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Risk Factors for Inadvertent Hypothermia During Adult Living-Donor Liver Transplantation

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ABSTRACT

Background. Hypothermia (core temperature <35°C) causes multiple physiologic disturbances, including coagulopathy and cardiac dysfunction. Patients undergoing liver transplantation are at risk of inadvertent hypothermia and might be more vulnerable to its adverse effects. We sought to identify the factors contributing to hypothermia during living-donor liver transplantation (LDLT), which have not yet been studied in depth.

Methods. Medical records of 134 recipients who underwent adult-to-adult LDLT were reviewed. Core temperature at the following time points were taken: anesthetic induction, skin incision, start and end of the anhepatic phase, and hourly after hepatic reperfusion.

Results. Of 134 recipients, 29 (21.6%) developed hypothermia during surgery. Four independent risk factors for hypothermia were identified: small body weight–to–body surface area ratio, acute hepatic failure, high Model for End-Stage Liver Disease (MELD) score, and low graft-to-recipient weight ratio. The amount of core temperature drop was positively correlated with the number of involved risk factors. Each risk factor had a respective contribution according to the operative phases: body weight–to–body surface area ratio and the MELD score for the preanhepatic phase, acute deterioration of hepatic failure for the anhepatic phase, and graft-to-recipient weight ratio was for the postreperfusion phase.

Conclusions. Hypothermia was independently associated with the recipient's morphometric characteristics, emergency of end-stage liver disease, MELD score, and graft volume. These factors showed a cumulative effect, and the role of each factor was different according to the operative phase. These results should aid in the development of an optimal thermal strategy during LDLT.

HYPOTHERMIA, which has been generally defined as body core temperature <35°C, occurs often under general anesthesia [1] and produces multiple physiologic disturbances, including coagulopathy and cardiac dysfunction [2–4]. Even a short period of mild hypothermia is known to produce adverse outcome [5]. Patients undergoing liver transplantation might be at particular risk of hypothermia owing to extended operating time, wide surgical field, and the absence of hepatic heat production during the anhepatic phase. In addition, it is expected that liver recipients are more vulnerable to the adverse effects of hypothermia because the underlying medical condition is impaired due to end-stage liver disease, and hemostatic impairment and electrolyte imbalances are further superimposed in the course of surgery. Thus, thermal homeostasis has represented a major issue in the field of liver transplantation, and a variety of warming measures have been introduced [6].

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To perform optimal thermal management, it is required to identify clinical factors contributing the change in core temperature. Because there has been no research determining the independent relationship between various liver transplantation–related parameters and hypothermia, we designed a multivariate study aiming to identify risk factors for intraoperative hypothermia and evaluate how the factors interact.

PATIENTS AND METHODS

The Institutional Review Board approved this retrospective study and waived the requirement for written informed consent. Computerized medical records and prospectively collected liver transplantation data of all recipients who underwent adult-to-adult living donor liver transplantation (LDLT) from April 2009 to August 2011 were reviewed. Exclusion criteria included thyroid dysfunction, preoperative hypothermia, induced hypothermia, and intraoperative cardiac arrest. Overall, 134 recipients were enrolled in the study. Records of core temperature via pulmonary arterial catheter at the following time points were made: immediately after anesthetic induction (baseline temperature, esophageal probe) and skin incision, start and end of the anhepatic phase, and hourly after hepatic reperfusion.

During the study period, anesthetic management was performed according to the standardized guideline of our hospital. Mechanical ventilation delivered 2 L/min medical air in oxygen and was controlled to obtain a tidal volume of ≥8 mL/kg and normocapnia. The ambient temperature was thermostatically controlled at 23°C in principle. A circulating water mattress (Blanketrol II; Sub-Zero Products, Cincinatti, Ohio) set at 40°C was placed over the operating bed. A passive humidifier was placed between the endotracheal tube and the Y-piece. Patient extremities were wrapped with cotton blankets and vinyl covers. During placement of multiple vascular lines, patients were covered by a wide sterilized cotton blanket with a hole. All administered fluids and transfused blood components were warmed, with the exception of 5% albumin, dextrose solutions, cryoprecipitates, and platelet concentrates.

After procurement, the graft was perfused through the portal vein by gravity flow with 2.5–3.0 L histidine-tryptophan-ketoglutarate solution at ~5°C until the perfusate was clear. After graft reperfusion, the surgical field was irrigated and washed with the use of warm saline solution.

The data were analyzed with the use of SPSS 19.0 (SPSS, Chicago, Illinois). Continuous variables are expressed as median with IQR and were analyzed with the use of Mann-Whitney *U* test. Categoric variables are expressed as *n* (%) and were analyzed with the use of chi-square or Fisher exact test as appropriate. Binary logistic regression was performed with hypothermia as the dependent variable and with all tested variables in univariate analysis as the dependent variables. Subsequently, multiple linear regression analysis was performed with core temperature change during the different surgical phases as the dependent variable and with previously determined risk factors for hypothermia as the independent variables. A P value of <.05 was considered to be statistically significant.

RESULTS

Core temperature generally dropped immediately after anesthetic induction and during the anhepatic phase and then gradually recovered after hepatic reperfusion, as reported previously [6]. Of 134 recipients, 29 (21.6%) developed hypothermia during surgery. As presented in Table 1, univariate analysis identified that the following were potentially associated with hypothermia: sex, morphometric parameters including body weight–to–body surface area ratio (BW/BSA), emergency of end-stage-liver disease (acute or acute-on-chronic vs chronic), the Model for End-Stage Liver Disease (MELD) score, and unwarmed transfusion. Multivariate analysis was further performed and identified 4 independent risk factors for hypothermia: small BW/BSA, <1.0% graft-to-recipient weight ratio (GRWR), acute hepatic failure, and high MELD score. A 2.5 kg/m^2 decrease in BW/BSA was associated with a ~3-fold increase in hypothermia (odds ratio [OR], 2.83; 95% confidence interval [CI], 1.38–5.79). Every increase of 10 in the MELD score led to a ~80% increased probability of hypothermia (OR, 1.84; 95% CI, 1.02–3.31). The cutoff values of the MELD score and BW/BSA derived from receiver operating characteristic curves were 17 and 37.5 kg/m^2, respectively.

Subsequently, 134 recipients were stratified into 4 groups according to the number of involved risk factors (0, 1, 2, and 3–4) with MELD score ≥17 and BW/BSA <37.5 kg/m^2 being counted as risk factors. Delta core temperature (baseline temperature minus the minimum intraoperative temperature) was positively associated with the number of risk factors ($P < .001$; Kruskal-Wallis test) with strong correlation ($r = 0.415$; $P < .001$; Spearman test). Also, the incidence of hypothermia was significantly increased in accordance with the accumulation of risk factors (univariate logistic regression; $P < .001$).

Each risk factor influenced core temperature change with respective significances according to the different operative phases. During the preanhepatic phase, BW/BSA ($\beta = 0.052$; SE = 0.017; $P = .002$) and MELD score ($\beta = -0.012$; SE = 0.004; $P = .002$) showed significant association with core temperature changes. During the anhepatic phase, acute deterioration of end-stage liver disease alone showed an independent association ($\beta = -0.176$; SE = 0.085; $P = .039$). Finally, GRWR was solely associated during the reperfusion phase ($\beta = 0.189$; SE = 0.089; $P = .036$).

DISCUSSION

Because the liver is a large metabolic heat producer, liver recipients who have less hepatic functional reserve are supposed to be at greater risk of hypothermia. This might explain our findings that the MELD score was positively associated with the incidence of hypothermia during transplantation. This result suggested an additional implication of the MELD score, which has shown versatile clinical implications other than as an organ allocation algorithm [7–9].

During the anhepatic phase, metabolic heat supply depends on extrahepatic heat production. Acute liver failure detrimentally affects the systemic medical status without enough time for compensatory adaptation, and thus it