88 (74–101.5)	89 (75–107)	.886
CIT (min)	192 (116–270)	177 (105–255)	.477	200 (115–270)	190 (101–260)	.712
Operation time (min)	590 (500–660)	641 (555–730)	.008*	590 (500–665.5)	600 (535–680)	.289
Blood loss (mL)	1500 (1000–3000)	1500 (1000–3000)	.845	1500 (1000–3000)	1500 (1000–2500)	.932
PRBC transfusion (U)	6 (1.5–8)	4.75 (0–10)	.895	6 (1.75–8.75)	6 (2–10.5)	.539
Plasma transfusion (mL)	800 (550–1450)	1000 (600–1650)	.976	850 (575–1525)	1050 (600–1800)	.611
Platelet transfusion (U)	0 (0–0)	0 (0–0)	.539	0 (0–0)	0 (0–0)	.822
GRWR	0.929% ± 0.184%	0.932% ± 0.224%	.913	0.929% ± 0.189%	0.911% ± 0.207%	.512

ALB = albumin, BMI = body mass index, CIT = cold ischemia time, GRWR = graft-to-recipient weight ratio, HTK = histidine-tryptophan-ketoglutarate, INR = international normalized ratio, MELD score = model for end-stage liver disease score, TB = total bilirubin, UW = University of Wisconsin.

was no significant difference in surgical characteristics between the 2 groups, including the duration of the anhepatic phase, CIT, overall operation time, blood loss, transfusion volume, and graft-to-recipient weight ratio.

3.4. Receptor complications and prognostic factors

All the information of complication after PSM is listed in Table 3. There was no statistic significant difference in intraoperative complications between the 2 groups. We defined early postoperative complications as complication occurred in first 3 months. Postoperative abdominal bleeding and vascular complications were classified according to the Clavien-Dindo classification,[18] and Grade ≥III complications were the main complications we observed. Early allograft dysfunction is characterized by TB ≥10 mg/dL 1 week after surgery, INR ≥1.6 one week after surgery, and alanine or aspartate aminotransferase > 2000 IU/L in the first post-transplantation week.[19] Among all the results, we found that the length of intensive care unit (ICU) stay in the UW group was significantly longer than that in the HTK group ($P = .022$), but there was no difference in the total length of hospital stay between the 2 groups ($P = .277$). No significant difference was observed in the incidence of complications, especially in the incidence of biliary tract complications, which was similar between the 2 groups. However, the incidence of EDA in the HTK group was slightly lower than that in the UW group (HTK: UW = 14.1%: 20.7%), although the difference was not statistically significant. In addition, we also compared TB, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, glutamyl transpeptidase, and INR at 1, 3, 5, 7, 14, 21, and 30 days after surgery, and the results of the 2 groups were nearly consistent (Fig. 2).

Table 2

Donor demographic factors before and after propensity score matching.

Variable	Before matching			After matching		
	HTK group (n = 128)	UW group (n = 170)	*P* value	HTK group (n = 106)	UW group (n = 106)	*P* value
Age	37.7 ± 10.2	36.7 ± 10.4	.389	37.6 ± 10.4	37.4 ± 10.5	.894
Sex (male)	61 (47.7%)	109 (64.1%)	.004*	57 (53.8%)	59 (55.7%)	.783
BMI (kg/m^2)	23.1 ± 2.5	23.0 ± 2.7	.871	23.0 ± 2.5	23.0 ± 2.8	.978
TB (μmol/L)	13.8 ± 5.3	14.6 ± 7.1	.262	13.7 ± 5.3	15.2 ± 7.6	.104
AST	23.9 ± 13.1	22.3 ± 9.8	.238	23.6 ± 14.0	22.5 ± 10.5	.527
ALT	25.3 ± 17.1	25.6 ± 18.7	.871	25.0 ± 17.9	26.1 ± 20.6	.684
ABO compatibility	128 (100%)	169 (99.4%)	.218	106 (100%)	106 (100%)	1.000
Operation time (min)	424 ± 84	430 ± 87	.564	420 ± 86	427 ± 84	.578

ALT = alanine aminotransferase, AST = aspartate aminotransferase, BMI = body mass index, HTK = histidine-tryptophan-ketoglutarate, TB = total bilirubin, UW = University of Wisconsin.

Table 3

Complication description of patients after propensity score matching.

Variable	HTK group (n = 106)	UW group (n = 106)	*P* value
Postoperative respiratory support time (h)	10 (6–25)	10 (7.5–16)	.855
Endotracheal re-intubation	7 (6.6%)	8 (7.5%)	.759
Length of ICU stay (h)	187 (142.5–301)	239 (168–333)	.022*
Length of hospital stay (d)	28 (18–36.5)	28.5 (21–37.5)	.277
Intraoperative complications			
Cardiac arrest	0 (0%)	1 (0.9%)	1.000
Massive hemorrhage	3 (2.8%)	2 (1.9%)	1.000
Stenosis of the hepatic vein	1 (0.9%)	0 (0%)	1.000
Stenosis of the portal vein	1 (0.9%)	1 (0.9%)	1.000
Low blood pressure	0 (0%)	2 (1.8%)	.498
Early postoperative complications			
Abdominal bleeding	5 (4.7%)	5 (4.7%)	1.000
Hepatic artery embolization	1 (0.9%)	2 (1.8%)	1.000
Portal vein embolization	2 (1.8%)	2 (1.8%)	1.000
Stenosis of the hepatic vein	1 (0.9%)	0 (0%)	1.000
Multiple organ failure	2 (1.8%)	2 (1.8%)	1.000
Acute rejection	3 (2.8%)	0 (0%)	.236
EAD	15 (14.1%)	22 (20.7%)	.205
Late postoperative complications			
Hepatic artery embolization	0 (0%)	0 (0%)	
Portal vein embolization	0 (0%)	1 (0.9%)	1.000
Stenosis of the hepatic vein	1 (0.9%)	0 (0%)	1.000
Chronic rejection	4 (3.8%)	2 (1.8%)	.679
Biliary complications	15 (14.1%)	13 (12.2%)	.685
Biliary stenosis	13 (12.3%)	9 (8.5%)	.368
Biliary leakage	4 (3.8%)	5 (4.7%)	1.000

EAD = early allograft dysfunction, HTK = histidine-tryptophan-ketoglutarate, ICU = intensive care unit, UW = University of Wisconsin.

3.5. Survival

As shown in Figure 3, in the survival analysis of the 2 groups, the 1, 3, and 5-year patients survival rates of the HTK group were 85.5%, 70.2%, and 65.1%, respectively, while the 1, 3, and 5-year patients survival rates of the UW group were 83.1%, 67.2%, and 59.8%, respectively ($P = .558$). Similarly, the 1, 3, and 5-year grafts survival rates of the HTK group were 84.4%, 69.0%, and 64.0%, respectively, while the 1, 3, and 5-year grafts survival rates of the UW group were 80.6%, 65.6%, and 57.9%, respectively ($P = .503$)

4. Discussion

Organ preservation is not only an important part of organ transplantation surgery but also a major challenge in organ transplantation surgery, which is related to the prognosis of the recipient.[3] Despite the current vigorous development of machine perfusion[20–22] and the conclusion from various studies that machine perfusion can reduce the incidence of postoperative biliary complications and graft dysfunction,[23] static cold perfusion still used as main technique for graft preservation in most liver transplantation centers at present and may not be fully replaced by machine perfusion for a long time. For static cold perfusion, the selection of preservation solution is key. Although the comparison of UW solution and HTK solution, 2 most common liver preservation solutions, has been ongoing for decades, disputes still exist regarding the effects of these solutions on DDLT.

Compared with DDLT, LDLT has its unique advantages:

1) an optimized time of the transplant operation and a decreased time on waitlist of patients; and
2) more detailed assessment of graft quality, short cold ischemia time, and more stable donor hemodynamic.[24,25]

However, the disadvantages of LDLT are also obvious:

1) the technique of LDLT is complicated, the operation is difficult, and vascular and biliary complications are increased; and
2) LDLT will put healthy donors at higher risk.[24,26]

The discrepancies between LDLT and DDLT make the choice of preservation solution more confusing. Although the short CIT

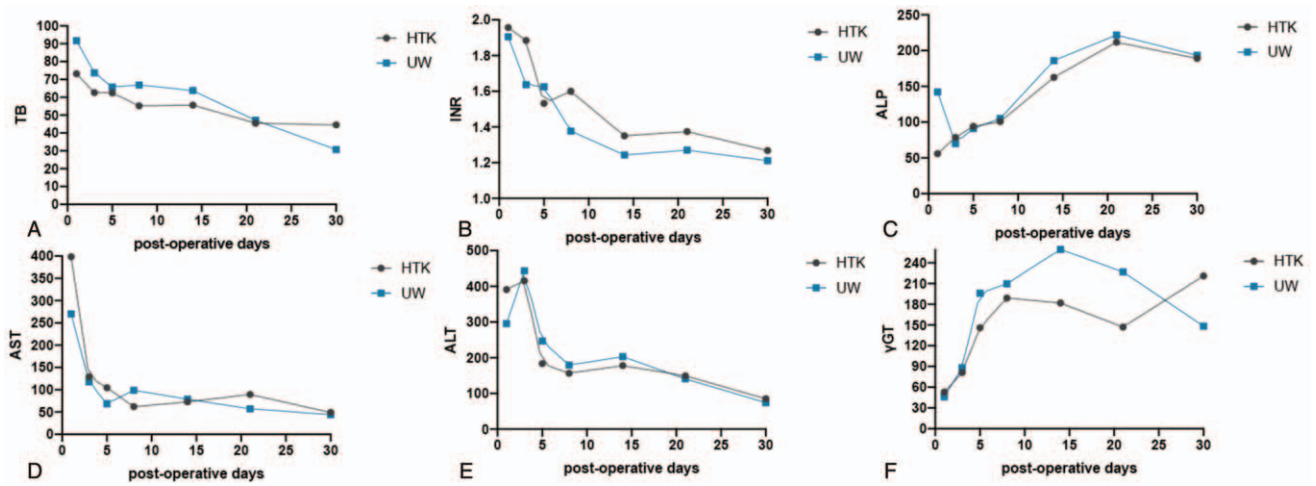

Figure 2. The development of postoperative total bilirubin, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, glutamyl transpeptidase, and international normalized ratio at 1, 3, 5, 7, 14, 21, and 30 days after surgery. γGT = glutamyl transpeptidase, ALP = alkaline phosphatase, ALT = alanine aminotransferase, AST = aspartate aminotransferase, HTK = histidine-tryptophan-ketoglutarate, INR = international normalized ratio, TB = total bilirubin, UW = University of Wisconsin.

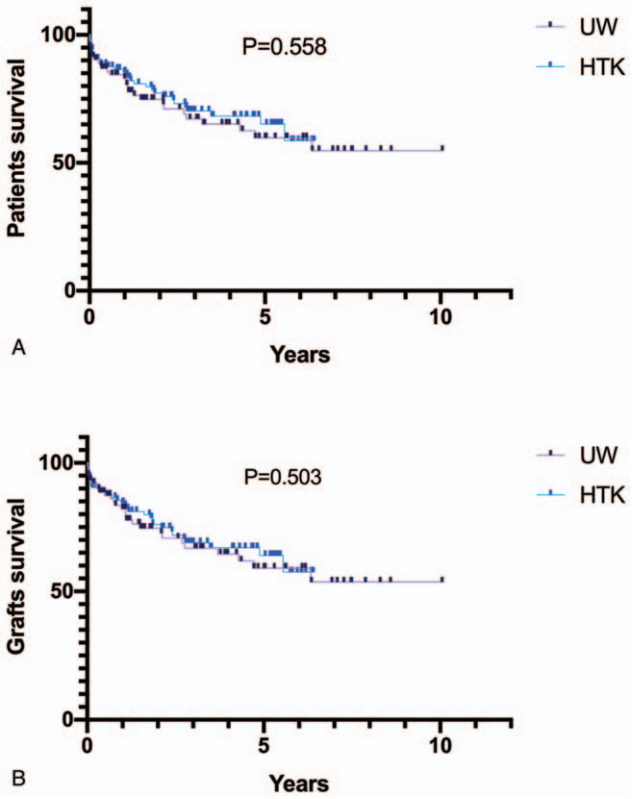

Figure 3. Patients survival and grafts survival after propensity score matching.

and the excellent quality of the donor liver, may reduce the potential different influences between preservation solutions. The transplanted liver is only a partial liver, and the safety of the donor should be ensured as much as possible. Therefore, the survival of liver cells should be ensured as much as possible, which increases the dependence on the preservation fluid. Therefore, the requirements of the preservation solution for LDLT are different from those of DDLT. However, only a few articles have comprehensively analyzed the application of HTK and UW solutions in LDLT.[5,10] Moreover, the sample sizes were small, and the baseline indicators were not consistent.

To our best knowledge, this is the first PSM based case-match study to compare the potential different influence between UW and HTK solutions on LDLT. According to our results, the incidence of intraoperative complications was similar in both groups. Previous study have suggested that a sudden influx of a high potassium concentration from UW solution can bring about significant various arrhythmias and myocardial depression, even leading to cardiac arrest.[7] Additionally, S. Ghafaripour et al reported that HTK solution will lead hypotension after reperfusion, especially for graft not flushed before.[27] In our study, only 1 patient suffered cardiac arrest before the anhepatic phase. And 2 cases of low blood pressure were caused by massive hemorrhage. We did not observe hemodynamic abnormalities due to electrolyte disturbance after opening the blood flow. This could be due to portal vein irrigation was routinely performed with albumin prior to transplantation both in UW solution and HTK solution cases. Additionally, it is of note that the length of stay in the ICU was significantly longer for the UW solution group than the HTK solution group ($P=.022$), but the total length of hospital stay was similar. Since the liver function parameters at each study time point were comparable between groups, the reason underlying disparity of the length of ICU stay between groups can explained by the change of ICU discharge criteria along with the time variation.

Regarding postoperative complications, both the early postoperative complications and the late postoperative complications were similar in the 2 groups. Although there was no significant difference, the incidence of early allograft dysfunction in the UW group was higher than that in the HTK group (UW: HTK = 20.7%: 14.1%, $P=.205$). For the most controversial biliary complications, we observed that the total incidence of biliary complications (UW: HTK = 12.2%: 14.1% $P=.685$) and the incidence of biliary stenosis (UW: HTK = 8.5%: 12.3% $P=.368$) in the HTK group were slightly higher than those in the UW group, but the differences were not statistically significant. In other studies, the role of 2 preservation solutions in biliary complications created tremendous controversy. In the study of Rojbin Karakoyun et al, UW solution was considered to be an independent risk factor for postoperative biliary complications, and they concluded that because of the low viscosity of HTK solution, it had a protective effect on the occurrence of biliary complications.[13] Christoph Heidenhain et al, also found that Organs that were perfused with UW solution developed ischemic-type biliary lesions significantly more often than HTK group.[28] But some studies have come to the opposite conclusion that HTK solution is associated with an increased risk of biliary complications.[9,14] But all above studies focused on DDLT even DCD. For LDLT, because of its short ischemia time is short, the risk factors for biliary complications are different from DDLT. A study have suggested that the biliary complications of LTLD are major related to donor age and anatomical structure.[29] Therefore, the type of preservation solution may have little influence on biliary complications in LDLT. Results from our study also remain in line with results presented by Chan SC et al.[5]

In terms of patients survival rate and grafts survival, the 1, 3m and 5-year patients survival rates of the HTK group were 85.5%, 70.2%, and 65.1%, respectively while the 1, 3, and 5-year survival rates of the UW group were 83.1%, 67.2%, and 59.8%, respectively. Similarly, the 1, 3, and 5-year grafts survival rates of the HTK group were 84.4%, 69.0%, and 64.0%, respectively, while the 1, 3, and 5-year grafts survival rates of the UW group were 80.6%, 65.6%, and 57.9%, respectively. And there was no significant difference between the 2 groups.

Interestingly, however, the average amount of preservation fluid used per patient in the UW group was 3156 mL, while that in the HTK group was 3850 mL, and the price of UW fluid per liter was nearly twice the price of HTK fluid per liter. Therefore, from an economic perspective, HTK solution has a better cost-performance ratio, and the choice of HTK solution can save hospital costs for patients to a certain extent.

Our study also has some shortcomings. First, although our PSM analysis eliminated some confounding factors, it also lost some sample information; therefore, a well-designed randomized controlled trial is warranted to confirm our results. In addition, the time span of this study covered over 18 years, and during this time, UW solution was used first and then changed to HTK solution. But we did not take the learning curve of the surgeons into account, which may cause a certain degree of deviation to the results.

In conclusion, our study shows that UW solution and HTK solution are equivalent in perioperative safety, the recovery of transplanted liver function, the occurrence of postoperative

complications and overall survival and both can be safely and effectively applied to adult LDLT. If economic factors are taken into account, HTK solution can save costs to a certain extent.

Author contributions

Jia-Yin Yang, Xi Xu, Yun-Feng Zhu designed this study; Tao Lv, Xi Xu, Jin-Li Zheng, Bo-Han Zhang collected and analyzed the data; and Xi Xu, Yong-kun Li, Li Jiang prepared the manuscript, Jia-Yin Yang revised the manuscript.
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Software: Tao Lv, Xi Xu.
Writing – original draft: Xi Xu, Yong-kun Li, Li Jiang.
Writing – review& editing: Jia-yin Yan.

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