Certification training and liver transplant experience improves liver procurement outcomes: the Dutch approach

Lam, H.-D.; Ploeg, R.; Nijboer, W.N.; Alwayn, I. P. J.; Coenraad, M.; Hemke, A.C.; ... ; Baranski, A.

Certification Training and Liver Transplant Experience Improves Liver Procurement Outcomes: The Dutch Approach

Hwai-Ding Lam, MD,[1] Rutger Ploeg, MD, PhD,[1,2,3] Willemijn N. Nijboer, MD, PhD,[1,4] Ian P.J. Alwayn, MD, PhD,[1] Minneke Coenraad, MD, PhD,[5] Aline C. Hemke, PhD,[6] Esther Bastiaannet, PhD,[7] Hein Putter, PhD,[8] and Andrzej Baranski, MD, PhD[1]

Background. This study investigates the impact of certification training and liver transplant experience on procurement outcomes of deceased donor liver procurement in the Netherlands. **Methods.** Three groups (trainee, certified, and master) were formed, with further subdivision based on liver transplant experience. Three key outcomes—surgical injury, graft discard after injury, and donor hepatectomy duration—were analyzed. **Results.** There were no significant differences in surgical graft injury in the three groups (trainee, 16.9%; certified, 14.8%; master, 18.2%; $P = 0.357$; 2011 to 2018). The only predictor for surgical graft injury was donation after circulatory death (odds ratio [OR], 1.49; 95% confidence interval [CI], 1.10-2.02). Of the three groups, the master group had the highest discard rate after surgical injury (trainee, 0%; certified, 1.3%; master, 2.8%; $P = 0.013$). Master group without liver transplant experience (OR, 3.16; 95% CI, 1.21-8.27) and male donor sex (OR, 3.58; 95% CI, 1.32-9.73) were independent risk factors for discarding livers after surgical injury. Independent predictors for shorter hepatectomy durations included donors older than 50 years (coefficient [Coeff], −7.04; 95% CI, −8.03 to −3.29; $P < 0.001$), and master group (Coeff, −9.84; 95% CI, −14.37 to −5.31; $P < 0.001$) and certified group with liver transplant experience (Coeff, −6.54; 95% CI, −10.83 to −2.26; $P = 0.003$). On the other hand, master group without liver transplant experience (Coeff, 5.00; 95% CI, 1.03-8.96; $P = 0.014$) and donation after circulatory death (Coeff, 10.81; 95% CI, 8.32-13.3; $P < 0.001$) were associated with longer hepatectomy durations. **Conclusions.** Training and certification in abdominal organ procurement surgery were associated with a reduced discard rate for surgical injured livers and shorter hepatectomy times. The contrast between master group with and without liver transplant experience underscores the need for specialized training in this field.

(*Transplantation* 2024;108: 2093–2099).

INTRODUCTION

Competence in deceased donor procurement surgery is a prerequisite to success in organ transplantation.[1-5] Without an appropriately procured organ, successful transplantation cannot take place. A recent survey on training experiences of the American Society of Transplant Surgeons fellowship programs showed that a didactic curriculum was only present in 19% of all fellowship programs in the United States. The complex procedure of organ procurement was taught by the attending supervisor in half of the cases followed by the senior fellow in the other half.[6]

Received 5 September 2023. Revision received 18 February 2024.

Accepted 22 February 2024.

[1] Department of Transplantation Surgery, LUMC Transplant Center, Leiden University Medical Center, Leiden, the Netherlands.

[2] Nuffield Department of Surgical Sciences, University of Oxford, Oxford, United Kingdom.

[3] Oxford Biomedical Research Centre, University of Oxford, Oxford, United Kingdom.

[4] Landelijk Overleg Regionale Uitname Teams, Leiden, the Netherlands.

[5] Department of Gastroenterology and Hepatology, LUMC Transplant Center, Leiden University Medical Center, Leiden, the Netherlands.

[6] Dutch Transplantation Foundation, Leiden, the Netherlands.

[7] Epidemiology, Biostatistics and Prevention Institute, University of Zurich, Zurich, Switzerland.

[8] Section Medical Statistics, Department of Biomedical Data Sciences, Leiden University Medical Center, Leiden, the Netherlands.

H.-D.L. is the principal author, designed the study, and wrote the article. R.P., W.N.N., I.P.J.A., and M.C. participated in the writing of the article. A.C.H. participated in the performance of the research and in the writing of the article. E.B. participated in the statistical analysis and in the writing of the article. H.P. reviewed the statistics and participated in the writing of the article. A.B. participated in the research design, performance of the research, and writing of the article.

The authors declare no funding or conflicts of interest.

Correspondence: Hwai-Ding Lam, MD, Department of Transplantation Surgery, Leiden University Medical Centre, Albinusdreef 2, 2333 ZA Leiden, the Netherlands. (h.lam@lumc.nl).

ISSN: 0041-1337/20/10810-2093

DOI: 10.1097/TP.0000000000005024

In the Netherlands, a national organ procurement service was developed in the past 2 decades, in which procurement teams are usually not affiliated with the transplant center that actually will accept the liver or other abdominal organs, which is different from common practice in many other countries. For instance, Belgium has implemented a program whereby nontrained and nontransplant surgeons have the opportunity to conduct these procedures, learning on the job under the guidance of experienced practitioners. The advantage of the national system is a shared responsibility to retrieve organs in a dedicated region with higher efficiency of logistics and faster access to the donor hospital while cost and disutility for procurement teams are reduced to a minimum. However, especially when introducing the national system, trust between transplant teams has to grow to accept organs procured by other dedicated teams, which can effectively be improved by using a transparent quality performance system. To ensure agreement and organ utilization, a quality curriculum was established in the Netherlands, including criteria and educational tools to teach and certify surgical colleagues regarding multi-organ abdominal procurement for transplantation. From 2010 onward, it has been obligatory in the Netherlands for surgeons seeking to participate in abdominal organ procurement to successfully complete this curriculum before being allowed to independently procure abdominal donor organs for transplantation. This curriculum consists of an online learning module, a 2-d masterclass with theoretical teaching as well as hands-on practice using specially prepared cadavers, a surgical logbook of at least 10 cases as primary surgeon under direct supervision of a certified procurement surgeon, and a final on-site examination during a procurement procedure by a certified surgeon who is not from the same team.[1,7] In the past years, we have been able to demonstrate that this quality system and mandatory certification system has led to improvement in surgical outcomes, especially in liver and pancreas transplantation.[1,7,8]

To maintain and enhance quality, a national oversight committee in procurement surgery (Landelijk Overleg Regionale Uitname Teams [LORUT]) under the shared auspices of the Dutch Transplantation Society (NTV) and Dutch Transplantation Foundation (NTS) as the competent authority has been created with representation of all 5 Dutch procurement teams. Its task is to monitor processes, coordinate scientific research, improve outcomes, and implement national protocols and logistics in cooperation with national healthcare instances. Transparency has been improved by digitally recording mandatory variables concerning the procurement details in quality forms. These forms, completed by the donor surgeon, are then cross-checked by the corresponding transplant surgeon in the transplant center that has accepted these organs for discrepancies. Any discrepancy is automatically fed back through an automated email response to increase awareness. In case of disagreements, the surgeons have the liberty to elaborate on the case. This transparency leads to an instantaneous feedback within 24 h and quality improvement without blaming and shaming. The quality forms have also been used for oversight of the process and to categorize organ anatomy, quality, procurement injury, and issues around organ packaging in a systematic way, allowing periodic reporting and comparative outcome analysis as previously described.[1,7,9]

In this study, we have focused on quality aspects of donor liver procurement as an important part of the multi-organ procurement procedure. In the past years, the injury rate of donor livers in the Netherlands dropped from 34% to 17% after the introduction of the quality and certification system.[2,7] In this regard, a potential key factor, that is, the role of the training and experience of the procuring surgeon, has not been analyzed yet. The aim of this study was to evaluate whether possible predictive factors such as surgical experience and mandatory training affected 3 clinically relevant outcomes of procurement surgery, including the duration of the hepatectomy, the incidence of surgical injury to the donor liver, and the organ discard rate.

MATERIALS AND METHODS

An institutional review board approval for this study was obtained by the hospital ethics committee (reference G18.137/SH/sh) as well as by LORUT. From September 2010 to September 2018, data on start time of aortic flush-out and cold perfusion, end time of hepatectomy and pancreatectomy when both organs are retrieved to differentiate between liver pancreas en block versus serial individual organ procurement, donation after circulatory death (DCD) or donation after brain death (DBD) donor type, standard donor demographic information (age, sex, weight, height, diabetes, smoking, cause of death), the quality forms of liver retrievals by both the procuring and transplant surgeon, and whether the liver was transplanted were all collected from the Dutch Transplantation Foundation database. Quality forms were online forms detailing the anatomical and surgical findings, filled in by the procurement surgeon and confirmed by the liver transplant surgeon after receiving the liver for inspection on the back-table at their center. In case of discrepancy, the liver transplant surgeon's quality form was considered final for data collection. Daytime and nighttime were categorized according to the time of start of cold perfusion. Daytime was considered from 8:00 AM until 5:00 PM and nighttime was considered from 5:00 PM until 8:00 AM. Cases where quality forms were missing, incomplete, or livers that were retrieved without initially having been offered for transplantation but for research purposes were excluded from analysis.

A coding for the quality forms was used to categorize procurement outcomes. This coding has been previously described alphabetically in 5 distinct categories[9]: A, no abnormality; B, disagreement about anatomical aspects between procuring and transplant surgeon (eg, missed aberrant right hepatic artery); C, confirmed surgical injury to donor organ, whereby C1 implies salvage for transplantation and C2 discard of the organ for transplantation; D, nonanatomical variance or nonprocurement-related damage of the donor organ such as tumors, hematoma due to initial trauma, steatosis or massive atherosclerosis; and E, other abnormality including different packaging and absence of iliac vessels or other issues to be named. Three outcome parameters were used for our analysis: the duration of hepatectomy, C events, and C2 events. Hepatectomy time was defined as the duration from the initiation of cold aortic flush until the removal of the liver from the donor body, encompassing both DCD and DBD procedures.

LORUT and the Dutch Transplantation Foundation obtained permission of the individual procuring surgeons to reveal their personal information, that is, name and center of employment, to the principal investigator with the assurance of anonymity and for the purpose of being able to calculate experience and training only. Each surgeon was subsequently labeled as "certified" (having completed the curriculum and being certified, operating as an independent procurement surgeon), "master" (experienced surgeons who had been procuring organs for years before the curriculum was introduced), or "in-training" (following the training curriculum without being certified yet, and under direct supervision by a certified or master surgeon). All abdominal procurements are performed by a team of 2 surgeons, with at least 1 being a certified or master surgeon. If a trainee is involved, they are designated as the primary surgeon according to the Dutch curriculum always under direct supervision of either a certified or a master surgeon as the second surgeon. Data about involvement of individual surgeons in liver transplantation at their unit were also collected. This could only be the case in 3 of 5 teams in the Netherlands.

Statistical Analysis

Univariate and multivariate logistical analysis was performed using IBM SPSS software, version 29, to compare the categorical variables for outcome variables using chi-square or Fisher exact test, where applicable. For continuous variables, the Student *t*-test or 1-way ANOVA, where applicable, was used if normal distribution was followed or otherwise Mann-Whitney *U* test or Kruskal-Wallis test, where applicable. A multivariate logistic regression for binary outcomes and a linear regression for continuous outcomes were used, where applicable, to find factors associated with C events, C2 events, and hepatectomy durations. For the multivariate linear regression, STATA/SE software, version 12.0 (StataCorp, TX), was used to make the calculations. A P value of <0.05 was considered significant.

RESULTS

After excluding 1 surgeon who objected to disclosing his/her personal information, and cases with missing and incomplete quality forms by either procuring or transplant surgeons, there remained 1254 cases to be analyzed from May 2011 to September 2018 divided among 54 surgeons in 3 different groups (trainee total procedures, n = 207; certified total procedures, n = 399; and master total procedures, n = 648). In the trainee group, there were initially 28 surgeons. Of these, 24 progressed to become certified, with 1 certified surgeon already holding certification at the start time of the analysis. This resulted in a total of 25 surgeons in the certified group. Simultaneously, there were 25 surgeons classified as master. The master group consistently performed the highest number of procedures per surgeon, followed by the certified group, and finally, the trainee group (median 40 (interquartile range, IQR 30 to 49) versus 34 (IQR 18 to 51) versus 20 (IQR 12 to 15); $P < 0.001$). The background liver transplantation experience varied among groups, with the master group having the lowest percentage of experience (31%, compared with 63.9% in the certified group and 60.9% in the trainee group; $P < 0.001$) (Table 1).

DCD procurement percentages were similar among the trainee, certified, and master groups (33.8% for all 3 groups; $P = 1.00$), as were median donor age (50, 53, and 53, respectively; $P = 0.28$), donor hypertension (20.1%, 28.7%, and 24.8%; $P = 0.067$), donor smoking (64.7%, 56.9%, and 57.6%; $P = 0.145$), donor cerbrovascular accident cause of death (30.4%, 32.3%, and 29.8%; $P = 0.778$), median donor body mass index (24, 25, and 25 kg/m^2; $P = 0.05$), donor diabetes (5.3%, 6.8%, and 5.6%; $P = 0.658$), and daytime procedure (32.4%, 38.8%, and 31.9%; $P = 0.067$). Differences were observed in the certified group, where they obtained a higher proportion of female donors (54.9%, compared with 49.8% in the trainee group and 47.1% in the master group; $P = 0.049$). Additionally, the certified group had fewer liver–pancreas en block procurements (44.3%, compared with 65.2% in the trainee group and 70.9% in the master group; $P < 0.001$) and fewer procurements of livers without pancreas (58.9%, compared with 65.2% in the trainee group and 67.6% in the master group; $P = 0.016$) (Table 1).

In the univariate outcome analysis, the certified group exhibited a shorter median hepatectomy duration

TABLE 1.

Comparison between the 3 groups on donor demographics and liver transplantation experience

Total (N = 1254)	Trainee (n = 207)	Certified (n = 399)	Master (n = 648)	P
Median total procedures	20 (IQR 12–25)	34 (IQR 18–51)	40 (IQR 30–49)	**<0.001**
Liver transplantation experience	126 (60.9%)	255 (63.9%)	201 (31%)	**<0.001**
Donation after circulatory death	70 (33.8%)	135 (33.8%)	219 (33.8%)	1
Daytime procedure	67 (32.4%)	155 (38.8%)	207 (31.9%)	0.067
Donor female sex	103 (49.8%)	219 (54.9%)	305 (47.1%)	**0.049**
Liver pancreas en block	23 (67.6%)	35 (44.3%)	73 (70.9%)	**<0.001**
Liver only without pancreas	135 (65.2%)	235 (58.9%)	438 (67.6%)	**0.016**
Median donor age (y)	50 (IQR 39–60.5)	53 (IQR 44–61.5)	53 (IQR 41–60)	0.28
Median donor body mass index	24 (IQR 22–26.5)	25 (IQR 22–2822–28)	25 (IQR 22–28)	**0.05**
Donor diabetes	11 (5.3%)	27 (6.8%)	36 (5.6%)	0.658
Donor hypertension	40 (20.1%)	112 (28.7%)	154 (24.8%)	0.069
Donor smoking	132 (64.7%)	226 (56.9%)	368 (57.6%)	0.145
Donor CVA cause of death	63 (30.4%)	129 (32.3%)	193 (29.8%)	0.778

Bold represents values with statistical significance ($P < 0.05$).
CVA, cerebrovascular accident; IQR, interquartile range.

(49 min, IQR 38 to 65 min) compared with the trainee group (54 min, IQR 43 to 67 min) and the master group (54 min, IQR 43 to 67 min) ($P = 0.012$). Surgical injury rates (C event) did not show significant differences among the 3 groups (trainee 16.9% versus certified 14.8% versus master 18.2%; $P = 0.357$). However, a notable distinction was observed in C2 event (discard rate if surgical injury occurred), with the master group demonstrating the highest rate (2.8%), followed by the certified group (1.3%), and none in the trainee group ($P = 0.013$). When accounting for liver transplantation experience, a distinction in hepatectomy times emerged. Master and certified surgeons with a background in liver transplantation exhibited the shortest median times (46, IQR 36 to 58, and 46, IQR 34 to 63, respectively), whereas master surgeons without liver transplantation background had the longest hepatectomy times (58, IQR 45 to 75; $P < 0.001$). Regarding C2 event, master surgeons without liver transplantation background demonstrated the highest discard rates (3.4%) compared with the other groups ($P = 0.045$). This effect was not seen in surgical injury (Table 2).

The majority of surgical injuries observed during the procurement process were parenchymal (n = 116; 54.7%), followed by arterial injuries (n = 91; 42.9%). In 15.5% of cases, multiple injuries were noted. Notably, the trainee group exhibited a higher incidence of portal vein injuries, although these incidents did not result in graft discard for transplantation. Similarly, in the context of C event, the incidence of C2 events indicated that parenchymal damage was the primary factor leading to liver discard (n = 14; 60.9%), followed by arterial injuries (n = 9; 39.1%). Three cases involved caval injuries (13%). No significant differences were observed among the 3 groups in this regard (Table 3).

On multivariate analysis, predictors for C event revealed that only DCD emerged as a significant risk factor (odds ratio [OR], 1.49; 95% confidence interval [CI], 1.10-2.02; $P = 0.01$). The level of training (trainee, certified, and master) and background experience as a liver transplant surgeon did not exert any influence on the surgical injury rate (Table 4). Regarding predictors for C2 event, being a male donor (OR, 3.58; 95% CI, 1.32-9.73; $P = 0.013$) and being a master without background liver transplant experience (OR, 1.55; 95% CI, 1.21-8.27; $P = 0.005$) were identified as risk factors for the loss of the liver organ after a surgical injury (Table 5).

In the multivariate linear regression for hepatectomy duration, DCD (Coeff, 10.8; $P < 0.001$) and being a master without liver transplant experience (Coeff, 5.00; $P = 0.014$) were independent predictors for longer duration. Conversely, donor older than 50 years (Coeff, −5.66; $P < 0.001$), being certified with liver transplant experience (Coeff, −6.54; $P = 0.002$), and being a master with liver transplant experience (Coeff, −9.84; $P < 0.001$) were predictors for shorter hepatectomy durations (Table 6).

DISCUSSION

Implemented in 2010, the Dutch mandatory trajectory of training, e-learning, and certification aims to bolster surgical quality and foster trust among various stakeholders. Previous evidence has demonstrated the effectiveness of this curriculum in lowering organ injury rates.[1,7] The present study represents the first comprehensive analysis of the impact of the Dutch certification program. The analysis concentrated on evaluating diverse levels of surgical expertise and training in abdominal organ procurement throughout the Netherlands. It revealed a positive influence when the procurement surgeon had experience in liver transplantation. However, although the surgical injury rates among the 3 groups were comparable, the primary finding indicated that certification demonstrated fewer discards after surgical injury, whereas the lack of liver transplant experience showed a higher discard rate after injury and prolonged hepatectomy times. Our findings also indicated that a high procedure volume does not always lead to better outcomes regarding skill acquisition or maintenance. Proficiency is not solely determined by the number of procedures; instead, it allows surgeons to progress individually at their own pace. This parallels the approach of graduating surgical residents in the United States, who use Entrustable Professional Activities rather than traditional case logs.[10]

The association between certification, faster hepatectomy times, and reduced postinjury liver graft losses is unsurprising, particularly when contrasted with surgeons lacking certification. This is evident in the master group, where despite a higher caseload and more extensive experience, longer hepatectomy times and a higher percentage

TABLE 2.

Univariate analysis of the impact of the 3 groups (trainee, certified, and master) with or without liver transplantation experience on the 3 surgical outcomes (C event, C2 event, and donor hepatectomy times)

Total (N = 1254)	Trainee (n = 207)	Certified (n = 399)	Master (n = 648)	P
Surgical injury (C event)	35 (16.9%)	59 (14.8%)	118 (18.2%)	0.357
Without liver transplantation experience	16 (19.8%)	24 (16.7%)	91 (20.4%)	0.149
With liver transplantation experience	19 (15.8%)	35 (13.7%)	27 (13.4%)	
Discard due to injury (C2 event)	0 (0%)	5 (1.3%)	18 (2.8%)	**0.013**
Without liver transplantation experience	0 (0%)	3 (2.1%)	15 (3.4%)	**0.045**
With liver transplantation experience	0 (0%)	2 (0.8%)	3 (1.5%)	
Hepatectomy duration (min), median (IQR)	54 (43–67)	49 (38–65)	54 (43–67)	**0.012**
Without liver transplantation experience	55 (43–68.5)	53 (42–69)	58 (45–75)	**<0.001**
With liver transplantation experience	53 (42.5–65)	46 (34–63)	46 (36–58)	

Bold represents values with statistical significance ($P < 0.05$).
IQR, interquartile range.

TABLE 3.

Univariate analysis of types of injuries in C and C2 events between the 3 groups (trainee, certified, and master)

	Total	Trainee (n = 207)	Certified (n = 399)	Master (n = 648)	*P*
Surgical injury (C event)	212 (16.9%)	35 (16.9%)	59 (14.8%)	118 (18.2%)	0.357
Arterial	91 (42.9%)	9 (25.7%)	27 (45.8%)	55 (46.6%)	0.079
Caval	27 (12.7%)	4(11.4%)	4 (6.8%)	19 (16.1%)	0.208
Portal	5 (2.4%)	4 (11.4%)	0 (0%)	1 (0.8%)	**<0.001**
Inadequate flush	12 (5.7%)	5 (14.3%)	2 (3.4%)	5 (4.2%)	0.053
Parenchymal	116 (54.7%)	20 (57.1%)	34 (57.1%)	62 (52.5%)	0.775
More than 1 injury	33 (15.5%)	6 (16%)	8 (13.6%)	19 (16.8%)	0.743
Discard because of surgical injury (C2 event)	23 (1.8%)	0 (0%)	5 (1.3%)	18 (2.8%)	**0.013**
Arterial	9 (39.1%)	0 (0%)	1 (20%)	8 (44.4%)	0.611
Caval	3 (13%)	0 (0%)	0 (0%)	3 (16.7%)	1
Portal	0 (0%)	0 (0%)	0(0%)	0 (0%)	1
Inadequate flush	0 (0%)	0 (0%)	0(0%)	0 (0%)	1
Parenchymal	14 (60.9%)	0 (0%)	5 (100%)	9 (50%)	0.116
More than 1 injury	3 (13%)	0 (0%)	1 (20%)	2 (11.1%)	0.539

Incidence in percentage of total events per group. Bold represents values with statistical significance ($P < 0.05$).

TABLE 4.

Multivariate logistic regression model for independent C event prediction

C events	OR (95% CI)	*P*
Donation after circulatory death	1.491 (1.101–2.019)	**0.01**
Certified and no liver transplantation experience		0.265
Master with liver transplantation experience	0.716 (0.461–1.111)	0.136
Trainee with liver transplantation experience	0.801 (0.478–1.344)	0.402

Bold represents values with statistical significance ($P < 0.05$).
CI, confidence interval; OR, odds ratio.

TABLE 5.

Multivariate logistic regression model for independent C2 event prediction

C2 events	OR (95% CI)	*P*
Donation after circulatory death	1.705 (0.752–3.87)	0.202
Male donor	3.577 (1.316–9.727)	**0.013**
Liver without pancreas procurement	1.36 (0.595–3.106)	0.466
Certified and no liver transplantation experience	2.079 (0.503–8.587)	0.312
Master and no liver transplantation experience	3.163 (1.21–8.267)	**0.019**
Trainee and no liver transplantation experience	0	0.997

Bold represents values with statistical significance ($P < 0.05$).
CI, confidence interval; OR, odds ratio.

of discard rates were observed. Upon closer examination of the impact of liver transplant experience, it became apparent that the positive influence of such experience was more pronounced in the master group compared with other groups. Consequently, it could be considered that the master group with liver transplant experience, even without formal training, might be exempted from the curriculum. Additionally, although not within the scope of our analysis, digital feedback seemed to have minimal impact, suggesting that older surgeons who have established practices may find it challenging to adapt to feedback. Perhaps a real-time continuous outcome monitoring system with benchmark targets might alter this in the future[7]?

The Halstedian approach to traditional surgical training whereby the concept of "see one, do one, and teach one" has been installed in the Dutch curriculum with success in our opinion.[11] The observation phase (see one) comes during the master class with hands-on training on cadavers and e-learning modules and is the first part of the learning process. The action phase (do one) is during the training time and experience (teach one) comes after certification. The superior C2 outcome observed for the trainee, as opposed to the same surgeon in their certified capacity, underscores the significance of a proficient, certified mentor. This finding aligns with the Halstedian principle of residency training, suggesting that outcomes are enhanced when mentoring a trainee rather than performing the surgery oneself, as demonstrated by the improved results during the training period. Surgeons in mentorship roles have demonstrated the ability to cultivate reflection and progressive autonomy in procedures, leading to improved long-term outcomes in previous studies.[11,12]

In a prior analysis of surgical risk factors for procurement injury, DCD procurement continued to emerge as a predictor for C events in our current analysis, even after incorporating the surgeon's level of training and experience.[3,9] Irrespective of surgical experience and training, DCD procurement persists as a formidable challenge compared with DBD procurement. This challenge is attributed to the bloodless dissection, as evidenced by the 3 groups showing similar rates of C events. More than half of the reported surgical injuries stemmed from capsular tears and this remained the main reason to discard a liver.[7] Capsule tears can occasionally result in uncontrollable mortal hemorrhage after liver transplant reperfusion, but more significantly, they serve as the primary cause of postoperative subcapsular hematoma. These hematomas have

TABLE 6.

Univariate and multivariate linear regression model for donor hepatectomy times

Training level	Liver transplant experience	Hepatectomy duration (min) median (interquartile range)	Univariate coeff (95% CI)	*P*	Multivariate coeff (95% CI)	*P*
Certified	No	53 (42–69)	Reference		Reference	
Certified	Yes	46 (34–63)	−6.91 (−11.39 to −2.44)	**0.002**	−6.54 (−10.83 to −2.26)	**0.003**
Master	No	58 (45–75)	5.00 (0.86 to 9.14)	**0.018**	5.00 (1.03 to 8.96)	**0.014**
Master	Yes	46 (36–58)	−9.96 (−14.68 to −5.23)	**<0.0005**	−9.84 (−14.37 to −5.31)	**<0.0005**
Trainee	No	55 (43–68.5)	−0.97 (−6.89 to 4.96)	0.75	−0.44 (−6.13 to 5.24)	0.88
Trainee	Yes	53 (42.5–65)	−1.29 (−6.51 to 3.93)	0.63	−2.18 (−7.19 to 2.83)	0.39
Professional (master and certified)		52 (40–68)	Reference			
Trainee		54 (43–67)	0.33 (−3.01 to 3.67)	0.85		
Donation after brain death		49 (38–63)	Reference		Reference	
Donation after circulatory death		60 (46–80)	12.15 (9.60 to 14.70)	**<0.0005**	10.81 (8.32 to 13.30)	**<0.0005**
Age below50 y old		56 (45–73)	Reference		Reference	
Age above 50 y old		49 (38–64)	−7.04 (−9.51 to −4.56)	**<0.0005**	−5.66 (−8.03 to −3.29)	**<0.0005**

Bold represents values with statistical significance ($P < 0.05$).
CI, confidence interval; coeff, coefficient.

the potential to expand, lead to late bleeding, and develop into complications such as abscesses and bilomas. This situation poses a serious complication that may sometimes require retransplantation as an extreme therapeutic measure.[2,13,14] The second main reason for declining a liver after procurement injury was mainly because of the iatrogenic arterial injuries. With a bloodless dissection, the lack of direct feedback through bleeding during dissection, and the absence of pulsatile vascular structures, it is understandable that arterial structures are overlooked. It is well reported that arterial complications such as stenosis or thrombosis can be increased despite successful repair being undertaken and the benefit of transplanting a very sick patient with this risk must be carefully considered versus waiting for a better liver.[2,14]

It has also been shown that longer donor hepatectomy duration is associated with worse outcomes in the liver transplant recipient characterized by more early liver allograft loss and ischemic cholangiopathy.[4,5,15,16] This is the reason that donor hepatectomy duration was chosen as our third important outcome parameter besides C and C2 events. Predictors for shorter hepatectomy duration were related to experience in liver transplantation but also to the training level, DCD, and older donors. Correlation between hepatectomy duration and C event was seen as the certified group had the shortest donor hepatectomy times independently correlated with the lowest C event among the 3 groups. Furthermore, the background experience in liver transplantation varied significantly within the master group. Individuals with prior liver transplantation experience exhibited the shortest donor hepatectomy duration, whereas those in the master group without a background in liver transplantation displayed the longest outcomes for the entire cohort. The influence of liver transplantation experience was less prominent in the certification group, as evidenced by the smaller negative coefficient. Notably, there was no discernible impact on hepatectomy duration in the trainee group, underscoring the significance of completing the curriculum over relying solely on prior liver transplant experience. Our analysis faces a notable limitation due to the low occurrence especially in the case of C2 events, increasing the risk of overfitting in our multivariate models. Additionally, the absence of information on simultaneous thoracic organ procurements during data acquisition posed a challenge. Given the typical procedural wait for abdominal teams on the thoracic team, we assume, due to the lack of data, that younger donors had a longer donor hepatectomy duration in our analysis. Despite longer hepatectomy times, studies indicate that these younger donors exhibit better liver transplant outcomes, creating a conflict in determining the true impact of donor hepatectomy times on overall transplant success.[17] Nevertheless, a rapid donor procurement remains beneficial as organs tend to be better cooled once they are faster out of the donor body.[18]

In conclusion, the certification curriculum as developed in the Netherlands has resulted in less liver discard after procurement injury and faster hepatectomy times. This could contribute to more and better liver transplant outcomes. Those who are already independent procuring surgeons without liver transplant experience and have never undergone the training might consider retraining to improve their outcome.

REFERENCES

1. Lam HD, Schaapherder AF, Kopp WH, et al. Professionalization of surgical abdominal organ recovery leading to an increase in pancreatic allografts accepted for transplantation in the Netherlands: a serial analysis. *Transpl Int*. 2017;30:117–123.
2. Nijkamp DM, Slooff MJ, van der Hilst CS, et al. Surgical injuries of postmortem donor livers: incidence and impact on outcome after adult liver transplantation. *Liver Transpl*. 2006;12:1365–1370.
3. Ausania F, White SA, Coates R, et al. Liver damage during organ donor procurement in donation after circulatory death compared with donation after brain death. *Br J Surg*. 2013;100:381–386.
4. Farid SG, Attia MS, Vijayanand D, et al. Impact of donor hepatectomy time during organ procurement in donation after circulatory death liver transplantation: the United Kingdom experience. *Transplantation*. 2019;103:e79–e88.

5. Bekki Y, Kozato A, Kusakabe J, et al. Impact of the donor hepatectomy time on short-term outcomes in liver transplantation using donation after circulatory death: a review of the US national registry. *Clin Transplant*. 2022;36:e14778.
6. Connelly CR, Quillin RC, Biesterveld BE, et al. Training experiences of American Society of Transplant Surgeons fellows in deceased donor organ procurement. *Transplantation*. 2021;105:e87–e88.
7. Lam HD, Schaapherder AF, Alwayn IP, et al. Quality assessment of donor liver procurement surgery using an unadjusted CUSUM prediction model. A practical nationwide evaluation. *Clin Transplant*. 2023;37:e14940.
8. de Graauw JA, Mihály S, Deme O, et al. Exchange of best practices within the European Union: surgery standardization of abdominal organ retrieval. *Transplant Proc*. 2014;46:2070–2074.
9. de Boer JD, Kopp WH, Ooms K, et al. Abdominal organ procurement in the Netherlands—an analysis of quality and clinical impact. *Transpl Int*. 2017;30:288–294.
10. Montgomery KB, Mellinger JD, Jones A, et al. Validity of entrustable professional activities in a national sample of general surgery residency programs. *J Am Coll Surg*. 2024;238:376–384.
11. Kotsis SV, Chung KC. Application of the “see one, do one, teach one” concept in surgical training. *Plast Reconstr Surg*. 2013;131:1194–1201.
12. LeCompte M, Stewart M, Harris T, et al. See one, do one, teach one: a randomized controlled study evaluating the benefit of autonomy in surgical education. *Am J Surg*. 2019;217:281–287.
13. Massarollo PC, Shiroma ME, Rodrigues AJ Jr, et al. Subcapsular hematoma of the graft after liver transplantation. *Transplant Proc*. 2004;36:964–966.
14. Lerut J, Reding R, de Ville de Goyet J, et al. Technical problems in shipped hepatic allografts: the UCL experience. *Transpl Int*. 1994;7:297–301.
15. Adelmann D, Roll GR, Kothari R, et al. The impact of deceased donor liver extraction time on early allograft function in adult liver transplant recipients. *Transplantation*. 2018;102:e466–e471.
16. Jochmans I, Fieuws S, Tieken I, et al. The impact of hepatectomy time of the liver graft on post-transplant outcome: a Eurotransplant cohort study. *Ann Surg*. 2019;269:712–717.
17. Lué A, Solanas E, Baptista P, et al. How important is donor age in liver transplantation? *World J Gastroenterol*. 2016;22:4966–4976.
18. Maathuis MH, Leuvenink HG, Ploeg RJ. Perspectives in organ preservation. *Transplantation*. 2007;83:1289–1298.