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Surgical Complications Following Renal Transplantation in a Large Institutional Cohort

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Background. Successful renal transplantation (RTx) relies on immunosuppression and an optimal surgical course with few surgical complications. Studies reporting the postoperative complications after RTx are heterogeneous and often lack systematic reporting of complications. This study aims to describe and identify postoperative short-term and long-term complications after RTx in a large institutional cohort and identify risk factors for a complicated surgical course. **Methods.** The study is a retrospective single-center cohort of 571 recipients who underwent living or deceased donor open RTx between 2014 and 2021. Data were collected on background information and perioperative and postoperative data. Complications were defined as short-term (<30 d) or long-term (>30 d) after transplantation and graded according to the Clavien-Dindo classification. Multivariable logistic regression was performed to evaluate risk factors for serious short-term complications and multivariable time-dependent Cox regression to evaluate risk factors for long-term complications. **Results.** A total of 351 patients received a graft from a deceased donor, and 144 of these grafts were on perfusion machine before transplantation. One or more short-term complications occurred in 345 (60%) patients. Previous RTx was associated with short-term Clavien-Dindo >2 complications in recipients (odds ratio = 2.08; 95% confidence interval [CI], 1.18-3.69; $P = 0.01$). Being underweight (body mass index <18.5) in combination with increasing age increased the odds of short-term Clavien-Dindo >2 and vascular complications. Increasing blood loss per 100 mL was associated with increased odds of short-term Clavien-Dindo >2 (odds ratio = 1.11; 95% CI, 1.01-1.21; $P = 0.032$). No associations were found for long-term complications after RTx. The 5-y cumulative incidence of graft loss was 12.6% (95% CI, 8.9-16.3). **Conclusions.** Short-term complications are common after RTx, and risk factors for severe short-term complications include previous RTx, increasing age, and low body mass index. No risk factors were identified for severe long-term complications. Further studies should explore whether new surgical techniques can reduce surgical complications in RTx.

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Since the 1950s, renal transplantation (RTx) has been the best treatment for end-stage renal disease for suitable patients. Improvements in medical management after RTx have facilitated better patient outcomes and significantly optimized long-term graft function over the years.[1,2] The success of RTx depends on the quality of the surgical procedure and postoperative care. The surgical quality of RTx is influenced by factors related to both the recipient and donor factors and surgeon expertise.[3]

Few studies have described overall surgical complications after RTx, and often the studies lack systematic reporting of complications according to current guidelines.[4] Furthermore, the studies are heterogeneous in quality and number of recipients and report conflicting results.[5-7] Most studies have

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focused on specific groups of complications such as ureteral strictures, vascular complications, lymphoceles, and wound complications.[7-11] Increased risk of postoperative complications has been identified in recipients with a higher Charlson comorbidity score and a high body mass index (BMI) in some studies but not in others.[5,12-15] Underweight (BMI <18.5) has been shown to affect long-term graft survival but has not conclusively shown to affect postoperative complications in kidney transplantation.[16]

The conflicting results and heterogeneous reporting of complications call for further studies of overall surgical complications and the identification of modifiable risk factors. Therefore, this study aims to systematically describe and identify postoperative short-term and long-term complications after RTx in a large institutional cohort and identify risk factors for a complicated surgical course.

MATERIALS AND METHODS

All recipients who underwent living or deceased donor RTx at Rigshospitalet, Copenhagen, Denmark, between September 2014 and August 2021 were included. Recipients who received RTx more than once during the study period were included with their last transplantation. Recipients who underwent double organ transplantation and pediatric transplantations (patients aged younger than 18 y) were excluded to focus solely on the surgical aspects of kidney transplantation. Furthermore, recipients who underwent graftectomy within 24 h of RTx because of rejection or complications were excluded. All deceased donors were donation after brain death because a donation after circulatory death donor program has yet to be implemented in Denmark.

The study was approved by the Danish Data Protection Agency (P-2019-661).

Data Collection

Data on background information, comorbidities, perioperative and postoperative data, and surgical complications were collected retrospectively from chart review using the Danish electronic patient file system. Comorbidity was graded according to the Charlson comorbidity index, with a 2-point extraction to exclude chronic kidney disease.[17] Information on smoking habits was divided into 3 groups: never smoker, previous smoker, and current smoker. Delayed graft function (DGF) was defined as the need for dialysis within the first week after transplantation. Residual urine output pretransplantation was defined as diuresis >100 mL/d. Recipients were followed until loss of graft function, for example, start of permanent dialysis or graftectomy, death, loss to follow-up, or December 31st, 2021, whichever came first. Loss to follow-up was if the recipient migrated to another region or country.

Surgical Technique

RTx were performed after the preparation of the graft on the organ back table. A Gibson incision was performed in the right or left iliac fossa, and the renal vessels were anastomosed end-to-side to the external iliac vessels using a monofilament synthetic nonabsorbable suture 6-0. Before all vascular anastomosis, the vessel lumens were flushed with heparin. The graft was placed extraperitoneally. The ureteroneocystostomy was performed and modem Woodruff and a double-J catheter was placed for 2 wk. Drains were inserted if deemed necessary by the surgeon and removed if the secretion was <50 mL in a 24-h period. The fascia was closed in layers using a synthetic absorbable polyglactin suture and a monofilament synthetic suture. The skin was closed using a monofilament, synthetic resorbable suture intracutaneously. A perioperative biopsy was performed for baseline histological assessment in case of later graft dysfunction. The prophylactic antibiotics used perioperatively were cephalosporin until 2021, after which piperacillin in combination with tazobactam was used. The antibiotics were given as a single perioperative dose unless a drain was inserted perioperatively, and then antibiotics were continued until the drain was removed.

An indwelling bladder catheter was used for 5 d postoperatively. Ten different specialized surgeons performed RTx in the included period.

Postoperative Assessment and Surgical Complications

Complications were registered as short term if occurring within the first 30 d after transplantation and as long term if occurring after 30 d. Complications were graded by the Clavien-Dindo (CD) classification as suggested by the Martin criteria,[18,19] and reasons for reoperations, and readmissions were registrered. Surgical complications were defined as any reported adverse event, either during the initial hospital stay or during outpatient follow-up, assessed to be related to surgery by the data collector.

Vascular complications were defined as arterial stenosis requiring radiological stenting or reoperation, renal graft thrombosis, bleeding requiring reoperation, and symptomatic hematomas, including those requiring drainage or reoperation and blood transfusions. Urologic complications were defined as sonographic verified hydronephrosis with the need for nephrostomy or reinsertion of a double-J catheter, ureteral stricture radiologically verified, or the need for reimplantation or transposition of the graft ureter to the bladder. Urinary tract infections (UTIs) were defined as a positive urine culture and patient symptoms. Recurrent UTIs were defined as ≥3 or more culture-verified UTIs in 1 y.

Immunosuppression and Rejections

The standard immunosuppressive regimen induction therapy included methyl-prednisone (250 mg) and basiliximab (20 mg, day 0 and 4). The standard maintenance regimen was tacrolimus aiming at blood concentrations of 5 to 10 ng/mL, mycophenolate mofetil (750 mg 2×), and prednisone 20 mg tapered to 5 mg after 6 mo. Cytomegalovirus prophylaxis was valganciclovir for 3 mo. Pneumocystis pneumonia prophylaxis was 6 mo with sulfamethoxazole with trimethoprim. Rejections within the first year posttransplantation were classified according to the BANFF classification.[20] Rejections within the first year after transplantation were registered for the recipients who were transplanted until January 1, 2021, because they have a minimum of 1 y follow-up. Only treated rejections were considered for analysis.

Statistical Analysis

Continuous variables are reported as median with interquartile range (IQR) values or mean with SD. Categorical variables are reported as frequency accompanied by percentages of the total.

Multivariable logistics regression analysis was used to analyze the association between short-term surgical complications, and it included the variables, such as gender, age at time of RTx, smoking status, Charlson comorbidity index >3, BMI, and previous RTx. Subgroup analysis was performed, and vascular complications were the outcomes. The results are presented by odds ratio (OR) with 95% confidence interval (95% CI). Model control was performed using the Hosmer-Lemeshow Goodness of fit test. Multivariable time-dependent cause-specific Cox proportional hazard regression was performed to analyze the risk of long-term complications with death as a competing event, and results were presented by hazard ratio (HR) and 95% CI.

Graft survival is reported as cumulative incidence and analyzed using the Aalen-Johansen estimator for competing risks. Death with a functioning graft was treated as a competing event. Overall mortality was assessed using the Kaplan-Meier estimate. Median follow-up is defined as the median time to censoring.

All tests were 2-sided and *P* values <0.05 were considered statistically significant. Statistical analysis was performed in SPSS and R-studio version 4.1.0.

RESULTS

A total of 571 consecutive recipients were included. Two recipients were excluded because of immediate perioperative graft thrombosis. Twenty-one kidney transplantations in children (age younger than 18 y) and 54 cases of double organ transplantations were performed in the included period but were excluded from this study.

Donor and Recipient Data

Table 1 shows the background information on the recipients before transplantation and perioperative information. More than half of the recipients were male individuals (63%), and the most common cause of kidney failure was glomerulonephritis (24%). A total of 25% of recipients were never biopsied and had therefore an unknown cause of kidney failure. The use of hypothermic machine perfusion was introduced in Rigshospitalet, Copenhagen, in December 2017, and 144 of 298 grafts in the period were on a perfusion machine before transplantation.

The median length of stay was 11 d (IQR, 8–16) and 133 of 501 recipients (26.5%) had a rejection within the first year after transplantation.

Postoperative Surgical Complications

The short-term complications are displayed in Table 2. In short, one or more short-term complications occurred in 60% of all recipients. The most common complications were postoperative need for blood transfusion (36%), symptomatic hematomas (10%), UTIs (8.6%), and sepsis (3.0%). When excluding blood transfusion as a short-term complication, 46% of the recipients had ≥1 short-term complications. Few recipients experienced a CD grade >3b (2.5%). Lymphoceles (4.7%) within 30 d were treated with percutaneous drainage, but 1 recipient with lymphoceles required operative management. No clinically meaningful differences regarding complications between living and deceased donors were observed (**Appendix 1, SDC,** http://links.lww.com/TXD/A645). Surgical causes for readmissions within the first 30 d can be seen in Appendix 2 (**SDC,** http://links.lww.com/TXD/A645). The most typical was hydronephrosis (n = 6).

Long-term complications are listed in Table 3. Long-term complications included recurrent UTIs (18%), lymphoceles (4.9%), hydronephrosis (with no verified structural cause; 4.4%), abscess/infection in the graft (4.0%), and ureteral strictures (3.2%). The most common type of complication was CD grade 2 (23%). Most long-term complications occurred within the first 9 mo after RTx (Figure 1A).

Risk Factors

Risk factors for serious short-term complications (CD >2) are presented in Table 4. Recipients with previous transplantation had a 2.08 times higher probability of CD >2 complications (95% CI, 1.18-3.69; *P* = 0.01). Furthermore, the probability of CD > 2 complications increased by 1.12 times for a 1-y increase of age at RTx in underweight recipients (BMI <18.5; 95% CI, 1.01-1.23; *P* = 0.03). However, other BMI groups did not affect the odds of CD >2 complications (Figure 1C). Laterality of the kidney and placement side of the kidney were not significantly correlated to the risk of short-term complication CD >2 (data not shown).

Subgroup analysis for short-term vascular complications (hematoma, reoperation because of bleeding, arterial stenosis, and anastomosis insufficiency) demonstrated that female individuals were at higher risk than male individuals (OR 1.78; 95% CI, 1.11-2.84; *P* = 0.02). Also, increasing age in underweight (BMI <18.5) patients was significantly associated with vascular complications (OR 1.13; 95% CI, 1.01-1.26; *P* = 0.04; Table 4). Subgroup analysis for perioperative factors for short-term complications (CD >2) is displayed in Table 5. Blood loss (per 100 mL increase) was associated with serious short-term complications (OR 1.11; 95% CI, 1.01-1.21; *P* = 0.032). Placement of a drain perioperatively, CIT, time of surgery, and multiple vessels were not identified as risk factors for short-term complications (CD >2).

The long-term complications occurred predominantly in the first year after transplantation (Figure 1A). In multivariable time-dependent Cox regression analysis, none of the variables were found to be associated with long-term complications after RTx (Table 4).

As the perfusion machine was introduced in 2017, we tested whether there was any difference between long-term complications before and after the year 2017 (**Appendix 3, SDC,** http://links.lww.com/TXD/A645). Grays test showed no significant difference between the 2 time periods (*P* = 0.2).

Survival

The median follow-up after RTx was 44 mo (IQR, 21–67 mo). Five-year patient survival was 86% (95% CI, 82-99; Figure 1B). The cumulative incidence of graft loss at 5 y after RTx was 12.6% (95% CI, 8.8-16.3; Figure 1D) and the mortality with a functioning graft 5 y after RTx was 8.8% (95% CI, 5.6%-12%).

DISCUSSION

RTx is a potentially life-saving procedure that relies on effective immunosuppression as well as a successful surgical

TABLE 1.

Baseline patient demographics and perioperative characteristics of kidney recipients (N = 571)

Variable	
Age at transplantation, y, median (IQR)	52 (42–62)
Gender male, n (%)	358 (62.7)
BMI, median (IQR)	24.8 (22.3–28.2)
BMI groups, n (%)	
Underweight <18.5	24 (4)
Normal weight 18.5–25	272 (48)
Overweight 25–30	191 (34)
Obese >30	84 (15)
Smoking status, n (%)	
Never smoker	256 (45)
Previous smoker	216 (38)
Current smoker	99 (17)
Previous transplantation, n (%)	73 (13)
Nephrological diagnosis/cause of kidney failure, n (%)	
Diabetic nephropathy	50 (8.8)
Hypertension and arteriosclerosis	42 (7.4)
Glomerulonephritis	136 (24)
Chronic pyelonephritis, interstitial nephritis, reflux nephropathy	19 (3.3)
Polycystic kidney disease	97 (17)
Systemic disease (ie, SLE, amyloidosis)	20 (3.5)
Other	61 (11)
Unidentified	146 (26)
Months on waiting list, median (IQR)	14 (5–34)
Months in dialysis, median, (IQR)	25 (10–51)
Preemptive transplantation, n (%)	88 (15)
Patients with remaining diuresis, n (%)	394 (69)
Amount of remaining diuresis per day, mL, n (%)	
<100	7 (1.8)
100–500	51 (13)
500–1500	104 (26)
>1500	174 (44)
Missing data	58 (15)
Comorbidities (Charlson comorbidity index),[a] n (%)	
0	311 (55)
1	131 (23)
2	75 (13)
3	36 (6)
4	11 (1.9)
>4	1 (0.2)
Comorbidities, n (%)	
Previous AMI	32 (6.3)
Previous apoplexia	40 (7)
Previous deep venous thrombosis	37 (5.6)
Previous cancer	37 (6.5)
Diabetes	
DM1	32 (5.6)
DM2	63 (11)
Perioperative and postoperative information, n (%)	
Left kidney	284 (50)
Living donor	220 (39)
Donor age, y, median (IQR)	
Living	55 (47–62)
Deceased	55 (42–65)
No. of graft arteries, n (%)	
1	444 (78)
2	109 (19)
3	15 (2.6)
4	1 (0.2)
No. of veins, n (%)	
1	546 (96)
2	19 (3.3)
3	2 (0.4)
4	1 (0.2)
Perfusion machine yes (N = 298),[b] n (%)	144 (43%)
CIT, h, mean ± SD	
Deceased donor	17.6 ± 6.6
Living donor	3 ± 0.9
Duration of surgery (N = 392), min, median (IQR)	133 (108–164)
Blood loss (N = 508), mL, median (IQR)	210 (100–400)
Perioperative complication,[c] n (%)	96 (17)
DGF, n (%)	126 (22)
Deceased donor	108 (31)
Living donor	18 (8.2)

[a]Adjusted Charlson comorbidity index where all recipients had extracted 2 points for renal disease.
[b]Since the introduction of the perfusion machine in December 2017.
[c]Perioperative complication if bleeding >1000 mL or any complication, that is, lesion of another organ.
AMI, acute myocardial infarction; BMI, body mass index; CIT, cold ischemia time; DGF, delayed graft function; DM1, diabetes mellitus type 1; DM2, diabetes mellitus type 2; IQR, interquartile range; SLE, systemic lupus erythematosus.

procedure. However, reporting surgical complications after RTx is heterogeneous and often lacks systematic grading.

In this single-center study from Denmark, surgical complications and risk factors of surgical complications are studied in renal transplant recipients while adhering to the reporting guidelines proposed by the European Association of Urology.[4]

Short-term complications were present in 3 of 5 patients and were most commonly infectious, urological, and vascular complications. Patient-related risk factors were previous transplantation and increasing age in underweight recipients (BMI <18.5). Increasing age in underweight recipients, as well as female gender, was seen to increase the probability of short-term vascular complications. We found no associated predictors for long-term complications CD grade >2. We found no difference in long-term complications before and after the introduction of the perfusion machine.

The reporting of complications in the surgical literature varies, making it difficult to compare complication rates. Our finding of an overall short-term complication rate of 60% is higher than reported in other studies (11%–47%),[5,7,21] possibly because we included blood transfusion as a surgical complication within the first 30 d.

One modifiable risk factor was the increased risk of postoperative complications in underweight recipients. This aligns with the findings in other types of surgery but has not been shown conclusively in kidney transplantation.[16,22] The "obesity paradox" has previously been described in other surgical specialties and underlines that both being underweight and morbidly obese (BMI >40) is a risk factor for complications, whereas patients with class 1 or 2 obesity seem at equal or even lower risk of complications compared with normal weight.[23] Malnutrition is common in patients with end-stage renal disease,[24] and this may lead to metabolic dysfunction when the body is exposed to the stress of surgery.[25] Consequently, the following inflammatory response may increase the risk of surgical complications.[26]

TABLE 2.

Short-term surgical complications (≤30 d)

Complication	n (%)
Recipients experiencing ≥1 short-term complications	345 (60)
Recipients experiencing ≥1 short-term complications (not including blood transfusion)	261 (46)
Reoperation	91 (16)
Vascular complications	
Arterial stenosis	13 (2.3)
Bleeding (reoperation)	26 (4.6)
Hematoma	58 (10)
Bleeding (blood transfusion)	204 (36)
Anastomosis insufficiency[a]	1 (0.2)
AV fistula in graft	10 (1.8)
Treated with coiling/embolization	5 (0.9)
Urological complications	
Hydronephrosis	8 (1.4)
Need for nephrostomy[b]	7 (1.2)
Fascia rupture	18 (3.2)
Need for reinsertion of urinary catheter	37 (6.5)
Testicular pain/swelling(genitalia)	18 (3.2)
Extravasation of urine	7 (1.2)
Wound rupture	21 (3.7)
Exploration of the graft to check vitality	18 (3.2)
Indication for removal of graft	5 (0.9)
Lymphocele	27 (4.7)
Treated by drainage	26 (4.5)
Managed operatively	1 (0.2)
Infectious	
Sepsis	17 (3.0)
UTI	49 (8.6)
Wound infection	11 (1.9)
Pneumonia (bacterial)	14 (2.5)
Graft infection[c]	1 (0.2)
Thromboembolic	
Thromboembolic event	14 (2.5)
Apoplexia	1
AMI[d]	6
Heparin infusion in leg because of prolonged capillary response	1
Lung embolus	1
Deep venous thrombosis	3
Kidney venous thrombosis	1
Kidney infarct	1
Miscellaneous	
Ileus	9 (1.6)
Need for admission to intensive care unit	7 (1.2)
Neuropathic pain	2 (0.4)
AFLI	10 (1.8)
Other[e]	4 (0.7)
Complications after CD	
CD 1	119 (21)
CD 2	270 (47)
CD 3a	31 (5.4)
CD 3b	85 (15)
CD 4a	8 (1.4)
CD 4b	1 (0.2)
CD 5	5 (0.9)

[a]One patient had a lesion of the intima of the artery and the arterial anastomosis had to be revised.
[b]One patient had hydronephrosis, but had the JJ stent removed earlier, and the hydronephrosis disappeared.
[c]Biopsy with microabcess and fungus infection in the graft.
[d]Two recipients with AMI died because of cardiac arrest.
[e]Other complications include pancreatitis, infection by drain site treated with antibiotics, intestinal paralysis managed with laxatives and a JJ catheter displaced to the bladder.
AFLI, atrial fibrillation; AMI, acute myocardial infarct; AV, arteriovenous; CD, Clavien-Dindo; UTI, urinary tract infection.

TABLE 3.

Long-term surgical complications (≥30 d)

Variable	n (%)
Overall complications[a] (N = 555)	202 (35)
Vascular complications	
Arterial stenosis	15 (2.6)
Deep venous thrombosis	9 (1.6)
Lung embolus	12 (2.1)
Thromboembolic event	10 (1.8)
Apoplexia	7
AMI	2
Other	1
Hematoma	3 (0.5)
AV fistula in graft	1 (0.2)
Urological complications	
Ureteral stricture	18 (3.2)
Neoimplantation/transposition	8
Genital pain/swelling	14 (2.5)
Hydronephrosis	25 (4.4)
Nephrostomy	20
JJ catheter	2
Urinary catheter	1
No intervention	2
Neuropathic pain in transplantation scar	4 (0.7)
Extravasation of urine	1 (0.2)
Chronic urethral catheter	5 (0.9)
Infectious	
Recurrent UTI	103 (18)
Abscess/infection in graft	23 (4.0)
Miscellaneous	
Lymphocele	28 (4.9)
Ileus	3 (0.5)
Hernia	14 (2.5)
Other	10 (1.8)
CD	
CD1	38 (6.7)
CD2	133 (23)
CD3a	40 (7.0)
CD3b	47 (8.2)
CD4	4 (0.7)
CD5[b]	2 (0.4)

[a]Sixteen recipients were not at risk for long-term complications, because they either died within the first 30 d or were lost to follow-up because of follow-up in another region or country (Faroe Islands or Greenland).
[b]Two recipients died because of long-term surgical complications.
AFLI, atrial fibrillation; AMI, acute myocardial infarct; AV fistula, arteriovenous fistula; CD, Clavien-Dindo; UTI, urinary tract infection.

Possible solutions to decrease the risk in these frail patients are to evaluate nutritional status or other frailty assessment tools before transplantation.[27,28] Furthermore, enhanced recovery after surgery programs have been shown to benefit kidney transplant recipients and offer possible solutions in this patient group.[29]

In our population, only two recipients (0.4%) had a BMI >40; and thus, no meaningful conclusions can be made from our data on this patient group. An obvious selection bias is that morbidly obese patients rarely undergo RTx. Transplantation offers survival benefits for obese patients compared with dialysis, so there is a need for developing surgical strategies for morbidly obese recipients if weight loss cannot be achieved easily.[30] Robot-assisted kidney transplantation could offer a new possibility for these patients, but the evidence is still scarce.[31]

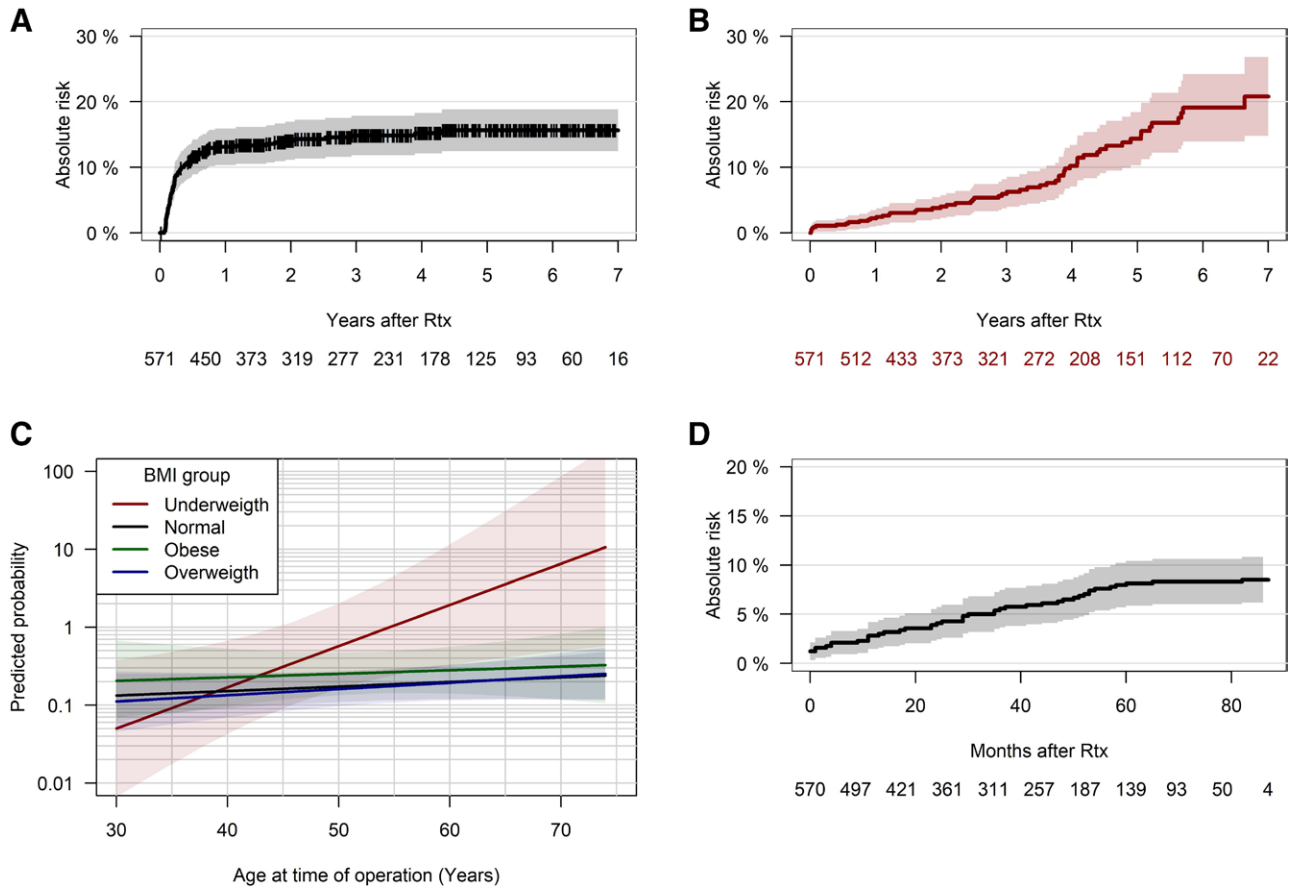

FIGURE 1. Absolute risk for serious long-term Clavien-Dindo >2 complications, overall survival after RTx, and risk of graft loss. A, Time from transplantation to long-term Clavien-Dindo >2 complications. The figure shows the cumulative incidence for long-term Clavien-Dindo >2 complications. B, Time from transplantation to death. C, In the logistic regression model 1 for short-term Clavien-Dindo >2 complications, there was a significant interaction between increasing age and underweight (BMI <18.5). D, Time from transplantation to graft loss. Note that the y-axes are truncated. BMI, body mass index; RTx, renal transplantation.

There are complications to RTx that are of special interest as they often significantly impact the patient trajectory and quality of life. We observed a low incidence of lymphoceles of 4.7% compared with other studies (2%–16%).[5,7,9,32,33] Similarly, the rate of wound infections found here was low (1.9%) compared with other studies (1.6%–8.8%).[5,8,9,33] However, the definition of wound infections varies significantly and should be interpreted with caution. The frequencies of arterial stenosis (2.3%) and reoperation (4.6%) were comparable with the incidence reported in the literature (0.6%–4% and 2%–5.5%, respectively).[5,7,8,33]

The observed 5-y cumulative incidence of graft loss (13%) was in agreement with the current literature, which is important because it is the most important endpoint of the combined surgical and medical effort after RTx.[34] Furthermore, the DGF rate of 8.2% in living donor transplantations aligns with other studies.[35,36]

We found previous RTx as a risk factor for short-term severe complications, which is supported by one other study that found that previous transplantation increased the risk for lymphoceles and perirenal hematomas.[33] However, another study found no difference between those with and without complications regarding age, comorbidities, BMI, cause of kidney failure, and previous transplantation.[8] Possible explanatory factors for the increased risk in those with multiple transplantations could be the technically more challenging procedure or the frailty of a recipient with previous transplantations.

This article gives an overview of surgical complications and patient-centered risk factors after RTx in a single-center cohort. RTx is a procedure with many aspects influencing the outcome of the transplantation, such as surgeon experience, daytime versus nighttime, donor availability, and center experience, and this should be the subject for further studies.[3,37]

Although we have used a thorough methodology and adhered to guidelines, this study has several limitations. These include the retrospective design, which entails a risk of selection bias. Patient-reported information, such as a history of smoking, entails a risk of reporting bias. We have not reported Kidney Donor Risk Index[38] because the data were missing for 19% of the deceased donors; however, we have reported donor age and we have no donation after circulatory death donors in Denmark. The close follow-up of the recipients postoperatively and the electronic medical records ensures a lot of follow-up data on the recipients despite the retrospective nature of this study. We reported a median BMI of 24.8 and 15% recipients with obesity, which might limit the generalizability to other cohorts with higher median BMI. Furthermore, this is a single-center study, but surgical technique and immunosuppressive protocols are similar in most centers, and our complication rates are comparable with other studies.

TABLE 4.

Multivariable models for risk factors for severe short-term and long-term Clavien-Dindo ≥2 complications

	Model 1: Multivariable logistic model for risk factors for severe short-term complications (Clavien-Dindo >2)			Model 2: Multivariable logistic subgroup analysis for vascular complications (hematoma, reoperation because of bleeding, arterial stenosis, and anastomosis insufficiency)			Model 3: Multivariable Cox risk regression for severe long-term complications (Clavien-Dindo >2)		
Variable	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***	**HR**	**95% CI**	***P***
Gender male	1	Reference		1	Reference		1	Reference	
Gender female	1.09	0.70-1.70	0.69	1.78	1.11-2.84	0.02*	0.95	0.60-1.50	0.82
Age at the time of RTx	1.01	0.99-1.04	0.25	1.00	0.98-1.02	0.99	1.01	0.96-1.03	0.13
Never smoker	1	Reference		1	Reference		1	Reference	
Previously smoker	1.19	0.74-1.91	0.48	1.09	0.66-1.83	0.72	1.12	0.69-1.82	0.66
Current smoker	1.34	0.73-2.45	0.34	0.97	0.49-1.90	0.93	1.13	0.61-2.11	0.70
CCI <3	1	Reference		1	Reference		1	Reference	
CCI >3	1.48	0.41-5.31	0.55	1.79	0.44-7.26	0.42	0.55	0.08-4.02	0.56
Normal weight	1	Reference		1	Reference		1	Reference	
Underweight (BMI <18.5)	0.02	0.0001-1.75	0.08	0.007	0.00-1.70	0.07	1.92	0.72-5.14	0.19
Overweight (BMI >25)	0.72	0.09-5.76	0.76	1.80	0.23-14.11	0.58	1.18	0.72-1.91	0.52
Obese (BMI >30)	1.67	0.11-25.10	0.71	0.19	0.01-6.40	0.35	1.05	0.53-2.09	0.89
Previous RTx	2.07	1.14-3.8	0.01*	1.03	0.51-2.07	0.94			
Time in dialysis, y	1.003	0.93-1.08	0.92	0.99	0.92-1.08	0.97			
Per year increasing age and underweight	1.12	1.01-1.23	0.03*	1.13	1.01-1.26	0.04*			
Per year increasing age and overweight	1.01	0.97-1.04	0.79	0.99	0.95-1.03	0.64			
Per year increasing age and obese	1.0	0.95-1.05	0.92	1.03	0.97-1.10	0.36			

*Significant P values (<0.05).
BMI, body mass index; CCI, Charlson comorbidity index; CI, confidence interval; HR, hazard ratio; OR, odds ratio; Rtx, renal transplantation.

TABLE 5.

Subgroup analysis for short-term Clavien-Dindo ≥2 complications (perioperative factors)

Variable	**OR**	**95% CI**	***P***
No drain	1	Reference	
Drain	0.70	0.34-1.44	0.33
CIT, h	0.99	0.97-1.03	0.99
Time of surgery, min	1.00	0.99-1.01	0.21
Blood loss per 100 mL	1.11	1.01-1.21	0.03*
Single vein	1	Reference	
Multiple veins	0.64	0.14-2.99	0.57
Single artery	1	Reference	
Multiple arteries	0.64	0.32-1.28	0.21

*Significant P values (<0.05).
CI, confidence interval; CIT, cold ischemia time; OR, odds ratio.

A strength of this study is that overall complication rates are reported, whereas many other studies have reported solely urological complications[10,11,32] or vascular complications.[39] Moreover, most previous publications have not used a systematic grading system for reporting surgical complications.[5,7,9,11,32] The lack of use of grading systems in surgical literature on surgical complications prohibits comparison of results and will often result in an underreporting of minor complications (CD grade 1).[19] Furthermore, if complications are not divided into short-term and long-term complications, this also prohibits comparing results and complication rates. Other strengths of this study include a clear definition of complications and that only two persons were involved in the collection of data, which minimizes interrater discrepancies. The large sample size of 571 transplantations ensures that the complication rates are representative, and our long follow-up period enables long-term complications to occur.

CONCLUSION

Short-term and long-term surgical complications after RTx are frequent, most commonly infectious, vascular, and urological complications. Recipients with previous transplantation, older, underweight, and female individuals are the most vulnerable to surgical complications. These recipients could benefit from preoperative nutritional evaluation, enhanced recovery programs, or robot-assisted RTx, which has been shown to decrease morbidity after other surgical procedures. However, further studies are needed to examine how surgical complications can be reduced in the future.

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