The Association of the Mayo Adhesive Probability (MAP) Score With Total Operative Time in Patients Undergoing Hand-assisted Laparoscopic Donor Nephrectomy

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OBJECTIVE To assess whether donor kidney Mayo Adhesive probability (MAP) score is associated with (total operative time) ORT in patients undergoing hand-assisted laparoscopic donor nephrectomy (HALDN).

METHODS Three hundred and thirty-one patients undergoing HALDN were reviewed. Donor kidney MAP scores were recorded based on preoperative computed tomography or magnetic resonance imaging. Single variable and multiple variable regression analysis were used to evaluate the correlation between MAP score and ORT.

RESULTS Three hundred and thirty-one patients underwent HALDN between January 2007 and April 2017. Median body mass index was 26.4 kg/m^2 (interquartile range 23.4, 29.5) and median age at time of surgery was 45 years (interquartile range 37, 53). Two hundred and thirty-one patients had donor kidney MAP = 0. Hundred patients had donor kidney MAP >0. Mean ORT was 163 minutes for females with MAP = 0 and 166 minutes for females with MAP >0. Median ORT was 180 minutes for males with MAP =0 and 191 minutes for males with MAP >0. Donor kidney MAP score > 0 was significantly correlated with longer ORT (increase of 24.4 minutes, $P = .001$) in single variable analysis. In multivariable analysis, this correlation was only significant for males (increase of 28.9 minutes, $P = .013$).

CONCLUSION MAP score > 0 is associated with longer ORT for males undergoing HALDN. UROLOGY 124: 142–147, 2019. © 2018 Elsevier Inc.

According to the Organ Procurement and Transplantation network, over 4000 living donor nephrectomies were performed in the United States in 2017.[1] Laparoscopic donor nephrectomy is the preferred surgical technique for living donors given decreased morbidity and earlier recovery as compared to open procedures.[2] Patients selected for donor nephrectomy are most often healthy individuals with limited comorbidities. However, in recent years many institutions have expanded their qualifications for donation to include select volunteers who are obese.[3] The implications of obesity on postoperative outcomes in carefully selected donors remains debatable, but many studies have shown some association between obesity (body mass index [BMI] >30 kg/m^2) and longer total donor nephrectomy operative times.[4-6] Anderson et al showed no correlation between operative time and BMI. However, their study did show a positive correlation between operative time and anterior and posterior perirenal fat measurements obtained from preoperative imaging.[7] Narita et al had similar outcomes in their study, which associated longer operative time with preoperative perinephric fat measurement and intraoperative surgeon identification of adherent perinephric fat (APF).[8]

Planning for potentially extended operative times in the altruistic patient population undergoing donor nephrectomy is advantageous in coordinating donor and recipient anesthesia while minimizing renal ischemia time. Preoperative imaging plays a vital role in surgical planning and patient selection for donor nephrectomy. Perinephric and visceral fat identified on preoperative

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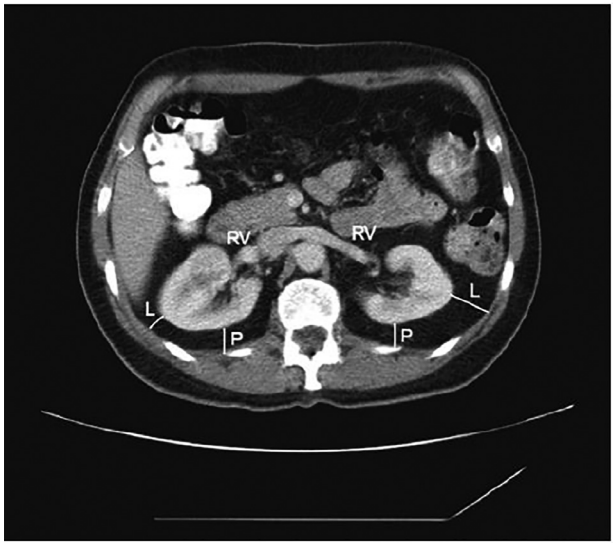

Figure 1a. Method of determining perinephric fat measurement (P) at the level of the renal vein (RV). Adapted from Figure 1 of ref. 9.

imaging have been correlated with longer operative time and higher surgical complexity in patients undergoing open and robotic partial nephrectomy.[9-11] The Mayo Adhesive Probability (MAP) score is an accurate image-based scoring system that has been used in partial nephrectomy patients to quantify an image-derived measurement of perinephric fat distance and fat stranding in the prediction of adherent perinephric fat.[9,12] Narita et al showed a significant association between MAP score components and the identification of APF at the time of donor nephrectomy. In addition, APF identification was significantly associated with median total operative time.[8] In this study, we evaluate the impact of preoperative donor MAP score on total donor nephrectomy operative time.

MATERIALS AND METHODS

Hand-assisted Laparoscopic Donor Nephrectomy

Hand-assisted laparoscopic donor nephrectomy (HALDN) was performed by fellowship-trained transplant surgeons at 1 institution using a standard Gelport device and 2 additional trocars.[13] A 5 mm camera port was placed at the surgeon's discretion and a 12 mm working port was placed superior and medial to the iliac spine ipsilateral to the donor kidney. The perinephric fat was dissected and hilum exposed in each case. The ureter was circumferentially dissected and sharply divided distally after control with a clip. An endovascular stapler was used to take the renal artery and the renal vein separately. Gonadal and lumbar veins were clipped and cut when necessary. The kidney was then freed of its attachments and transported to the recipient surgeon.

Data Collection

Following approval by the Institutional Review Board, 331 consecutive patients who underwent HALDN between January 2007 and April 2017 were evaluated. Total HALDN operative time was our primary outcome variable, which was defined as the number of minutes from incision to closure. MAP score of the donated kidney was our predictor variable of interest. Data collected include patient characteristics (age, sex, and race), preoperative laboratory values (BMI, estimated glomerular filtration rate, hemoglobin, platelets, white blood cell count), and sidedness of donor kidney. All data were entered into a prospectively maintained database.

Calculation of MAP Score

A single independent reviewer evaluated the preoperative imaging (computed tomography or T1-weighted magnetic resonance imaging) for each patient undergoing HALDN. The MAP score was calculated for each patient utilizing the measurement of posterior renal fat thickness and the measure of severity of perinephric stranding as previously outlined by Davidiuk et al (See Fig. 1a and b). Perinephric fat thickness was measured at the level of the renal vein for the donated kidney. Posterior renal fat was measured at this level as a direct line from the level of the renal capsule to the posterior abdominal wall.[9] This distance was measured in centimeters (<1 cm = 0 points, 1.1-1.9 cm = 1 point, >2.0 cm = 2 points).

Perinephric stranding was identified as soft tissue attenuation in the fat surrounding the kidney. This was graded according to severity if present (0 = no stranding, 2 = thin mild stranding, and 3 = diffuse stranding).[9]

The MAP score was calculated (score 0-5) in each scenario as the sum of the values obtained for posterior renal fat and perinephric stranding.

Statistical Analysis

Patient characteristics were summarized for the entire cohort and separately for males and females. Categorical variables were summarized with the number and percentage of patients. Continuous variables were summarized with the sample median and interquartile

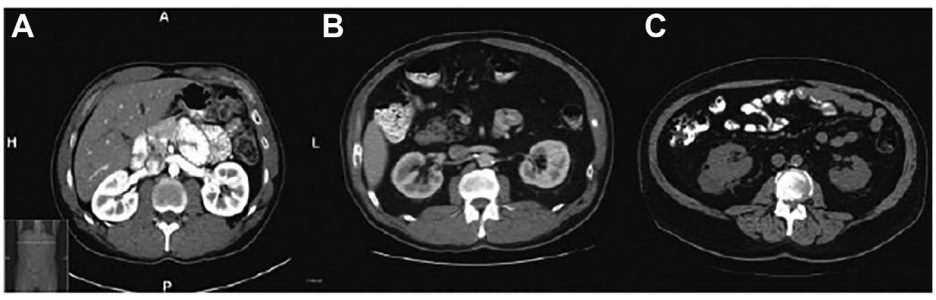

Figure 1b. Method of determining perinephric stranding score. (**A**) No stranding: 0 points. (**B**) Mild/moderate (type 1): 2 points. (**C**) Severe stranding (type2): 3 points. Adapted from Figure 2 of ref. 9.

Table 1. Preoperative characteristics of patients who underwent donor nephrectomy between January 2007 and April 2017

Characteristic	All Kidney Donors ($N = 331$)	Females ($N = 200$)	Males ($N = 131$)
Age (y)	45 (37, 53)	45 (37, 54)	45 (37, 52)
Race, *n* (%)			
White	269 (81.3%)	162 (81.0%)	107 (81.7%)
Black	45 (13.6%)	25 (12.5%)	20 (15.3%)
Other	13 (3.9%)	10 (5.0%)	3 (2.3%)
Not disclosed	4 (1.2%)	3 (1.5%)	1 (0.8%)
Left-sided donor kidney, *n* (%)	296 (89.4%)	178 (89.0%l)	118 (90.1%)
Body mass index (kg/m^2)	26.4 (23.4, 29.5)	27.7 (22.7, 28.9)	26.4 (24.8, 29.7)
Creatinine (mg/dL)	0.9 (0.7, 1.0), $n = 330$	0.8 (0.7, 0.8), $n = 199$	1.0 (0.9, 1.1), $n = 131$
eGFR≥60, *n* (%)	316 (98.8%), $n = 320$	191 (99.0%), $n = 193$	125 (98.4%), $n = 127$
Hemoglobin (mg/dL)	13.7 (12.8, 14.7)	13.0 (12.4, 13.7)	14.8 (14.1, 15.5)
WBC	6.3 (4.9, 9.2)	6.3 (4.9, 13.0)	6.2 (4.9, 8.2)
MAP score—donated kidney, *n* (%)			
0	231 (69.8%)	170 (85.0%)	61 (46.6%)
1	56 (16.9%)	16 (8.0%)	40 (30.5%)
2	31 (9.4%)	9 (4.5%)	22 (16.8%)
3	4 (1.2%)	2 (1.0%)	2 (1.5%)
4	9 (2.7%)	3 (1.5%)	6 (4.6%)
ASA score, *n* (%)			
1	205 (61.9%)	113 (56.5%)	92 (70.2%)
2	119 (36.0%)	81 (40.5%)	38 (29.0%)
3	7 (2.1%)	6 (3.0%)	1 (0.8%)

eGFR, estimated glomerular filtration rate; MAP, Mayo Adhesive Probability; WBC, white blood cell; ASA, American Society of Anesthesiologists. Median (25th percentile, 75th percentile) is given for numeric characteristics. Number (percentage) is given for categorical characteristics. The number of patients with available information is given when the characteristic is missing for 1 or more patients.

range [IQR]. For our primary analyses we categorized MAP score as 0 or >0 for the following reasons: (1) there was a limited number of patients, especially females, with a MAP score >0 and (2) visual displays (not shown) of the bivariate relationship between MAP score and operative time do not provide strong evidence of a linear relationship. Single variable linear regression models were utilized to examine the unadjusted association of predetermined covariates and MAP score with total operative time. The coefficients for numeric variables (age and BMI) were presented as a per-IQR increase (75th percentile vs 25th percentile). American Society of Anesthesiologists (ASA) scores of 2 and 3 were combined given the low frequency of patients with an ASA score = 3.

For the primary analysis, we constructed a multivariable linear regression model with operative time in minutes as our outcome variable. Covariates included age, sex (1 = male, 0 = female), race (1 = non-African American, 0 = African American), BMI, ASA score (1 = ASA 2 or ASA 3, 0 = ASA 1), side of donated kidney (1 = right, 0 = left), MAP score (1 = MAP >0, 0 = MAP 0), and a variable for the interaction between sex and MAP score (1 = Male and MAP >0, otherwise 0). Likelihood ratio tests were used to evaluate the overall association of MAP score >0 with operative time. Statistical significance was considered at $P < .05$. All analyses were performed using SAS statistical software (version 9.4M5, SAS Institute Inc., Cary, NC).

RESULTS

A total of 331 kidney donors were evaluated in our analysis. Table 1 summarizes preoperative donor patient characteristics, laboratory values, and MAP scores. Two hundred patients were female (60.4%). A large majority of the patients underwent left-sided donor nephrectomy (89.4%). Median BMI was 26.4 kg/m2. A majority of patients had a MAP score of 0 (69.8%). However, 30 female patients (15%) and 70 male patients (53.4%) had a MAP score greater than 0.

The median total operative time for all patients was 171 minutes (IQR 140-216 minutes.) Median total operative time was 163 minutes for females with MAP=0 (IQR 131, 206) and

Table 2. Impact of covariates and MAP score on operative time using single variable linear regression

	Effect (95% CI)	*P* Value
Age (53 vs 37 y)	−4.6 (−14.1 to 4.9)	.34
Gender (male vs female)	27.9 (14.0-41.7)	<.001
Race (non-AA vs AA)	−1.4 (−21.6 to 18.8)	.89
Body mass index (29.5 vs 23.4 kg/m^2)	−0.8 (−10.8 to 9.2)	.87
ASA score (2-3 vs 1)	7.2 (−7.0 to 21.5)	.32
Side of donated kidney (right vs left)	−9.2 (−31.7 to 13.3)	.42
MAP score, donated kidney (1-4 vs 0)	24.4 (9.6-39.3)	.001

CI, confidence interval.
The effect is the estimated difference (unadjusted) in total operative time (minutes): for continuous variables the effect is based on the difference between the 75th percentile and 25th percentile with the values shown in parentheses next to the variable. Donors who did not disclose their race were included in the non-African American (AA) group.

Table 3. Multivariable analysis for predicting total hand-assisted laparoscopic donor nephrectomy operative time

	Effect (95% CI)	*P* Value
Age (53 vs 37 y)	−10.0 (−20.4, 0.4)	.059
Race (non-AA vs AA)	−0.1 (−20.3, 20.1)	.99
Body mass index (29.5 vs 23.4 kg/m^2)	−7.3 (−17.5, 3.0)	.16
ASA score (2-3 vs 1)	13.6 (−1.2, 28.4)	.071
Side of donated kidney (right vs left)	−5.6 (−27.7, 16.5)	.62
Interaction of sex and MAP>0		
Sex (male vs female) when MAP = 0	16.9 (−2.0, 35.8)	.080
Sex (male vs female) when MAP>0	35.2 (8.5, 62.0)	.010
MAP score (>0 vs 0) when sex = male	28.9 (6.3, 51.5)	.013
MAP score (>0 vs 0) when sex = female	10.6 (−14.6, 35.8)	.41

CI, confidence interval.
The effect is the estimated difference in total operative time (minutes) assuming other variables in the model are the same: for continuous variables the effect is based on the difference between the 75th percentile and 25th percentile with the values shown in parentheses next to the variable. Donors who did not disclose their race were included in the non-African American (AA) group.

163 minutes for females with MAP >0 (IQR 131, 197). Median total operative time was 180 minutes for males with MAP = 0 (IQR 145, 214) and 191 minutes for males with MAP >0 (IQR 155, 269).

Single variable linear regression analyses outlining the unadjusted association of patient characteristics and MAP score with total operative time are shown in Table 2. In single variable analysis, the estimated total operative time was 27.9 minutes longer with males compared to females(95% confidence interval [CI] 14.0-41.7 minutes; P <.001) and 24.4 minutes longer in those with a MAP score > 0 compared to those with a MAP score = 0 (95% CI 9.6-39.3 minutes, P = .001). No other predetermined covariates were associated with total operative time in single variable analysis (all |coefficients| ≤9.2 minutes, all P ≥.32).

In multivariable analysis, we included all variables in Table 2 in addition to an interaction term for sex and MAP score >0. There was evidence that both sex and MAP score >0 were associated with operative time independent of each other as well as the other patient characteristics (likelihood ratio test for sex: P = .008; likelihood ratio test for MAP >0: P = .032). Among males, the estimated total operative time was 28.9 minutes longer for those with a MAP score >0 compared to those with a MAP score = 0 (95% CI 6.3−51.5 minutes; P = .013). Among females, the estimated total operative time was 10.6 minutes longer for those with a MAP score >0 compared to those with a MAP score = 0 (95% CI −14.6 to 35.8 minutes; P = .41). The impact of other covariates on total operative time is shown in Table 3.

DISCUSSION

Preoperative surgical imaging in the form of computed tomography or magnetic resonance imaging is currently utilized in patients undergoing living donor nephrectomy to assess renal size and morphology, vascular anomalies, and pathology that would preclude transplantation.[14] Imaging findings can dictate patient selection and foretell surgical complexity and therefore are widely incorporated in the preoperative paradigm for careful selection of donor nephrectomy patients. These findings have the potential to change management and distinguish cases that may require additional planning or the expertise of an experienced surgeon.

Many studies have correlated preoperative assessment of adherent perinephric fat with surgical complexity in patients undergoing open and robotic partial nephrectomy. The MAP is an image-based scoring system that accurately predicts the presence of adherent perinephric fat in patients undergoing robotic-assisted partial nephrectomy.[9] Higher MAP score has been correlated with longer operative time and higher complication rate in patients undergoing laparoscopic partial nephrectomy.[15]

The correlation of patient BMI with operative time has been well studied given the growing population of obese patients undergoing donor nephrectomy.[16] Concern regarding the implications of this trend has led to many studies investigating the effect of obesity on operative time, blood loss, and complication rate. Heimback et al showed a correlation between higher waist circumference and longer operative time and complication rate in laparoscopic donor nephrectomy patients.[5] Hu et al and Jacobs et al reported similar findings in their articles outlining determinants of donor nephrectomy outcomes.[17,18] In a systematic review, Lafrance et al reported an overall increase in operative time by 16.9 minutes in patients with BMI >30 based on a conglomerate of studies.[19] However, each of these studies utilizes BMI as a primary independent variable in correlating outcomes. BMI is an imperfect and imprecise patient-specific measure, especially for the otherwise healthy donor nephrectomy population. In our cohort, with a median BMI of 26.4 kg/m^2, we did not find any evidence of increased operative time with increased BMI.

MAP score utilizes specific measurements from preoperative imaging, incorporating perinephric fat measurements, and fat stranding scores to provide an objective measurement that is patient-specific and surgically applicable. We found that MAP score >0 increased estimated total operative time by nearly 29 minutes among men (P = .01) but only by 11 minutes in females (P = .41). The association between MAP score >0 and longer operative time had higher statistical significance for men undergoing HALDN. Looking at the breakdown of patient characteristics in Table 1, the number of men with MAP >0 outnumbers those with MAP = 0. Men presented with a more variable distribution of MAP scores compared to women, which

may account for the lack of statistical significance in our gender-based analysis for females.

Anderson et al previously examined the effect of perirenal fat on total operative time in patients undergoing donor nephrectomy.[7] In their study, men were noted to have a greater amount of perirenal fat compared to women. However, male sex was not significantly associated with longer operative time on univariate analysis while perirenal fat measurement was significantly correlated with longer operative time.[7] Davidiuk et al similarly evaluated these variables in creation of a risk score for preoperative evaluation of partial nephrectomy patients and found that perinephric fat thickness and perinephric stranding measurements produced the highest area under the curve (0.83) for predicting APF at the time of partial nephrectomy.[9] Inclusion of male sex as a variable in the model did not produce a noticeable different in the estimated area under the curve (AUC).[9] Our study found MAP score >0 and male sex to be statistically associated with longer operative time. One limitation that may have affected our results is the lower proportion of female patients with MAP score >0. This may contribute to the limited statistical significance of the correlation between MAP score and operative time for females in our study.

Another limitation of our study is the lower proportion of patients with MAP score 1-4 compared to MAP of 0. This is inherently due to the healthy patient population studied. Kidney transplant donors are screened for pathology and comorbidities that preclude donation, which often excludes patients that may be at risk for higher MAP score (ie, history of recurrent infections, obstructive uropathy, renal deterioration, malignancy, etc). Renal pathology can contribute to the finding of perinephric stranding, which is graded as 0,2, or 3 using the MAP score. Perinephric stranding has the greatest inter-rater discrepancy in calculating the MAP score, which has been found in previous studies to have an overall inter-rater concordance of 89%.[20] We believe that dichotomizing the score into MAP = 0 and MAP >0 helps correct for inter-rater variability while adapting the score specifically to the donor nephrectomy population by creating a high (MAP >0) and low (MAP = 0) score classification.

We recognize that vascular anomalies encountered during dissection could contribute to variances in operative time. We also recognize that differences in surgical technique may affect intraoperative complexity related to perinephric fat dissection. The relationship between MAP score and operative time may therefore vary according to surgical practice (ie, left vs right sided donor nephrectomy with or without removal of perirenal fat in situ prior to transplantation) and/or vascular anomalies. However, we believe that the MAP score may still prove valuable even if perirenal fat is not removed in situ given universal need for identification of anatomic landmarks through fat dissection around the lower pole and hilum. In addition, higher MAP scores have been correlated with longer operative time for the dissection phase of robotic-assisted partial nephrectomy compared to other phases of the operation.[21] It is possible that higher MAP scores prolong surgery time regardless of surgical technique used.

CONCLUSION

MAP score greater than 0 is associated with longer overall operative time in male patients undergoing HALDN. MAP score may be beneficial in preoperative planning for male patients undergoing HALDN.

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