The association between skin-to-vessel distance and surgical complications in renal transplantation

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ABSTRACT

KEY MESSAGES

- Obesity is widespread in patients with ESRD awaiting renal transplantation.
- Increased skin to vessel distance (SVD) is an anatomic parameter that is associated with increased adverse postoperative outcomes in renal transplantation.
- SVD is a readily accessible and simple-to-use anatomic parameter that can be used as an adjunct tool to counsel patients in the pre-operative setting.

Introduction: Obesity is common among renal transplant recipients and increases the risk of perioperative complications. This study evaluated whether the distance from the skin to the external iliac vessels (SVD) is associated with adverse surgical outcomes in renal transplant recipients.
Methods: A retrospective cohort study of 167 consecutive patients with preoperative cross-sectional imaging who underwent renal transplantation was conducted at a single center. SVD was measured as the distance from the skin to the anterior edge of the external iliac vein at its bifurcation through the musculoaponeurotic layer of the transversus abdominis and oblique muscles. The primary outcome was the rate of postoperative complications, classified by the Clavien-Dindo system.
Results: SVD was associated with wound dehiscence (area under the curve [AUC] 0.696, 95% confidence interval [CI] 0.55–0.84, p=0.007) and wound complications (AUC

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0.719, 95% CI 0.60‒0.84, p<0.001). Using an SVD threshold of ≥19 cm, we observed an overall accuracy of 87.4% for predicting wound dehiscence and 85.6% for any wound complication. The retrospective, single-center design and absence of standardized criteria for CT imaging are inherent limitations that can introduce several biases.

Conclusions: SVD is associated with adverse perioperative outcomes in renal transplantation. Given the indication for preoperative imaging only in high-risk patients, prospective data with a more general renal transplant population is warranted to further evaluate SVD.

INTRODUCTION

Renal transplantation is the preferred treatment for individuals with end-stage renal disease (ESRD), significantly improving quality of life and survival.[1,2] The prevalence of obesity has been rising, particularly in North America, and is itself an independent risk factor for ESRD.[3]

Patients with obesity are often considered higher-risk transplant recipients due to increased perioperative complications, including wound dehiscence, infections, and delayed graft function, as well as long-term medical complications such as graft failure, and cardiovascular events.[4-6] Body mass index (BMI) is a widely used and validated metric for obesity assessment. BMI has been shown as an independent risk factor for graft loss and mortality; notably, its risk distribution follows a bimodal pattern, with an increased relative risk for individuals with a BMI >30 kg/m² and <20 kg/m².[7]

Although many centers still use BMI in transplant selection criteria, emerging evidence suggests that the surgical risk associated with BMI thresholds may be overstated.[8-10] BMI has well-documented limitations, failing to account for variations in body composition, fat distribution, and muscle mass.[6,11,12] . Given that many centers deny renal transplantation based solely on BMI, the need for a more precise measure of obesity to predict adverse outcomes is particularly important. Cross-sectional imaging is an essential tool for preoperative surgical planning, as it enables the assessment of vascular health and a safe target landing zone for the graft anastomosis. In addition, the preoperative images can also allow for better differentiation of anatomical adiposity, which may be a more accurate predictor of obesity-related risks in renal transplantation. This study aims to evaluate whether the distance from the skin to external iliac vessels (SVD) is associated with adverse perioperative and postoperative surgical outcomes in renal transplant recipients.

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METHODS

Study design and population

This was a retrospective cohort study of consecutive patients who underwent renal transplantation at a single center (St. Joseph's Hospital, Hamilton, Ontario) between 2015 to 2019. Patients were identified using the Trillium Gift of Life database. Consecutive adult (age ≥18) patients undergoing deceased or living donor renal transplantation (solitary kidney transplant only) with pre-operative computed tomography (CT) imaging within 12 months of surgery and a minimum of 12-month postoperative follow-up were included. Only potential recipients who were deemed high risk for atherosclerotic disease (i.e., advanced age, time on dialysis, smoking status, history of cardiovascular disease, previous failed transplant) underwent a pre-operative CT as a part of their transplant assessment cut-off. No specific BMI cut-off is used at our centre, though patients with a BMI ≥35 are encouraged to lose weight and are re-reviewed by a multidisciplinary prior to placement on the transplant list. The Hamilton integrated Research Ethics Board (HiREB) approved the study protocol (REB #8074).

Surgical approach and perioperative management

Induction immunosuppression was done using methylprednisolone and basiliximab (low risk or at the discretion of the transplant nephrologist) or anti-thymocyte globulin. Three surgeons performed all renal transplants via a modified Gibson incision. There was no use prophylactic mesh or perinephric drains. The fascia was closed using two #1 loop PDS sutures. Patients are left with a foley catheter for four days and a double J ureteric stent for 4-6 weeks.

Data collection

All data were collected using a standardized form with pre-specified categories including demographic information, comorbidities, body mass index (BMI), type of transplant, intraoperative details, post-operative complications, readmissions, graft function, and survival. SVD was measured from the skin to the anterior edge of the external iliac vein at its bifurcation through the musculoaponeurotic line of the transversus abdominis and oblique muscles. Measurements were performed using the axial sections from the pre-operative CT scan. All SVD measurements were recorded by a single author (BM).

The primary outcome was the rate of postoperative wound complications (including surgical site infections, superficial and deep wound dehiscence, hernias, and collections that required intervention). Secondary outcomes included wound complications that required procedural intervention (surgical or interventional radiology), all post operative complications with a Clavien-Dindo >3.

Statistical analysis

Statistical analyses were performed using the SPSS v.30 software. Categorical variables were expressed as counts and percentages, and continuous variables were expressed as medians, ranges, and interquartile ranges, based on normality testing. Univariable and multivariable-

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adjusted logistic regression was performed to evaluate the association (Odds ratio (OR) and 95% confidence interval (CI)) between pre-specified clinical variables and surgical outcomes. Missing variables were replaced with the median for that variable in the regression analysis based on a normality test. Receiver operating characteristic (ROC) curves were constructed to assess wound complications against BMI and SVD, and the area under the curve (AUC) of ROC curves was reported for the overall population. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy for different SVD distances. Correlational analysis was conducted using the Pearson correlation test (ρ). A two-tailed p-value <0.05 was considered statistically significant. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Supplementary Table 1).[13]

RESULTS

Patient demographics and clinical features

Table 1 summarizes the cohort demographic and surgical data. A total of 167 renal transplant recipients were included for analysis, with a median age of 58 years [interquartile range (IQR) 50-66], of whom 117 (70.1%) were male. Only 7 (4.2%) of individuals were not on dialysis before transplantation, 132 (79.0%) were on hemodialysis, 19 (11.4%) on peritoneal dialysis, and 9 (5.4%) transitioned between modalities. Most individuals (n=145, 86.8%) had no history of previous renal transplantation. The most prevalent comorbidities were hypertension 144 (86.2%), diabetes mellitus 91 (54.5%), cardiac disease 86 (51.5%), and a smoking history 52 (32.3%).

Renal transplant

Among the 167 recipients, 49 (29.3%) received living donor grafts, while 118 (70.7%) received deceased donor grafts. The median estimated blood loss (EBL) was 250 cc [IQR 200-400], the median warm ischemic time (WIT) was 34.5 minutes [IQR 29.0-41.0], and the median length of hospital stay was 7.0 days [IQR 6.0-10.0], and the 30-day all-cause readmission rate was 43.7%. Wound infections were observed in 12 (7.2%) of all recipients, and 83 (49.7%) experienced a major complication, including 14 (8.4%) of patients experiencing wound dehiscence.

Outcomes

The median SVD was 132.3 mm with an interquartile range of 111.8-157.5. On univariable analysis (Table 2), SVD was associated with an increased risk of all wound complications (OR 1.26, 95% CI: 1.09-1.45; p=0.002), wound complications requiring intervention (OR 1.21, 95% CI: 1.03-1.43; p=0.022) and all postoperative complications >CD3 (OR 1.13, 95% CI 1.03-1.24; p=0.012).

Similarly, SVD was a significant predictor for any wound complications (AUC=0.719, 95% CI: 0.60-0.84; p<0.001), wound complications requiring intervention (AUC=0.696, 95% CI: 0.55-0.84; p=0.007) and all post-operative complications. Using ≥19 cm as a threshold, the model achieved an accuracy of 87.4% for predicting wound dehiscence and 85.6% for predicting any wound complication.

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However, on multivariable analysis, SVD, was not significantly predictive our primary or secondary outcomes. BMI was significant predictor of wound complications (OR 1.17, 95% CI 1.07-1.29; p<0.001) and wound complications requiring intervention (OR 1.17, 95% CI 1.05-1.31; p=0.004).

SVD and BMI were positively correlated (Pearson coefficient 0.68, p<0.001). However, they clearly could differ based upon body composition and proportions. Figure 1 demonstrates an example of SVD measurement in two individuals with a BMI of 29 but differing SVD of (A) 114 mm and (B) 133 mm. In our sample, there were 16 patients (9.5%) that were in the upper quartile of BMI (>33.0) but not in the upper quartile of SVD (>15.8).

DISCUSSION

Despite continuous advancements in surgical technique and technology, perioperative complications remain a significant contributor to patient morbidity, hospitalizations, and healthcare costs. This study demonstrates that increased SVD is associated with worse postoperative outcomes in renal transplantation, postoperative wound complications wound complications that required procedural intervention, and overall post operative complications with a Clavien-Dindo >3.

However, it was not an independent predictor separate from BMI on multivariate analysis. Clearly SVD and BMI are highly corelated. However, BMI has well-documented limitations as it fails to account for body composition, fat distribution, or fluid status fluctuations in dialysis patients.[14,15] We did find a subset of our study population that had an elevated BMI but relatively normal SVD and those with an elevated SVD and BMI. However, given the size of our sample, we were not able to identify with BMI or SVT would be stronger predictor of their post operative risks.

Emerging literature is re-evaluating various obesity parameters in addition to BMI in surgical risk assessment. A notable cohort study of 248 overweight or obese renal transplant recipients also found that SVD was a significant predictor of postoperative complications within one year (OR 1.2, 95% CI: 1.1-1.3; p=0.002), corroborating our results.[11] Similarly, a study of 163 obese patients found that the abdominal perimeter was predictive of postoperative complications (OR 1.05, 95% CI 1.02-1.09; p=0.03).[16] Morphometric parameters can be quickly evaluated on routine pre-operative cross-sectional imaging. Increasing SVD may increase operative complexity by necessitating longer incisions for adequate exposure in deep dissections, thereby elevating the risk of wound-related complications such as surgical site infections, fascial dehiscence, and incisional hernias. As such, SVD offers a simple and practical supplement for preoperative risk stratification, facilitates patient counseling, and can be readily incorporated into clinical assessment.

A key motivation for improving obesity assessment in renal transplant is the well-documented increased perioperative risk in this population. Multiple studies have shown an increased risk of adverse outcomes, including delayed graft function, graft failure, increased urine protein, acute rejection, infections, dehiscence, and secondary interventions.[4,5,17] While

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BMI may not fully capture the complexities of obesity-mediated perioperative transplant morbidity, its role in stratifying perioperative risk underscores the need for a more nuanced approach to obesity assessment in renal transplant candidates. Some proponents advocate for early transplantation regardless of obesity status.[4] The "obesity paradox" suggests that weight loss may be associated with adverse outcomes, such as infections due to suboptimal nutritional status.[8,17] Additionally, delaying transplantation to allow for sufficient weight loss prolongs time on dialysis, which has been associated with worse postoperative graft function and patient overall survival.[9,16] Morphometric parameters, such as SVD, have the potential to provide an adjunct measure of body composition and post operative risks.

Recently, there has been increasing interest in robot-assisted renal transplantation, particularly for obese patients. Robotic techniques provide greater dexterity and precision for vascular anastomoses while also offering the minimally invasive benefits of laparoscopy.[19] Patient selection remains critical, and morphometric parameters such as SVD, may guide our choice of surgical approach.

This study benefits from a well-characterized cohort of renal transplant recipients representative of a real-world population, including variation in dialysis modality, donor type, and comorbidities. The inclusion of consecutive patients with standardized measurement of a novel morphometric parameter (i.e., SVD) from preoperative imaging, and its direct comparison to BMI—a widely used clinical benchmark—enhances the clinical relevance and interpretability of the findings.

However, the study is limited by its retrospective, single-center design, which introduces potential selection and measurement biases. The absence of standardized criteria for preoperative CT imaging raises the possibility of confounding by indication, as imaging was more likely obtained in higher-risk patients, including individuals with known coronary or peripheral vascular disease, chronic medical comorbidity (i.e., diabetes mellitus, hypertension), significant smoking history and obesity; this selection bias consequently introduces a demographic at higher risk for adverse perioperative outcomes within this cohort. Furthermore, the time interval between imaging and surgery was not controlled for, which may have affected the accuracy of SVD measurements relative to operative risk. The modest sample size has limited power for subgroup analysis, and residual confounding remains a concern despite multivariable adjustment. Future research should evaluate SVD prospectively, particularly in assessing its role in predicting outcomes following weight loss.

CONCLUSIONS

Obesity presents a significant challenge in renal transplantation due to its association with increased perioperative risks. Our study assessed the SVD, an anatomic morphometric parameter, and its association with adverse postoperative surgical outcomes, including major postoperative complications (Clavien-Dindo ≥3), wound complications, and wound dehiscence. While BMI remained a strong predictor of post operative complications, SVD may act as an

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adjunct measure in a subset of the population. Further research is required prior to its use as a validated tool in clinical practice.

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FIGURES AND TABLES

Figure 1. Sample calculation of skin to vessel distance for two individuals with a body mass index of 29, but differing skin to the external iliac vessels of (A) 114 mm and (B) 133 mm.

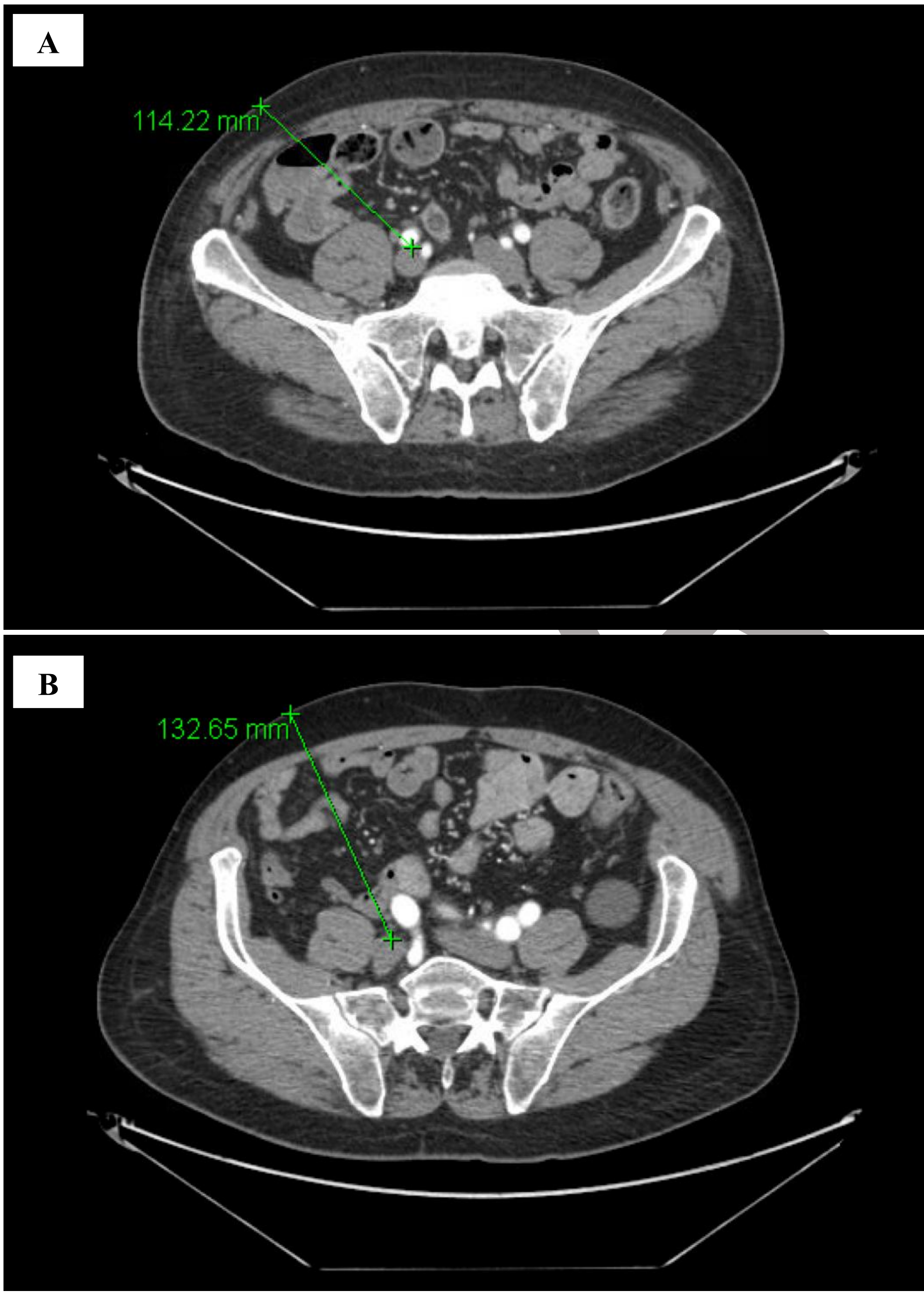

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Figure 2. (A) Pearson correlational analysis between body mass index (BMI) (kg/m^2) and skin-to-vessel distance (SVD) (ρ=0.682; p<0.001). Receiver operating characteristic (ROC) curves for (B) wound dehiscence in relation for BMI (area under the curve [AUC] 0.724, 95% CI 0.595–0.854, p=0.001) and SVD (AUC 0.696, 95% CI 0.553–0.840, p=0.007), and (C) any wound complication in relation for BMI (AUC 0.731, 95% CI 0.622 –0.840, p<0.001) and SVD (AUC 0.719, 95% CI 0.601–0.836, p<0.001). CI: confidence interval.

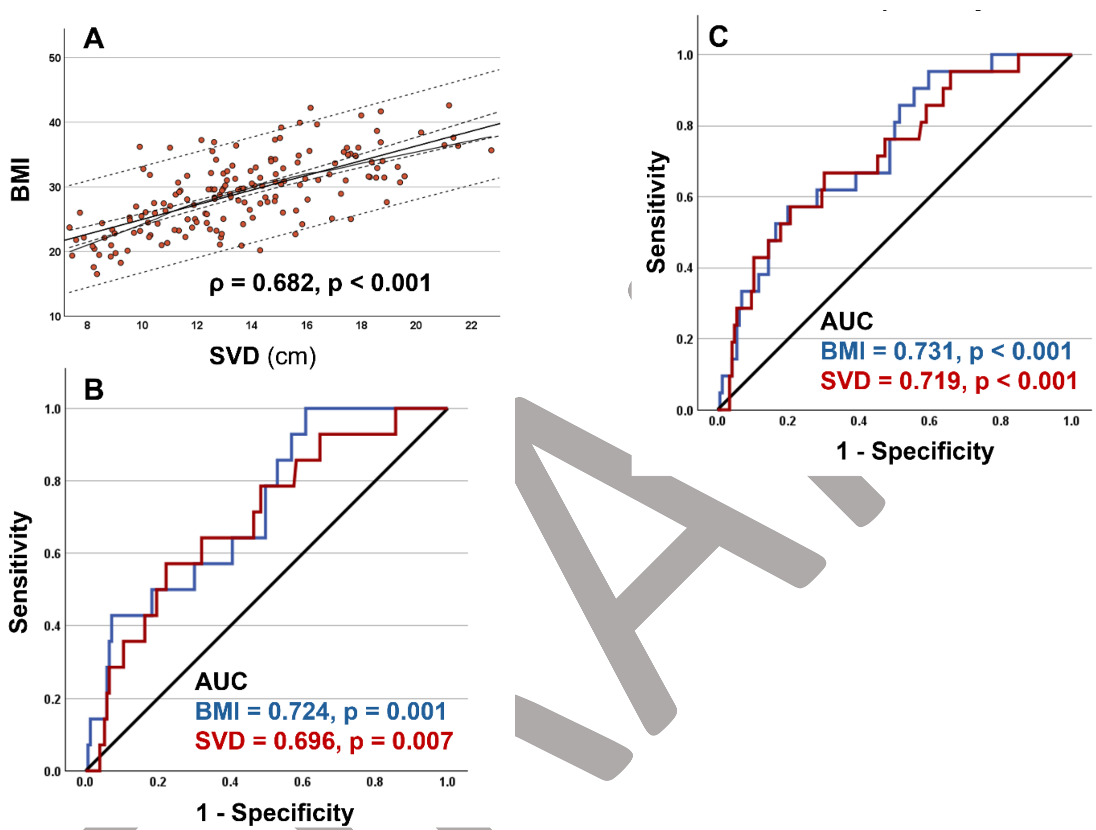

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Table 1. Demographic, morphometric and outcomes data	
Feature	**Renal transplant recipients (n=167)**
Age at transplant [years]	58.0 [50–66]
Sex	
Male	117 (70.1)
Female	50 (29.9)
Dialysis modality	
Hemodialysis	132 (79)
Peritoneal dialysis	19 (11.4)
No dialysis	7 (4.2)
Both	9 (5.4)
No previous RTx	145 (86.8)
RTx donor	
Living	49 (29.3)
NDD	38 (22.8)
DCD	80 (47.9)
Comorbidities	
Diabetes	91 (54.5)
Hypertension	144 (86.2)
Pulmonary disease	44 (26.3)
Cardiac disease	86 (51.5)
Ever smoker	54 (32.3)
Morphometric data	
BMI [kg/m^2]	29.4 [24.5–33.0]
SVD [cm]	13.23 [11.18–15.75]
Time from CT to RTx [mo]	9.0 [4.0–14.0]
Outcomes	
EBL [mL]	250 [200–400]
WIT [min]	34.5 [29.0–41.0]
LOS [days]	7.0 [6.0–10.0]
DGF	34 (20.4)
Any post-op complication	83 (49.7)
Wound infection	12 (7.2)
Wound dehiscence	14 (8.4)
Any wound complication	21 (12.6)
30-day readmission	73 (43.7)
Postoperative complications (≥3 Clavien-Dindo)	83 (49.7)

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Continuous variables reported as median [interquartile range]; nominal data reported as n (% cohort). BMI: body mass index; CT: computed tomography (contrast or non-contrast enhanced); DCD: donor after cardiac death; DGF: delayed graft function; EBL: estimated blood loss; LOS: length of stay; NDD: neurologic death donor; RTx: renal transplant; SVD: skin to external iliac vein distance; WIT: warm ischemic time.

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Table 2. Univariable and multivariable-adjusted logistic regression analysis to determine the association between clinical variables and postoperative complications

	Univariable								
	Wound dehiscence	**Any wound complication**	**Postoperative complications***						
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Age (per 1-year increase)	1.004	0.962–1.048	0.846	1.007	0.971–1.044	0.699	1.023	0.998–1.048	0.067
Sex (male vs. female)	3.524	1.154–10.762	0.027	1.921	0.753–4.900	0.172	1.017	0.525–1.973	0.960
BMI (per 1 kg/m^2 increase)	1.173	1.052–1.309	0.004	1.174	1.069–1.289	<0.001	1.036	0.981–1.095	0.199
Diabetes mellitus	1.559	0.499–4.866	0.445	1.792	0.684–4.698	0.235	1.589	0.860–2.935	0.139
Hypertension	2.183	0.272–17.536	0.463	3.548	0.453–27.810	0.228	1.644	0.669–4.040	0.278
Ever smoked	1.641	0.539–4.989	0.383	1.683	0.662–4.279	0.274	1.581	0.822–3.041	0.170
SVD (per 1 cm increase)	1.210	1.027–1.425	0.022	1.256	1.089–1.449	0.002	1.129	1.027–1.241	0.012
EBL (per 100 cc)	1.202	1.011–1.428	0.037	1.149	0.982–1.346	0.084	1.102	0.956–1.271	0.182
Warm ischemic time	1.004	0.966–1.043	0.853	0.997	0.959–1.036	0.873	1.017	0.988–1.047	0.250
Donor allograft									
Living	1			1			1		
Deceased	5.943	0.756 - 46.740	0.090	2.760	0.774–9.839	0.117	3.083	1.517–6.263	0.002
	Multivariable								

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	Wound dehiscence	**Any wound complication**	**Postoperative complications***						
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Age (per 1-year increase)	0.982	0.923–1.044	0.553	0.979	0.930–1.031	0.421	1.001	0.973 - 1.031	0.919
Sex (male vs. female)	3.602	0.987–13.140	0.052	1.864	0.633–5.490	0.259	1.058	0.516 - 2.168	0.878
BMI (per 1 kg/m^2 increase)	1.203	1.025–1.411	0.023	1.163	1.021–1.325	0.023	0.996	0.917–1.081	0.915
Diabetes mellitus	0.681	0.145–3.195	0.626	0.996	0.291–3.411	0.995	1.101	0.538–2.251	0.793
Hypertension	4.090	0.307–54.532	0.287	4.680	0.451–48.558	0.196	1.543	0.587–4.058	0.380
Ever smoked	1.845	0.458–7.424	0.389	2.153	0.693–6.683	0.185	1.606	0.789–3.272	0.192
SVD (per 1 cm increase)	1.035	0.801–1.337	0.794	1.102	0.898–1.353	0.354	1.102	0.957–1.270	0.177
EBL (per 100 cc)	1.111	0.924–1.335	0.265	1.077	0.908–1.278	0.395	1.048	0.898–1.223	0.552

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Warm ischemic time	0.997	0.939–1.059	0.923	0.986	0.934–1.041	0.613	1.003	0.974–1.031	0.863
Donor allograft									
Living	1			1			1		
Deceased	8.680	0.906–83.18	0.061	4.272	0.948–19.251	0.059	2.834	1.265–6.346	0.011

*Postoperative complications ≥3 Clavien-Dindo. BMI: body mass index; CI: confidence interval; SVD: skin-to-vessel distance; OR: odds ratio.

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