# Surgical site complications in kidney transplant recipients: incidence, risk factors and outcomes in the modern era

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**Background:** Surgical site complications (SSCs) are an important source of morbidity after kidney transplantation. We assessed the incidence, risk factors, outcomes and economic impact of SSCs in a large, diverse population of kidney transplant recipients.

**Methods:** We conducted a single-centre, observational cohort study of adult (age ≥ 18 yr) patients who underwent kidney transplantation between Jan. 1, 2005, and Dec. 31, 2015, with a minimum of 1 year of follow-up. Cases of SSC, including infections and wound dehiscence, were determined from patient records. Inpatient and outpatient hospital costs were determined 6 and 12 months after transplantation. We used the Kaplan–Meier product-limit method to determine the cumulative probability of SSCs and other outcomes. We evaluated risk factors and clinical outcomes using Cox proportional hazard ratios. Linear regression models were used to study the effect of SSCs on graft function.

**Results:** The incidence rate of SSCs within 30 days after transplantation was 4.19 per 100 person-months. The cumulative probability of developing an SSC within 30 days after transplantation was 4.13% (95% confidence interval [CI] 3.23%–5.28%). Increased recipient body mass index (BMI) (hazard ratio [HR] 1.07, 95% CI 1.02–1.11), longer cold ischemic time (HR 1.05, 95% CI 1.01–1.09) and transplantation in 2010–2012 versus 2005–2009 (HR 2.20, 95% CI 1.19–4.04) were risk factors for SSC development. In multivariable stepwise Cox proportional hazard models, SSC was a significant risk factor for death-censored graft failure (HR 3.08, 95% CI 1.60–5.90) and total graft failure (HR 2.09, 95% CI 1.32–3.32). Cumulative median hospital costs were $2238.46 greater for patients with an SSC than for those without.

**Conclusion:** Increased BMI, longer cold ischemic time and the 2010–2012 transplantation period predisposed to SSCs. The development of SSCs was associated with a higher risk of graft failure. Strategies to minimize SSCs may improve outcomes after kidney transplantation and reduce costs.

**Contexte :** Les complications affectant le site opératoire (CSO) sont une importante cause de morbidité après la transplantation rénale. Nous avons évalué l'incidence, les facteurs de risque, les résultats et l'impact économique des CSO auprès d'une volumineuse population hétérogène de receveurs de transplantations rénales.

**Méthodes :** Nous avons procédé à une étude de cohorte d'observation monocentrique regroupant des patients adultes (âge ≥ 18 ans) soumis à une transplantation rénale entre le 1er janvier 2005 et le 31 décembre 2015, et suivis pendant au moins 1 an. Les cas de CSO, incluant les infections et les déhiscences de plaies ont été confirmés à partir des dossiers des patients. Le coût des hospitalisations et des soins ambulatoires a été calculé 6 et 12 mois après la transplantation. Nous avons utilisé l'estimateur de produit-limite de Kaplan–Meier pour établir la probabilité cumulative de CSO et d'autres paramètres. Nous avons évalué les facteurs de risque et les paramètres cliniques par la méthode des risques proportionnels de Cox. Des modèles de régression linéaire ont servi à l'analyse de l'impact des CSO sur le fonctionnement des greffons.

**Résultats :** Le taux d'incidence des CSO dans les 30 jours suivant la transplantation a été de 4,19 par 100 mois-personnes. La probabilité cumulative d'une CSO dans les 30 jours suivant la transplantation a été de 4,13 % (intervalle de confiance [IC] de 95 % 3,23 %–5,28 %). Les facteurs de risque de CSO étaient indice de masse corporelle (IMC) élevé (risque relatif [RR] 1,07, IC de 95 % 1,02–1,11), durée plus longue de l'ischémie froide (RR 1,05, IC de 95 % 1,01–1,09) et transplantation effectuée en 2010–2012 c. 2005–2009 (RR 2,20, IC de 95 % 1,19–4,04). Dans les modèles à risques

proportionnels de Cox multivariés séquentiels, les CSO ont été d'importants facteurs de risque d'échec du greffon après censure des décès survenus avec des greffons fonctionnels (RR 3,08, IC de 95 % 1,60–5,90) et d'échec total du greffon (RR 2,09, IC de 95 % 1,32–3,32). Les coûts hospitaliers médians cumulatifs ont été de 2238,46 $ de plus chez les patients ayant connu une CSO par rapport aux patients indemnes de CSO.

**Conclusion :** Un IMC élevé, une durée plus longue de l'ischémie froide et la transplantation effectuée entre 2010 et 2012 ont prédisposé les patients à des CSO. Les CSO ont été associées à un risque plus grand d'échec du greffon. Les stratégies visant à prévenir les CSO pourraient améliorer les résultats de la transplantation rénale et en réduire les coûts.

Kidney transplantation is the preferred treatment for end-stage renal disease, offering enhanced survival and quality of life as compared to dialysis. However, surgical site complications (SSCs) represent an important source of morbidity for kidney transplant recipients. Several factors may contribute to the development of SSCs, including the recipient's body mass index (BMI) or history of diabetes, the quality of the donor organ, unsterile practices and posttransplantation immunosuppressive therapy.[1–5] Previous investigators reported the incidence of SSCs, including surgical site infections (SSIs) and wound dehiscence, in kidney transplant recipients to range from 2% to 26%;[6,7] however, these studies were published in 2012 and 2007, and SSI and wound dehiscence were considered separately. Surgical site complications typically arise early in the posttransplantation period and may affect short- to intermediate-term outcomes of the patient.[8] Clinical outcomes reported to be associated with SSC include hospital readmission, delayed graft function, graft loss and death.[1,9,10] Furthermore, SSCs are associated with a substantial economic impact on both hospitals and patients.[11,12]

Despite efforts to minimize SSCs through improved surgical techniques, perioperative antibiotic prophylaxis, targeted therapy and optimized immunosuppression, they remain a major clinical challenge.[13–15] Recent trends toward the increased use of marginal kidney donors in combination with transplantation in patients with a greater burden of comorbidities, including diabetes, older age and higher BMI, may be contributing factors.[16–18] A more precise understanding of the factors associated with the development of SSCs in the modern era, and the burden of SSCs on patients and health care providers, would allow for targeted quality-improvement initiatives.

In this study, we assessed SSCs at a high-volume Canadian transplantation centre by measuring the incidence of SSCs in kidney transplant recipients, identifying risk factors, studying their association with early and intermediate-term clinical outcomes, and quantifying their economic impact. Although a variety of surgical complications may arise after transplantation, this study focuses primarily on complications related to the surgical incision itself.

## Methods

### Study design and population

This single-centre cohort study used existing data for adult (age ≥ 18 yr) patients who underwent kidney transplantation between Jan. 1, 2005, and Dec. 31, 2015, with a minimum of 1 year of follow-up. Patients were excluded if they had received a prior nonkidney transplant or a simultaneous multiorgan transplant, or underwent transplantation at an outside centre.

### Data sources

Data for this study regarding the type and severity of SSC (defined as wound dehiscence or an SSI) were collected from patient medical records accessed through our institution's organ transplantation tracking record and electronic patient record. We obtained data such as patient demographic characteristics, median household income, donor information and information about the transplantation procedure from the institution's Comprehensive Renal Transplant Research Information System, a database that houses pre-, peri- and posttransplantation information concerning kidney transplant recipients.[19] We obtained inpatient- and outpatient-related hospital cost data from the institutional finance department. The study was approved by the University Health Network Research Ethics Board.

### Selection of cases

We examined patient records to determine SSC cases as classified by the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*.[20] Surgical site complications comprise wound dehiscence and SSIs, defined to include abscesses and infected fluid collections. We defined and grouped superficial, deep and organ/space infection using the criteria set forth by the U.S. Centers for Disease Control and Prevention, which capture SSC cases within 30 days of the transplantation.[21] We defined wound dehiscence as the spontaneous opening of the skin and subcutaneous tissues of a surgical wound within 30 days after transplantation. Ambiguous cases were adjudicated by experts in the field.

### *Covariates*

Recipient, donor and transplantation factors were included in the risk factors and outcomes analyses, as they have the potential to affect the likelihood of an SCC and associated outcomes. Recipient factors included age at transplantation, sex, race, BMI, history of diabetes, history of cardiovascular disease, time spent receiving dialysis before transplantation, peak panel reactive antibody and median household income. Donor factors included age at donation, living versus deceased donor, and expanded-criteria donor (ECD) versus non-ECD. Transplantation factors included cold ischemic time, duration of surgery, delayed graft function, type of immunosuppression and transplantation period (2005–2009, 2010–2012 or 2013–2015). We defined transplantation period a priori based on sample sizes to allow for sufficient group sizes.

### *Surgical site complications as exposure variable*

We analyzed the development of an SSC as a risk factor for posttransplantation outcomes including death-censored graft failure, death with graft function, total graft failure, kidney function and hospital readmission. Death-censored graft failure is defined as the return to long-term dialysis after transplantation. Total graft failure comprises a composite of death-censored graft failure and death with graft function. We calculated the estimated glomerular filtration rate 6 and 12 months after transplantation using the Chronic Kidney Disease Epidemiology Collaboration equation, which is the most widely used estimation of renal function in patients with native kidney disease and kidney transplant recipients.[22]

### *Costs*

We determined the inpatient and outpatient hospital costs 6 and 12 months after transplantation to study the economic impact of the clinical management of SSCs. These costs included all costs incurred by the hospital during inpatient and outpatient care, such as for procedures, room and board, and laboratory tests, but did not include physician costs.

### *Statistical analysis*

We used descriptive statistics to summarize recipient, donor and transplantation baseline characteristics. We used mean and median values to summarize normally distributed and skewed continuous risk factors, respectively. We obtained $p$ values from Student $t$ tests and Wilcoxon rank-sum tests. The distribution of categoric risk factors is presented as percentages. We calculated the cumulative probability of an SSC within 30 days after transplantation using the Kaplan–Meier product limit method and reported the incidence as a person-time incidence rate. Missing values were handled through multiple imputation, accounting for the uncertainties when predicting missing values, both within and between imputed data sets.

We identified risk factors for SSCs using univariable and multivariable Cox proportional hazards regression models to obtain hazard ratios (HRs) with 95% confidence intervals (CIs).

We evaluated the development of an SSC within 30 days after transplantation as a risk factor for the outcomes of death-censored graft failure, death with graft function and total graft failure using univariable and multivariable Cox proportional hazards regression models. Since patients had to survive with a functioning graft to 30 days after transplantation, any patients who were lost to follow-up or experienced graft failure (including death) during this period were excluded from the analysis of long-term outcomes. In addition, patients who did not receive induction therapy were excluded from the analysis of outcomes since it is the standard of care at this centre, and such cases are considered outliers. We studied the effect of an SSC on kidney function using simple and mixed linear regression models.[23] We compared the mean and median hospital costs of patients with and without SSCs 6 and 12 months after transplantation.

All analyses were conducted with Stata/MP, version 12.0 (StataCorp). A 2-tailed $p$ value of $< 0.05$ was considered statistically significant.

## Results

We identified 2054 patients who underwent kidney transplantation between Jan. 1, 2005, and Dec. 31, 2015, of whom 553 were excluded (because of prior nonkidney transplantation or simultaneous multiorgan transplantation in 362 cases, and because the patient underwent transplantation outside our centre in 191). Thus, our cohort consisted of 1501 kidney transplant recipients. The mean recipient age at the time of transplantation was 50.8 (standard deviation 13.4) years, and 905 recipients (60.3%) were male (Table 1). The type of donor was evenly divided, with 731 (48.7%) being living donors and 770 (51.3%) being deceased donors. The median duration of surgery was 2.3 (interquartile range [IQR] 2.0–2.7) hours.

There were 61 SSC events within the first month after transplantation. The incidence rate per 100 person-months of the first SSC within 30 days of transplantation was 4.19 (95% CI 3.26–5.39) (Appendix 1, Table S1, available at canjsurg.ca). The cumulative probability of developing an SSC within 30 days after transplantation was 4.13% (95% CI 3.23%–5.28%) (Figure 1). Patients with an SSC had a median length of stay of 12 (IQR 8–20) days, compared to 8 (IQR 7–12) days for patients without an SSC. Of the 61 patients who developed an SSC within the first 30 days after transplantation, 41 (67%) had only

**Table 1. Recipient, donor and transplantation characteristics for the entire cohort and for those with and without a surgical site complication within 30 days after transplantation***

| Variable | No. (%) of patients† | | |
|---|---|---|---|
| | Overall *n* = 1501 | No surgical site complication *n* = 1406 | Surgical site complication *n* = 59 |
| Recipient age at transplantation, mean ± SD, yr | 50.8 ± 13.4 | 50.7 ± 13.5 | 55.1 ± 11.7 |
| Recipient sex | | | |
| Male | 905 (60.3) | 845 (60.1) | 44 (74.6) |
| Female | 596 (39.7) | 561 (39.9) | 15 (25.4) |
| Recipient race | | | |
| Nonwhite | — | 482 (34.3) | 24 (40.7) |
| White | — | 820 (58.3) | 31 (52.5) |
| Missing | — | 104 (7.4) | 4 (6.8) |
| Recipient body mass index, mean ± SD (*n* = 1448) | 27.0 ± 5.5 | 26.9 ± 5.5 | 29.7 ± 6.3 |
| Recipient history of diabetes | | | |
| No | 1049 (69.9) | 994 (70.7) | 29 (49.2) |
| Yes | 451 (30.0) | 411 (29.2) | 30 (50.8) |
| Missing | 1 (0.1) | 1 (0.1) | 0 (0.0) |
| Recipient history of cardiovascular disease | | | |
| No | 1091 (72.7) | 1028 (73.1) | 38 (64.4) |
| Yes | 409 (27.2) | 377 (26.8) | 21 (35.6) |
| Missing | 1 (0.1) | 1 (0.1) | 0 (0.0) |
| Median time receiving dialysis (IQR), yr | 3.2 (1.2–5.8) | 3.2 (1.2–5.8) | 3.6 (2.3–5.5) |
| Median length of stay (IQR), d (*n* = 1465) | 9 (7–12) | 8 (7–12) | 12 (8–20) |
| Peak panel reactive antibody, % | | | |
| 0 | — | 660 (46.9) | 21 (35.6) |
| > 0 | — | 745 (53.0) | 38 (64.4) |
| Missing | — | 1 (0.1) | 0 (0.0) |
| Donor age, mean ± SD, yr (*n* = 1499) | 47.2 ± 14.4 | 47.0 ± 14.3 | 52.5 ± 14.2 |
| Donor sex | | | |
| Male | — | 701 (49.9) | 37 (62.7) |
| Female | — | 699 (49.7) | 22 (37.3) |
| Missing | — | 6 (0.4) | 0 (0.0) |
| Donor type | | | |
| Living | 731 (48.7) | 687 (48.9) | 21 (35.6) |
| Deceased, ECD | 256 (17.1) | 233 (16.6) | 20 (33.9) |
| Deceased, non-ECD | 514 (34.2) | 486 (34.6) | 18 (30.5) |
| Induction therapy | | | |
| Nondepleting agent | — | 361 (25.7) | 5 (8.5) |
| Depleting agent | — | 1045 (74.3) | 54 (91.5) |
| Calcineurin inhibitor type at discharge | | | |
| Tacrolimus | — | 1209 (86.0) | 55 (93.2) |
| Cyclosporine | — | 176 (12.5) | 2 (3.4) |
| Missing | — | 21 (1.5) | 2 (3.4) |
| Cold ischemic time, mean ± SD, h (*n* = 712)‡ | 11.9 ± 5.2 | 11.8 ± 5.1 | 13.2 ± 6.5 |
| Delayed graft function | — | 280 (19.9) | 21 (35.6) |
| Median duration of surgery (IQR), h (*n* = 1491) | 2.3 (2.0–2.7) | — | — |
| Median household income (IQR), $ (*n* = 1312) | 66 412 (49 053–88 996) | 66 358 (49 187–88 935) | 70 853 (44 058–93 153) |
| Transplantation period | | | |
| 2005–2009 | 630 (42.0) | 589 (41.9) | 17 (28.8) |
| 2010–2012 | 434 (28.9) | 402 (28.6) | 26 (44.1) |
| 2013–2015 | 437 (29.1) | 415 (29.5) | 16 (27.1) |

ECD = expanded-criteria donor; IQR = interquartile range; SD = standard deviation.
*Thirty-six patients were excluded from the cohort since they were lost to follow-up or experienced graft failure during the first 30 days after transplantation, or did not receive induction immunosuppression.
†Except where noted otherwise.
‡Deceased donors only.

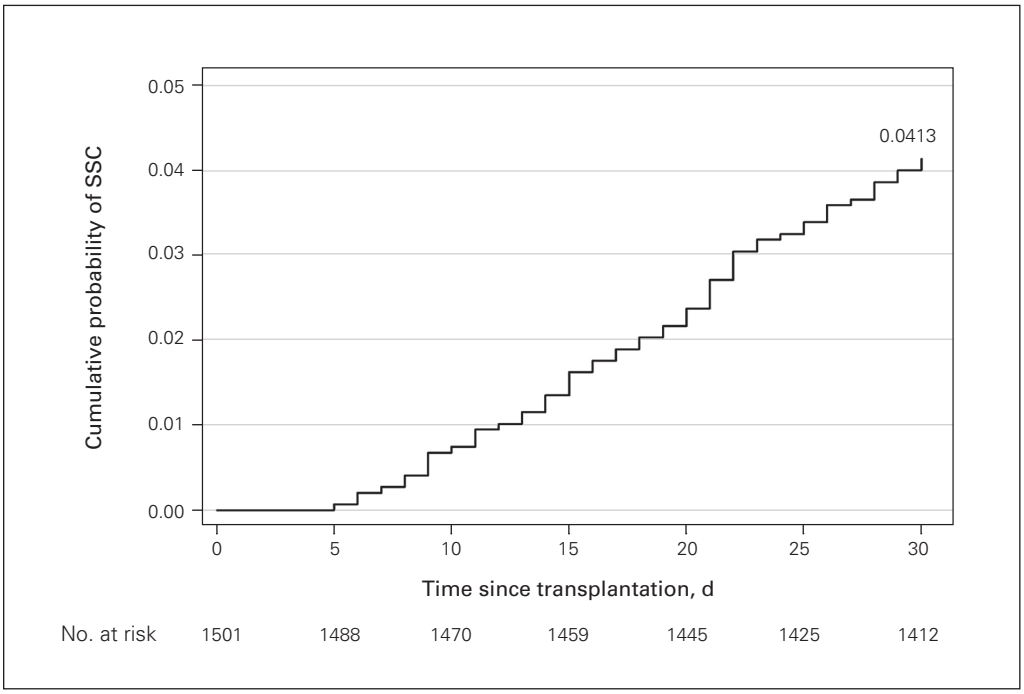


**Fig. 1.** Cumulative probability of the development of a surgical site complication (SSC) within the first 30 days after kidney transplantation.

**Table 2. Univariable Cox proportional hazards model for risk factors for development of surgical site complications**

| Risk factor | HR (95% CI) |
|---|---|
| Recipient age at transplantation (per 1-yr increase) | 1.03 (1.01–1.05) |
| Recipient sex (female v. male) | 0.53 (0.30–0.95) |
| Recipient body mass indexs (per 1 kg/m$^2$ increase) | 1.08 (1.04–1.12) |
| Recipient history of diabetes (yes v. no) | 2.32 (1.40–3.83) |
| Recipient history of cardiovascular disease (yes v. no) | 1.53 (0.91–2.59) |
| Time receiving dialysis (per 1-yr increase) | 1.04 (0.96–1.11) |
| Donor age (per 1-yr increase) | 1.03 (1.01–1.05) |
| Donor type | |
| Deceased ECD v. living | 2.78 (1.51–5.13) |
| Deceased non-ECD v. living | 1.35 (0.73–2.48) |
| Cold ischemic time (per 1-h increase) | 1.06 (1.02–1.09) |
| Duration of surgery (per 1-h increase) | 1.93 (1.53–2.44) |
| Median household income (per $5000 increase) | 0.99 (0.96–1.03) |
| Transplantation period | |
| 2010–2012 v. 2005–2009 | 2.33 (1.27–4.27) |
| 2013–2015 v. 2005–2009 | 1.44 (0.74–2.83) |

CI = confidence interval; ECD = expanded-criteria donor; HR = hazard ratio.

wound dehiscence, 10 (16%) had only SSI, and 10 (16%) had both. Of the 51 patients who experienced wound dehiscence, only 2 (4%) had dehiscence of the fascia.

Of the 20 patients with an SSI, 9 (45%) had a superficial SSI, 4 (20%) had a deep SSI, and 7 (35%) had an organ/space SSI. Gram-negative bacteria were grown in SSI cultures from 12 patients (60%), 6 (50%) of whom had gram-positive bacteria, with the most common being *Pseudomonas aeruginosa* (Appendix 1, Table S2). The most common type of gram-positive bacteria found was coagulase-negative *Staphylococcus* (4 cases [20%]). Yeast was found in the surgical site of 1 patient (5%), 3 patients (15%) had only commensal flora, and 3 patients (15%) had no culture done.

Most risk factors for SSCs were found to be significant in univariable analyses, such as recipient BMI (HR 1.08 per 1 kg/m$^2$ increase, 95% CI 1.04–1.12), donor age (HR 1.03 per 1-yr increase, 95% CI 1.01–1.05), cold ischemic time (HR 1.06 per 1-h increase, 95% CI 1.02–1.09) and transplantation in 2010–2012 versus 2005–2009 (HR 2.33, 95% CI 1.27–4.27) (Table 2). Factors that were not associated with development of an SSC included recipient history of cardiovascular disease, time spent receiving dialysis, and deceased non-ECD compared to living donor.

On multivariable stepwise Cox proportional hazards analysis, 3 risk factors were found to be significantly associated with the development of SSCs: greater recipient BMI (HR 1.07 per 1 kg/m$^2$ increase, 95% CI 1.02–1.11), longer cold ischemic time (HR 1.05 per 1-h increase, 95% CI 1.01–1.09) and transplantation in 2010–2012 versus 2005–2009 (HR 2.20, 95% CI 1.19–4.04) (Table 3). The degree of missingness of variables included in the models is provided in Appendix 1, Table S3.

For analysis of the clinical outcomes of death-censored graft failure, death with graft function, total graft failure and hospital readmission, 36 patients were excluded since they were lost to follow-up or experienced graft failure during the first 30 days after transplantation, or did not

**Table 3. Multivariable Cox stepwise model for risk factors for development of surgical site complications**

| Risk factor | HR (95% CI) |
|---|---|
| Recipient age at transplantation (per 1-yr increase) | 1.01 (0.99–1.03) |
| Recipient body mass index (per 1 kg/m$^2$ increase) | 1.07 (1.02–1.11) |
| Donor age (per 1-yr increase) | 1.02 (1.00–1.04) |
| Cold ischemic time (per 1-h increase) | 1.05 (1.01–1.09) |
| Duration of surgery (per 1-h increase) | 1.60 (0.94–2.73) |
| Transplantation period | |
| 2010–2012 v. 2005–2009 | 2.20 (1.19–4.04) |
| 2013–2015 v. 2005–2009 | 1.30 (0.66–2.57) |

CI = confidence interval; HR = hazard ratio.

receive induction immunosuppression. Among the remaining 1465 patients, there were 113 cases of death-censored graft failure and 156 cases of death with graft function, giving 269 total graft failure events over 7529.84 person-years of follow-up. The incidence rates per 100 person-years of total graft failure and hospital readmission were 3.57 and 14.11, respectively (Appendix 1, Table S1). Univariable Cox regression models showed SSC to be a significant risk factor for death-censored graft failure (HR 3.47, 95% CI 1.86–6.48), death with graft function (HR 2.37, [95% CI 1.25–4.51) and total graft failure (HR 2.84, 95% CI 1.82–4.44) (Table 4; Appendix 1, Figure S1). In multivariable stepwise Cox proportional hazard models, SSC was a significant risk factor for death-censored graft failure (HR 3.08, 95% CI 1.60–5.90) and total graft failure (HR 2.09, 95% CI 1.32–3.32) but not for death with graft function. Development of an SSC was not an independent risk factor for hospital readmission in any of the Cox models.

Simple linear models and linear mixed models showed no significant of SSCs on estimated glomerular filtration rate (Appendix 1, Table S4).

At both 6 and 12 months after transplantation, the cumulative mean and median hospital costs were greater for patients with SSCs than for those without SSCs (mean at 12 mo $12 462.67 v. $11 770.16, median at 12 mo $7557.25 v. $4879.27) (Table 5).

## Discussion

The incidence of first SSC within 30 days after transplantation at a high-volume Canadian centre was 4.19 per 100 person-months, and the cumulative probability of cases within 30 days was 4.13%, with most cases being wound dehiscence alone. Although the majority of potential risk factors for the development of SSC that were analyzed were significant when evaluated separately, multivariable analysis yielded only 3 significant risk factors: increased recipient BMI, longer cold ischemic time and the 2010–2012 transplantation period. Surprisingly, recipient age, donor type (living donor v. deceased ECD v. deceased non-ECD) and duration of surgery were not found to be significant risk factors for SSCs in the multivariable models. The univariable and multivariable models for the likelihood of hospital readmission after SSC were not significant, and similar trends were observed when assessing the association between SSC and graft function. Notably, occurrence of an SSC increased the risk of death-censored graft failure and total graft failure in both univariable and multivariable models. Cases of superficial wound dehiscence were more common than SSIs. The most common type of gram-negative

**Table 4. Univariable and multivariable Cox proportional hazards models for outcomes, with surgical site complications as a risk factor (other risk factors not shown)**

| | HR (95% CI) | | |
|---|---|---|---|
| Outcome | Univariable | Multivariable | Multivariable (stepwise) |
| Death-censored graft failure | 3.47 (1.86–6.48) | 2.90 (1.46–5.75) | 3.08 (1.60–5.90) |
| Death with graft function | 2.37 (1.25–4.51) | 1.62 (0.81–3.23) | 1.58 (0.82–3.06) |
| Total graft failure | 2.84 (1.82–4.44) | 2.04 (1.26–3.31) | 2.09 (1.32–3.32) |
| First hospital admission within first year after transplantation | 0.81 (0.52–1.25) | 0.75 (0.48–1.17) | 0.74 (0.48–1.14) |

CI = confidence interval; HR = hazard ratio.

**Table 5. Cumulative mean and median hospital costs incurred by patients with or without surgical site complications within 30 days of transplantation, 6 and 12 months after transplantation**

| | Cumulative mean cost per patient, $ | | | Cumulative median cost per patient, $ | | |
|---|---|---|---|---|---|---|
| Time period | No surgical site complication | Surgical site complication | Difference | No surgical site complication | Surgical site complication | Difference |
| Within 6 mo after transplantation | 8128.84 | 9669.32 | 1540.48 | 3460.50 | 5259.43 | 1798.93 |
| Within 12 mo after transplantation | 11 770.16 | 12 462.67 | 692.51 | 4879.27 | 7557.25 | 2677.98 |

and gram-positive bacteria found in SSIs was *P. aeruginosa* and coagulase-negative *Staphylococcus*, respectively.

Recipient BMI has also been identified as a risk factor for SSC development in other studies.[1,10,24] Although patients with higher BMI have similar survival benefits of transplantation as patients with lower BMI,[25] specific wound-management strategies such as additional layers of subcutaneous sutures during wound closure and closed-incision negative-pressure wound management may need to be considered in this group of patients to reduce the occurrence of SSCs, which are associated with substantial morbidity.[26,27]

Prolonged cold ischemia time has been previously identified as a risk factor for incisional infections after kidney transplantation.[1,28] Since cold ischemic time is also associated with other adverse events following kidney transplantation, such as delayed graft function,[29] this observation provides further rationale to minimize cold ischemic time whenever possible.

Importantly, SSCs were associated with an increased risk of death-censored graft failure and total graft failure; death-censored graft failure is likely to be the driving effect. Although it is possible to speculate on patient, graft and postoperative factors that likely contribute to this relation, further research is necessary to determine the specific mechanism behind this effect. Nevertheless, this finding provides a strong rationale to minimize SSCs in this group of surgical patients.

In addition to adverse clinical implications for patients, SSCs have an impact on hospital-related costs. This is likely related to the longer hospital stays required by patients with SSCs, more frequent outpatient visits, and additional costs associated with wound management and antimicrobial therapy. As our study focused on hospital-related inpatient and outpatient costs only, the total cost of SSCs is likely much higher than what we report here, since patients with SSCs often require prolonged therapy after discharge, including specialized wound monitoring and dressing care, antimicrobial therapy and community nursing visits.

### *Limitations*

Our study relied on the recording of complications in clinical notes and charts by health care providers, and there is inherent variation between practitioners. To mitigate the variation, we established strict definitions of cases a priori, and the few ambiguous cases were adjudicated by experts in the field. Only a small number of SSCs were found, which may have been due to variation in sensitivity of reporting. This may have resulted in underrepresentation of SSC cases, but multiple data sources were used throughout collection to address this possibility. Furthermore, although this study was conducted at a single centre and the findings may lack generalizability, our centre is the largest kidney transplantation program in Canada, with a very diverse patient population, including different racial and socioeconomic groups.

## Conclusion

This study shows the relevance of SSCs to both short- and intermediate-term outcomes of kidney transplant recipients. Increased BMI, longer cold ischemic time and the 2010–2012 transplantation period predisposed to SSC development, and SSCs were associated with a higher risk of graft failure. The identification of risk factors for SSCs presents opportunities for quality-improvement initiatives to decrease the occurrence of these complications in those at increased risk. Strategies to minimize the development of SSCs may improve outcomes of kidney transplant recipient and reduce costs.

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