Title

Early Hospital Readmission After Simultaneous Pancreas-Kidney Transplantation: Patient and Center-Level Factors.

Journal

American Journal of Transplantation, 16(2)

Authors

King, E

Kucirka, L

McAdams-DeMarco, M

et al.

Publication Date

2016-02-01

DOI

10.1111/ajt.13485

Peer reviewed

HHS Public Access

Author manuscript

Am J Transplant. Author manuscript; available in PMC 2018 August 30.

Published in final edited form as:

Am J Transplant. 2016 February ; 16(2): 541–549. doi:10.1111/ajt.13485.

Early Hospital Readmission After Simultaneous Pancreas-Kidney Transplantation: Patient and Center-Level Factors

Elizabeth A. King, MD[1], **Lauren M. Kucirka, ScM**[1,2], **Mara A. McAdams-DeMarco, PhD**[1,2], **Allan B. Massie, PhD**[1,2], **Fawaz Al Ammary, MD**[3], **Rizwan Ahmed, MD**[1], **Morgan E. Grams, MD**[3], and **Dorry L. Segev, MD PhD**[1,2]

[1]Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD

[2]Department of Epidemiology, Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD

[3]Department of Nephrology, Johns Hopkins University School of Medicine, Baltimore, MD

Abstract

Early hospital readmission is associated with increased morbidity, mortality, and cost. Following simultaneous pancreas-kidney transplantation, rates of readmission and risk factors for readmission are unknown. We used United States Renal Data System and Scientific Registry of Transplant Recipients data to study 3,643 adult Medicare primary first-time simultaneous pancreas-kidney recipients from December 1, 1999 – October 31, 2011. Early hospital readmission was any hospitalization within 30 days of discharge. Modified Poisson regression was used to determine the association between readmission and patient-level factors. Empirical Bayes statistics were used to determine the variation attributable to center-level factors. The incidence of readmission was 55.5%. Each decade increase in age was associated with an 11% lower risk of readmission to age 40, beyond which there was no association. Donor African-American race was associated with a 13% higher risk of readmission. Each day increase in length of stay was associated with a 2% higher risk of readmission until 14 days, beyond which each day increase was associated with a 1% reduction in the risk of readmission. Center-level factors were not associated with readmission. The high incidence of early hospital readmission following simultaneous pancreas-kidney transplant may reflect clinical complexity rather than poor quality of care.

INTRODUCTION

Hospital readmission is associated with increased morbidity, mortality and cost among patients in the United States. Approximately 20% of all Medicare patients are readmitted to the hospital within 30 days of hospital discharge. Readmission results in potentially

Corresponding Author: Dorry Segev, MD, PhD, Johns Hopkins Medical Institutions, 720 Rutland Ave, Turner 034, Baltimore, MD 21205, 410-502-6115 (tel) 410-614-7640 (fax) dorry@jhmi.edu, Requests for reprints should be sent to the corresponding author.

An abstract describing a portion of this work was presented at the American Society of Transplant Surgeons Winter Symposium, January 2015, Miami, Fl.

DISCLOSURE

The authors of this manuscript have no conflicts of interest to disclose as described by the American Journal of Transplantation.

avoidable costs as high as $12 billion annually (1). Since passage of the Affordable Care Act, rates of readmission are increasingly used as a measure of hospital quality (2). In 2009 the Centers for Medicare and Medicaid (CMS) began publicly reporting hospital readmission rates for pneumonia, heart attack, and heart failure, and in fiscal year 2013 they began the Hospital Readmission Reduction Program (HRPR), which financially penalizes hospitals with excess Medicare readmissions. In the first year alone, the HRPR resulted in penalties totaling $280 million. The clinical and financial impact has led to significant effort toward preventing early hospital readmissions (EHR) (3).

General surgical readmissions have been well characterized. EHR in surgical patients has been associated with length of stay, comorbidities, and surgical complications. Rates of EHR following general surgery are as high as 22%, varying by center and procedure (4–12). However, the frequency and patterns of readmission among transplant patients might differ greatly from those of general surgical patients because of the increased complexity of immunosuppression regimens, rejection, infection, and other transplant-specific complications. Based on national data, we recently demonstrated that 31% of kidney transplant recipients are readmitted within 30 days of discharge. We also identified a number of factors associated with EHR after kidney transplantation, including older age, African American race, various comorbidities (obesity, hypertension, diabetes, heart disease, chronic obstructive pulmonary disease, hepatitis C positive, and time on dialysis), expanded criteria donor, length of stay, lack of induction therapy, and frailty, a novel measure of physiologic reserve (13, 14).

Unlike our understanding of EHR among patients following kidney transplantation, little is known about EHR following simultaneous pancreas-kidney transplantation (SPK). SPK is an important treatment option for patients with diabetes and end stage renal disease, however it is substantially more complex than kidney transplantation alone (KTA). Technical failure rates following pancreas transplant are as high as 8%. Reasons for failure include graft thrombosis, graft pancreatitis, anastomotic leak, and infection (15–16). SPK recipients require increased immunosuppression and are at risk for developing metabolic derangement and hyperglycemia as their pancreas allograft begins to function (17–22). Existing long-term sequelae of diabetes, like gastroparesis, neurogenic bladder, and autonomic neuropathy, can compound complications post-transplant (23–25). Given the high risk of perioperative complications, SPK recipients, on average, remain in the hospital longer than their KTA counterparts and have a higher risk of perioperative mortality (16, 17, 24–26). We hypothesize that the high-risk perioperative period following SPK is associated with increased EHR. However, the national landscape of EHR following SPK has not been described and risk factors for EHR are largely unknown. Two single center studies, of 98 and 93 SPK recipients, both demonstrate a readmission rate of approximately 74% within the first three months after transplant (26, 28). Although, these studies begin to quantify the burden of EHR following SPK they do not identify which patients are at risk for EHR. In addition, these studies are limited by a small sample size and poor generalizability of single center data. To better understand EHR in SPK, we used United States Renal Data System (USRDS) and Scientific Registry of Transplant Recipients (SRTR) data to capture readmissions among Medicare beneficiaries undergoing SPK. The objectives of this study

were to identify factors associated with EHR after SPK and to explore center-level heterogeneity in EHR across the United States.

MATERIALS AND METHODS

Study Population and EHR Ascertainment

The study population included 3,643 adult first-time SPK recipients from December 1, 1999 through October 31, 2011 who had Medicare Part A and B as their primary insurance for at least 60 days before and 60 days following the date of transplant. As specified in our previously published model of EHR following KTA, EHR was defined as at least one hospital readmission to any acute care hospital within 30 days of discharge after initial SPK hospitalization (13). Time to readmission is defined as the number of days from the date of SPK hospitalization discharge to the date of admission for the readmission hospitalization. SPK recipients that died prior to discharge were excluded (n= 101). SPK recipients that died within the first 30 days after SPK were excluded (n=72), unless EHR occurred prior to death (n=14). Donor, recipient, and transplant factors were obtained from the Scientific Registry of Transplant Recipients (SRTR). The reason for EHR was ascertained by diagnosis related group (DRG) code from USRDS claims data. Mortality information was augmented by linkage to the Social Security Death Master File and to CMS data. This study was reviewed by the institutional review board at Johns Hopkins School of Medicine and determined to qualify for an exemption under 45 CFR 46.101(b) as study participants cannot be identified directly or through linked identifiers.

Potential Factors Associated with EHR

The following recipient, donor, and transplant factors were explored for potential association with EHR: age, sex, race, BMI, history of comorbidity (hypertension, cancer, hepatitis C positive, chronic obstructive pulmonary disease, type 1 diabetes, current smoker, congestive heart failure, peripheral vascular disease, cerebrovascular disease, and dialysis vintage), donor age, donor gender, donor race, donor height, donor BMI, donor type (standard criteria, extended criteria, donor after cardiac death), donor cause of death, cold ischemia time, terminal creatinine, human leukocyte antigen (HLA) mismatch, use of induction therapy, delayed graft function, method of exocrine drainage, length of stay for SPK admission, and year of transplant. These factors were chosen based on our previously published model of EHR following KTA, the SRTR risk models for SPK, and empirical exploration (13, 29).

Center-level Factors Associated with EHR

The following center-level factors were explored for potential association with EHR: total SPK volume, average length of stay, percent of SPK recipients who were African American, median time to transplant, and percent preemptive transplants. Each center-level factor was calculated from SRTR data. We also explored the association between readmission following SPK and readmission following KTA by determining the observed to expected readmission ratio using empirical Bayes estimation and correlating at the center-level.

Statistical Analysis

We estimated the relative risk of EHR by patient-level factors using modified Poisson regression (30). The functional form for each continuous variable was informed by previous studies and ultimately determined empirically. The final multivariate model was selected for parsimony by minimizing the Akaike Information Criteria (AIC). Center-level heterogeneity and associated factors were explored using a random intercept, hierarchical (multilevel) model adjusted for important patient-level factors as determined above. All analyses were performed using STATA 13.0/MP for Linux (College Station, TX, USA).

RESULTS

EHR Incidence

Of the 3,643 SPK recipients studied, 2,021 (55.5%) experienced at least one readmission within 30 days of discharge after initial SPK hospitalization (Table 1). Mean and median time to EHR was 8.8 (SD 7.4) and 7 (IQR 3–13) days (Figure 1). Mean and median length of stay for the EHR hospitalization was 7.3 (SD 9.7) and 4 (IQR 2–9) days.

Reason for EHR

Overall, the five most frequent primary reasons for EHR were infection (23.1%), kidney/ urinary tract disorders (16.2%), alimentary tract disorders (15.6%), pancreatic/ hepatobiliary disorders (11.1), and electrolyte/ nutritional disorders (10.3) (Table 2). Of all readmissions, 82.6% required medical management, 16.4% required surgical or procedural management, and management was unknown for 1%. The median length of the readmission varied by management type. The median length of stay was longer for readmissions requiring surgical or procedural management (11 days, IQR 6–18) compared to medical management (4 days, IQR 2–7).

Among patients with a readmission length of stay of 48 hours or less, or a short-stay readmission, the top five most frequent reasons for EHR were alimentary tract disorders (19.4%), electrolyte/ nutritional disorders (19.4%), infection (16.4%), kidney/ urinary tract disorders (15.8%), and pancreatic/ hepatobiliary disorders (6.5%). Among short-stay readmissions, 96.9% required medical management, 2.1% required surgical or procedural management, and management was unknown for 1%.

Recipient Factors Associated with EHR

Recipient age was associated with EHR (Table 3). For every decade increase in age there was a 11% lower risk of EHR for recipients up to age 40 (aRR 0.89 per decade, 95% CI: 0.82–0.97, p=0.005). For example, a 40-year-old recipient would have a 21% lower risk of EHR than an 18-year-old recipient (aRR 0.77, 95% CI: 0.64–0.92, p=0.005). For recipients over age 40 there was no association between age and EHR (aRR 1.05 per decade, 95% CI: 0.97–1.15, p=0.2). There was no evidence of a statistically significant association between EHR and African American recipient race, BMI, or history of peripheral vascular disease (Table 3). In preliminary models, there was no evidence of a statically significant association between EHR and recipient history of hypertension, cancer, hepatitis C, chronic obstructive pulmonary disease, type 1 diabetes, current smoker, congestive heart failure, cerebrovascular

disease, dialysis vintage, or delayed graft function. These factors were excluded from the final model.

Donor Factors Associated with EHR

African American donor race and donor BMI were associated with EHR (Table 3). African American donor race was associated with a 13% higher risk of EHR (aRR 1.13, 95% CI: 1.04–1.23, p=0.005). Overweight SPK recipients had a 12% higher risk of EHR compared to normal weight SPK recipients (aRR 1.12, 95% CI: 1.04–1.22, p=0.004). There was no evidence of a statistically significant association between EHR and an underweight BMI or obesity (Table 3). In preliminary models, there was no evidence of a statistically significant association between EHR and donor age, donor gender, donor height, donor cause of death, extended criteria donor, donation after cardiac death, or terminal creatinine >2.5mg/dL. These factors were excluded from the final model.

Transplant Factors Associated with EHR

The only transplant factor associated with EHR was length of stay for the initial SPK hospitalization (Table 3). Across the study population, length of stay ranged from 2 to 435 days; however, 93% of recipients had a length of stay between 5 and 30 days. Each increasing day of hospitalization was associated with a 2% increase risk of EHR up until 14 days (aRR 1.02 per day, 95% CI: 1.01–1.04, p<0.001), such that a length of stay of 14 days was associated with a 24% higher risk of EHR compared to a length of stay of 5 days (aRR 1.24, 95% CI: 1.13–1.37, p<0.001). After 14 days, each increasing day of hospitalization was associated with a 1% *decreased* risk of EHR (aRR 0.99 per day, 95% CI: 0.98–0.99, p<0.001), such that a length of stay of 30 days was associated with a 14% *lower* risk of EHR compared to a length of stay of 14 days (aRR 0.86, 95%CI: 0.80–0.92, p<0.001), and no difference in risk of EHR compared to a length of stay of 5 days (aRR 1.07, 95% CI: 0.98–1.17, p=0.2). There was no evidence of a statically significant association between EHR and use of induction therapy (Table 3). In preliminary models, there was no evidence of a statistically significant association between EHR and cold ischemia time, HLA mismatch, method of exocrine drainage, or year of transplant. These factors were excluded from the final model.

Center-level Heterogeneity

The unadjusted rate of EHR by center ranged from 0% to 100%. After adjusting for patient-level factors (as delineated above), the ratio of observed to expected EHR varied by center from 0 to 1.88 (mean 1.00, SD 0.26, median 1.00, IQR 0.87–1.13) (Figure 1). No center-level factors (total SPK volume, average length of stay, percent of African American SPK recipients, median time to transplant, or percent preemptive transplants) were associated with EHR after adjustment for patient-level factors (Table 4). Including transplant center in a multilevel model improved the fit and a likelihood ratio test yielded a p-value < 0.001. However, the interclass correlation coefficient was 0.014 (SD 0.006), meaning only 1.4% of the variation was at the center-level. After adjustment for patient-level risk factors, only one center had a statistically significantly different incidence of EHR than the national average (Figure 2). Almost no correlation was found between the observed to expected ratio of readmission for SPK and KTA within transplant centers (correlation coefficient 0.1).

DISCUSSION

In this national database study of readmission after SPK, 55.5% of first-time Medicare-primary adult SPK recipients were readmitted within 30 days of discharge following transplantation. The most common reason for readmission was infection. Only 16.4% of EHR was managed by surgical or procedural interventions. We identified several patient-level risk factors associated with EHR. Readmission was more likely to occur if recipients were younger, donor race was African American, or the donor was overweight. Length of stay following transplantation was associated with an increased risk of readmission to a threshold of 14 days, after which point the increased length of stay was protective against EHR. Center-level factors were not associated with EHR. In fact, center-level characteristics had almost no effect on the variation in EHR and the incidence of EHR was nearly constant across transplant centers.

Our findings provide a point of comparison between post-SPK and post-KTA readmissions. Overall, readmission is more prevalent following SPK (single center studies). In our previous study of 32,961 Medicare primary adult first-time KTA recipients, the incidence of EHR was 31% (13). The higher incidence of EHR following SPK is likely given that SPK is a longer, more technically challenging operation than KTA. In addition, SPK recipients are at high risk for rejection, infection, dehydration, and metabolic derangements (15–16, 18–19, 24, 26–28). Perioperative complications following SPK may necessitate readmission.

In our study, the most common reason for EHR was infection, accounting for 23.1% of readmissions. In our previous study of KTA, the most common reason for EHR was kidney/ urinary tract disorders, accounting for 36% of readmissions, while infection only accounted for 12% of all post-KTA readmissions (13). It is not surprising that a higher proportion of readmissions following SPK are due to infection. Diabetic patients are at a higher risk for serious post-operative infections, regardless of the operation. For immunosuppressed, diabetic patients, it may be safer and ultimately beneficial to treat infections in the hospital, under direct monitoring. Collectively, kidney/ urinary tract disorders and pancreatic/ hepatobiliary disorders accounted for an additional 27.3% of post-SPK EHR. These readmissions are assumed to be secondary to complications with the respective allograft. Readmission in this setting may mitigate the development of more serious and costly complications later in the post-transplant course. In our study, 16.4% of all readmissions were managed by surgical or procedural interventions. Although this is a relatively small proportion of total EHR, these readmissions may represent further examples of necessary and beneficial hospitalizations.

Among all readmissions, 26% were short-stays, meaning the readmission hospitalization lasted 48 hours or less. For short-stay readmissions, there is no point of comparison in the KTA literature. We would expect that short-stay readmissions be of lower acuity than prolonged readmissions. In our study, the most common reason for short-stay EHR was alimentary tract disorder or electrolyte/ nutritional disorder, each accounting for 19.6% of readmissions. As classified by DRG code, alimentary tract disorder may mean a trivial condition such as nausea or a more serious complication like gastrointestinal bleeding. Likewise, electrolyte disorder can range from minor hyperkalemia requiring intravenous

hydration to diabetic ketoacidosis causing coma. The severity of illness may not be evident at the time of initial evaluation. In clinical practice, recipients presenting with these symptoms may benefit from an intermediate level of observation before the decision is made to readmit. Intermediate monitoring may help tease out which recipients will improve with minimal intervention and which require further hospitalization.

Following SPK, each decade increase in recipient age, to a threshold of 40 years, was associated with an 11% lower risk of readmission. This is in contrast to our published findings in KTA. Following KTA, for recipients under age 40, each decade increase in age was associated with a 6% higher risk of readmission. One potential explanation for this discrepancy is that young diabetic patients may be less compliant with post-transplant care, as well as general management of their diabetes. Adherence to medication regimens and maintenance of glycemic control is particularly poor among adolescents and young adults with type 1 diabetes (31–36). Poor post-transplant compliance among young SPK recipients could contribute to a higher need for readmission.

Our study demonstrates that African American donor race is associated with an increased risk of readmission. This finding is consistent with inclusion of African American donor race in the pancreas donor risk index (PDRI). In creation of the PDRI, Axelrod et al. demonstrated that African American donor race is associated with a 27% increased risk of graft failure (37). Our study also demonstrates that *recipient* race is not associated with readmission. This finding is in contrast to the association between African American *recipient* race and inferior graft survival (38, 39).

Each day increase in length of stay was associated with a 2% higher risk of readmission until 14 days, beyond which each day increase was associated with a 1% reduction in the risk of readmission. The mechanism of this association is difficult to ascertain and likely complex. Prolonged length of stay can be due to medical complications, for example, delayed graft function, surgical site infection, or graft pancreatitis. Prolonged length of stay can also be secondary to non-medical factors, for example, poor understanding of new medication regimens, increased distance from the hospital, lack of family support at home, or even day of the week. In our study, a short length of stay was likely associated with a low risk of readmission because recipients discharged early tend to be low-risk themselves. These recipients are less likely to require readmission. On the other end of the spectrum, recipients with extremely prolonged hospitalization may not require readmission because their care has been optimized prior to discharge.

Certain factors associated with post-KTA EHR were not associated with post-SPK EHR. Donor type (deceased, living, ECD, DCD) is associated with EHR following KTA. All SPK transplants are performed using deceased donor organs and only a very small percentage of donors are classified as ECD or DCD (0.3% and 2.3%, respectively), making this factor less likely to contribute to organ quality and subsequent readmission. At the center-level, there was no correlation between readmission for SPK and readmission for KTA, suggesting that mechanistically these two types of readmissions are unique and independent of center-level practices.

Our study has several notable limitations. To ascertain EHR we had to limit our study population to SPK recipients with Medicare as their primary insurance. Inclusion of only Medicare primary patients could differentially affect younger and older recipients and limit generalizability. However, since all individuals with end stage renal disease requiring dialysis are eligible for Medicare, we believe this will minimally affect our results. In fact, the median and interquartile range for age of SPK recipients in our study and among all SPK recipients captured by SRTR was identical (median 40, IQR 34–46). Factors explored in our analysis were limited to those currently collected through the Scientific Registry of Transplant Recipients. As such, we were unable to ascertain certain factors that may be important to post SPK outcomes, for example mode of dialysis, blood transfusions, and post surgical complications. Furthermore, in using national registry data we are unable to ascertain more granular factors, like socioeconomic status, which may confound some of our findings. Due to the relatively low national volume of SPK compared to KTA, we may be underpowered to detect an association between center-level factors and EHR.

In conclusion, readmission of SPK recipients occurs with high frequency and though there is variation in the rate of EHR by transplant center, almost all of that variation is explained by differences in patient characteristics rather than differences in center-level practice. Younger SPK recipients are at higher risk for readmission and may benefit from better transitions of care and more frequent outpatient monitoring. The most common reasons for readmission were infection, kidney/ urinary tract disorder, and pancreatic/ hepatobiliary disorder. Readmission to treat infection or allograft complications may ultimately prevent the development of more serious post-transplant complications. Given the technical complexity of SPK and the high risk of diabetic complications among recipients, readmission may reflect clinical necessity rather than poor quality of care.

Acknowledgments

This work was supported in part by two grants from the National Institute of Diabetes Digestive and Kidney Diseases (K24DK101828 and F30DK095545) and a grant from the National Institute on Aging (F32AG044994). The data reported here have been supplied by the United States Renal Data System and the Minneapolis Medical Research Foundation (MMRF) as the contractor for the Scientific Registry of Transplant Recipients (SRTR). The interpretation and reporting of these data are the responsibility of the author(s) and in no way should be seen as an official policy of or interpretation by the SRTR or the U.S. Government.

ABBREVIATIONS

EHR	Early Hospital Readmission
CMS	Centers for Medicare and Medicaid
HRPR	Hospital Readmission Reduction Program
SPK	Simultaneous Pancreas-Kidney Transplantation
KTA	Kidney Transplantation Alone
SRTR	Scientific Registry for Transplant Recipients
USRDS	United States Renal Data System

HLA Human Leukocyte Antigen

PDRI Pancreas Donor Risk Index

References

1. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare Fee-for-Service Program. N Engl J Med. 2009; 360:1418–1428. [PubMed: 19339721]
2. Axon RN, Williams MV. Hospital Readmission as an Accountability Measure. JAMA. 2011; 305(5): 504–505. [PubMed: 21285430]
3. James J, Hall K, Joynt KE, et al. Health Policy Brief: Medicare Hospital Readmissions Reduction Program. Health Aff. 2013; 30(5)
4. Hannan EL, Zhong Y, Lahey SJ, et al. 30-day readmissions after coronary artery bypass graft surgery in New York state. JACC Cardiovasc Interv. 2011; 4:569–576. [PubMed: 21596331]
5. Goodney PP, Stukel TA, Lucas FL, et al. Hospital volume, length of stay, and readmission rates in high-risk surgery. Ann Surg. 2003; 238:161–167. [PubMed: 12894006]
6. Morris DS, Rohrbach J, Rogers M, et al. The surgical revolving door: Risk factors for hospital readmission. J Surg Res. 2011; 170:297–301. [PubMed: 21696766]
7. Emick DM, Riall TS, Cameron JL, et al. Hospital readmission after pancreaticoduodenectomy. J Gastrointest Surg. 2006; 10:1243–1252. [PubMed: 17114011]
8. Kiran RP, Delaney CP, Senagore AJ, et al. Outcomes and prediction of hospital readmission after intestinal surgery. J Am Coll Surg. 2004; 198:877–883. [PubMed: 15194068]
9. Kariv Y, Wang W, Senagore AJ, et al. Multivariable analysis of factors associated with hospital readmission after intestinal surgery. Am J Surg. 2006; 191:364–371. [PubMed: 16490548]
10. Gioia LC, Filion KB, Haider S, et al. Hospital readmissions following abdominal aortic aneurysm repair. Ann Vasc Surg. 2005; 19:35–41. [PubMed: 15714365]
11. Varela G, Aranda JL, Jimenez MF, et al. Emergency hospital readmission after major lung resection: Prevalence and related variables. Eur J Cardiothorac Surg. 2004; 26:494–497. [PubMed: 15302041]
12. Handy JR Jr, Child AI, Grunkemeier GL, et al. Hospital readmission after pulmonary resection: prevalence, patterns, and predisposing characteristics. Ann Thorac Surg. 2001; 72:1855–1860. [PubMed: 11789760]
13. McAdams-Demarco MA, Grams ME, Hall EC, et al. Early hospital readmission after kidney transplantation: Patient and center-level associations. Am J Transplant. 2012; 12:3283–3288. [PubMed: 23016838]
14. McAdams-DeMarco MA, Law A, Salter ML, et al. Frailty and early hospital readmission after kidney transplantation. Am J Transplant. 2013; 13:2091–2095. [PubMed: 23731461]
15. Wakil K, Sugawara Y, Kokudo N, et al. Causes of graft failure in simultaneous pancreas-kidney transplantation by various time periods. Clin Transpl. 2013:23–30. [PubMed: 25095489]
16. Sallinger HW, Odorico JS, Becker YT, et al. One Thousand Simultaneous Pancreas-Kidney Transplants at a Single Center With 22-Year Follow-Up. Ann Surg. 2009; 250(4):618–30. [PubMed: 19730242]
17. Monroy-Cuadros M, Salazar A, Yilmaz S, et al. Bladder versus enteric drainage in simultaneous pancreas-kidney transplantation. Nephrol Dial Transplant. 2006; 21:483. [PubMed: 16286430]
18. Robertson RP. Pancreatic and islet transplantation for diabetes- cures or curiosities? N Engl J Med. 1992; 327:1861–1868. [PubMed: 1448124]
19. Robertson RP. Islet transplantation as a treatment for diabetes – a work in progress. N Engl J Med. 2004; 350:694. [PubMed: 14960745]
20. Navarro X, Kennedy WR, Loewenson RB, et al. Influence of pancreas transplantation on cardiorespiratory reflexes, nerve conduction, and mortality in diabetes mellitus. Diabetes. 1990; 39:802–806. [PubMed: 2354747]
21. Gruessner RW, Sutherland DE, Gruessner AC. Mortality assessment for pancreas transplants. Am J Transplant. 2004; 4:2018. [PubMed: 15575904]

22. Newell KA, Woodle ES, Millis JM, et al. Pancreas transplantation with portal venous drainage and enteric exocrine drainage offers early advantages without compromising safety or allograft function. Transplant Proc. 1995; 27:3002. [PubMed: 8539812]
23. Nathan DM. Long-term complications of diabetes mellitus. N Engl J Med. 1993; 328(23):1676–1685. [PubMed: 8487827]
24. Freise CE, Narumi S, Stock PG, et al. Simultaneous pancreas-kidney transplantation: an overview of indications, complications, and outcomes. West J Med. 1999; 17(1):11–18.
25. Reddy KS, Stabelin D, Taranto S, et al. Long-term survival following simultaneous kidney-pancreas transplantation versus kidney transplantation alone in patients with type 1 diabetes mellitus and renal failure. Am J Kidney Dis. 2003; 41(2):464–70. [PubMed: 12552511]
26. Martins L, Henriques AC, Dias L, et al. Pancreas-kidney transplantation: complications and readmissions in 9-years of follow-up. Transplant Proc. 2010; 42:552–4. [PubMed: 20304190]
27. Sibley RK, Sutherland DE, Goetz F, et al. Recurrent diabetes mellitus in the pancreas iso- and allograft. A light and electron microscopic and immunohistochemical analysis of four cases. Lab Invest. 1985; 53:132. [PubMed: 3894793]
28. Stratta RJ, Taylor RJ, Sindhi R, et al. Analysis of Early Readmissions After Combined Pancreas-Kidney Transplantation. AJKD. 1996; 28(6):867–87. [PubMed: 8957039]
29. Scientific Registry of Transplant Recipients.
30. Zou G. A modified poisson regression approach to prospective studies with binary data. Am J Epidemiol. 2004; 159:702–706. [PubMed: 15033648]
31. Bryden K, Peveler R, Stein A, et al. Clinical and psychological course of diabetes from adolescence to young adulthood: a longitudinal cohort study. Diabetes Care. 2001; 24:1536–1540. [PubMed: 11522695]
32. Hood KK, Peterson CM, Rohan JM, et al. Association between adherence and glycemic control in pediatric type 1 diabetes: a meta-analysis. Pediatrics. 2009; 12:1171–1179.
33. Danne T, Mortensen HB, Hougaard P, et al. Persistent differences among centers over 3 years in glycemic control and hypoglycemia in a study of 3805 children and adolescents with type 1 diabetes from the Hvidore Study Group. Diabetes Care. 2001; 24(8):1342–1347. [PubMed: 11473067]
34. Mortensen HB, Hougaard P. Comparison of metabolic control in a cross-sectional study of 2873 children and adolescents with IDDM from 18 countries. Diabetes Care. 1997; 20(5):714–720. [PubMed: 9135932]
35. Springer D, Dziura J, Tamborlane WV, et al. Oprtimal control of type 1 diabetes mellitus in youth receving intensive treatment. J Pediatr. 2006; 149(2):227–232. [PubMed: 16887440]
36. Silverstein JH, Klingensmith G, Copeland K, et al. Care of children and adolescents with type 1 diabetes: a statement of the American Diabetes Assocaition. Diabetes Care. 2005; 28(1):186–212. [PubMed: 15616254]
37. Axelrod DA, Sung RS, Meyer KH, et al. Systematic Evaluation of Pancreas Allograft Quality, Outcomes and Geographic Variation in Utilization. Am J Transplant. 2010; 10(4):837–845. [PubMed: 20121753]
38. Luan FL, Kommareddi M, Cibrik DM, et al. Influence of recipient race on the outcome of simultaneous pancreas and kidney transplantation. Am J Transplant. 2010; 10(9):2074–81. [PubMed: 20645942]
39. Sampiaio MS, Kuo HT, Bunnapradist S. Outcomes of Simultaneous Pancreas-Kidney Transplantation in Type 2 Diabetic Recipients. Clin J Am Soc Nephrol. 2011; 6(5):1198–1206. [PubMed: 21441123]

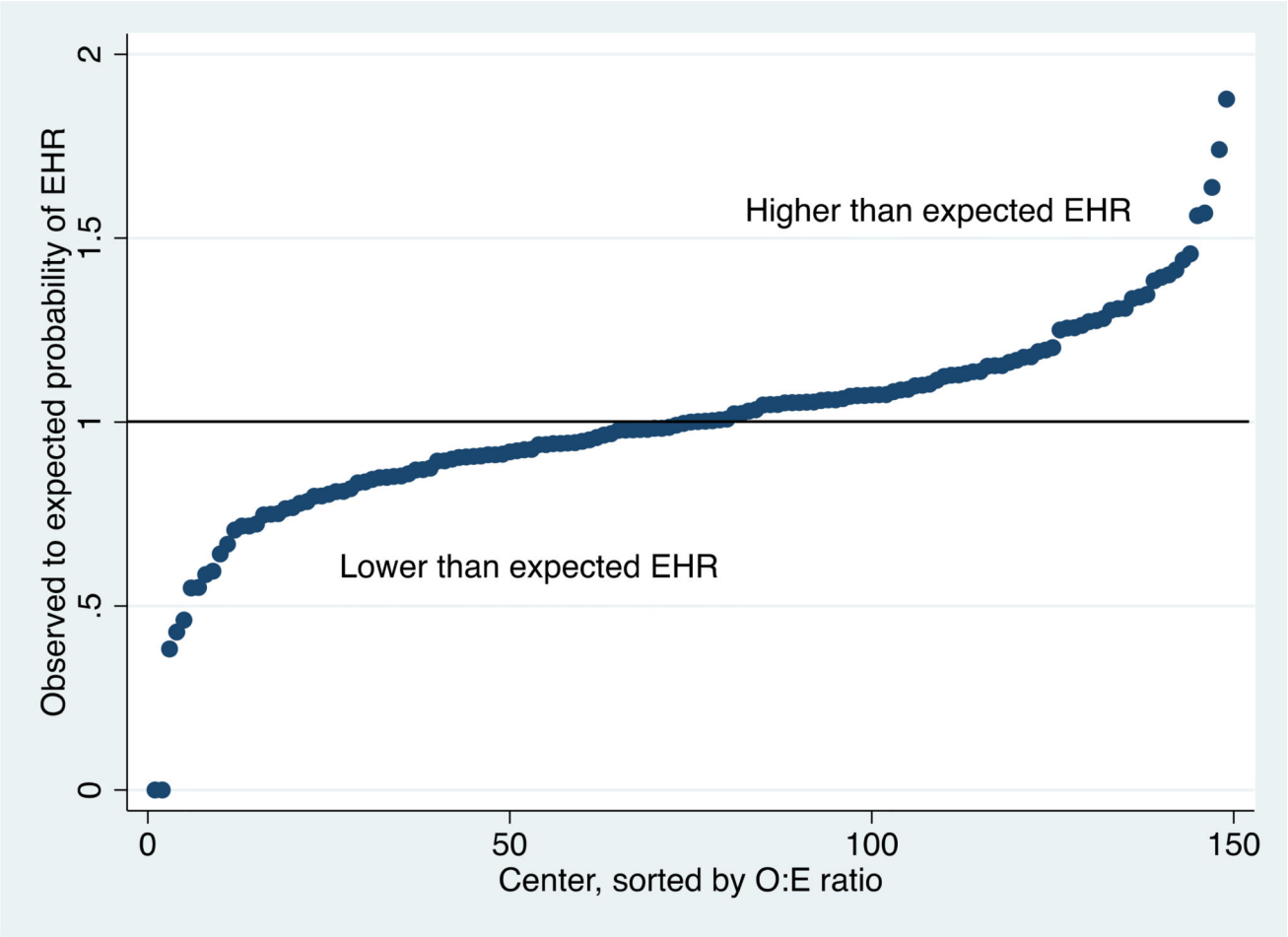

Figure 1. Ratio of observed to expected probability of early hospital readmission after simultaneous pancreas-kidney transplantation for each transplant center

The observed probability of EHR was calculated for each center. Based on each center's case mix an expected probability of EHR was derived from the final model. Each dot represents the ratio of observed to expected probability of EHR for a given transplant center. A center that readmits exactly as many patients as expected falls on the reference line. Those that admit less than expected fall below the reference line and those that admit more than expected fall above the reference line.

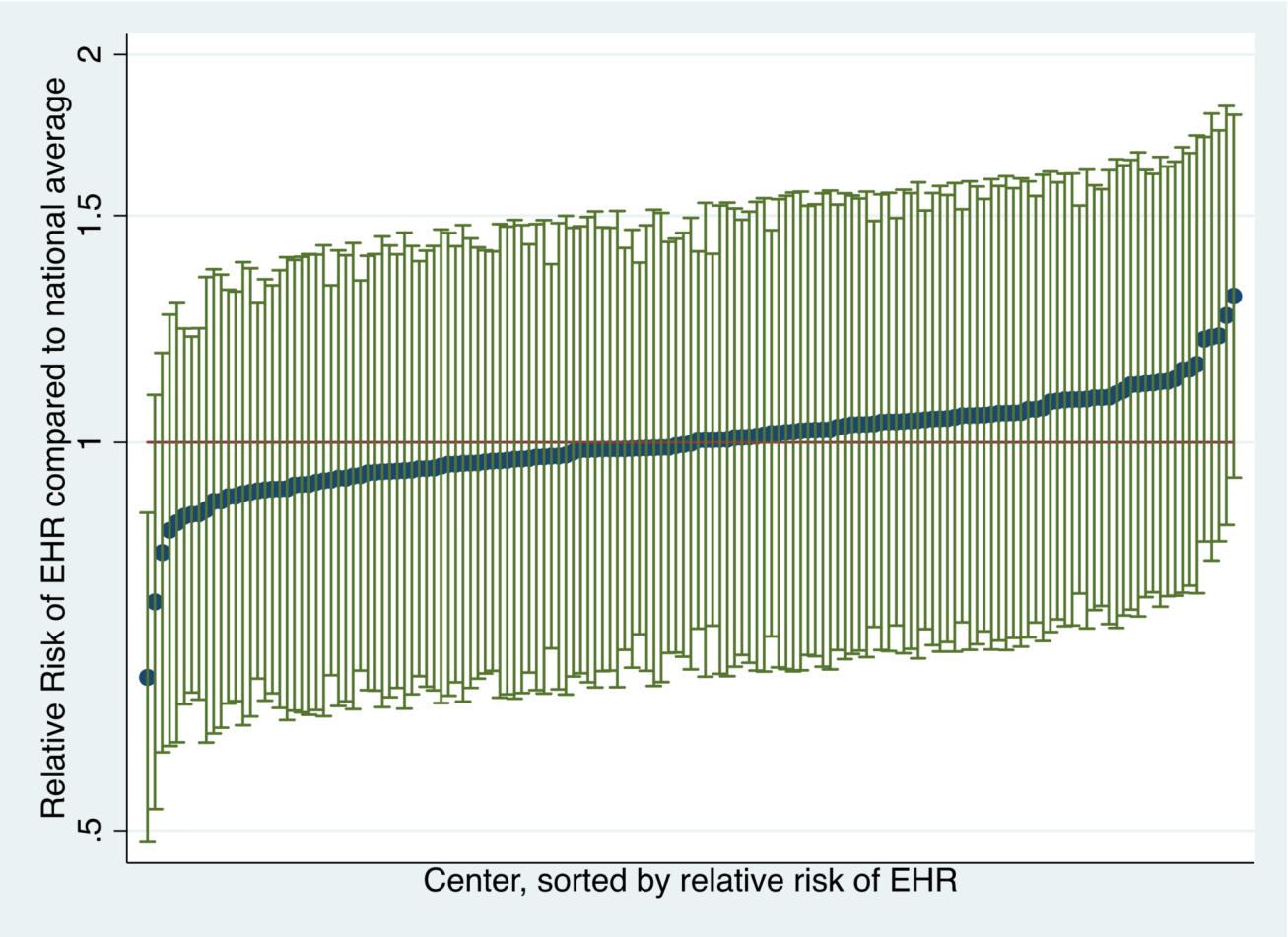

Figure 2. Relative risk of early hospital readmission after simultaneous pancreas-kidney transplantation by transplant center compared to national average

Each dot represents the relative risk of EHR for each transplant center in the United States, with 95% confidence interval. The confidence interval for all but one of the transplant centers overlaps the reference line, which represents the national average for EHR following SPK.

Table 1

Study population characteristics, by early hospital readmission.

Factors	No Early Hospital Readmissions n= 1,622	Early Hospital Readmissions n= 2,021	p-value
Mean Age, SD (years)	40.4, 8.0	39.9, 8.4	0.03
Female, %	34.7	36.6	0.2
African American race, %	18.4	22.4	0.004
Recipient BMI (kg/m_2), %			0.5
Underweight (<18.5)	2.5	3.1	
Normal (18.5–25)	54.3	55.5	
Overweight (25–30)	31.8	30.1	
Obese (>30)	11.3	11.3	
Hypertension, %	80.5	79.7	0.5
Cancer, %	0.3	0.4	0.7
Hepatitis C Positive, %	3.9	3.6	0.6
Chronic Obstructive Pulmonary Disease, %	0.9	1.2	0.3
Type 1 Diabetes, %	49.7	48.7	0.5
Current Smoker, %	5.9	6.6	0.4
Congestive Heart Failure	12.4	12.5	0.8
Cerebrovascular Disease	2.7	3.6	0.1
Peripheral Vascular Disease	9.5	10.7	0.2
Mean Dialysis Vintage, SD (years)	2.6, 1.9	2.6, 2.0	0.9
Mean Donor Age, SD (years)	25.7, 9.9	26.0, 10.1	0.5
Female Donor, %	31.3	30.8	0.7
Donor Race, %			0.001
Caucasian	67.6	64.0	
African American	13.6	18.1	
Other	18.7	17.9	
Donor BMI (kg/m_2), %			0.003
Underweight (<18.5)	9.9	7.3	
Normal (18.5–25)	48.0	45.0	
Overweight (25–30)	31.8	38.0	
Obese (>30)	10.2	9.6	

Factors	No Early Hospital Readmissions n= 1,622	Early Hospital Readmissions n= 2,021	p-value
Donor Type, %			0.8
Standard Criteria	97.4	97.4	
Extended Criteria	0.3	0.4	
Donation after cardiac death	2.4	2.2	
Donor Cause of Death, %			0.4
Anoxia	12.2	10.6	
Cerebrovascular Accident	17.8	19.0	
Head Trauma	67.1	67.7	
Other	2.9	2.7	
Terminal creatinine >2.5 mg/dL, %	0.56	1.24	0.03
Mean Length of Stay, SD (days)	14.1, 18.2	12.8, 9.9	0.02
Zero HLA Mismatch	2.3	1.8	0.3
Mean Cold Ischemia Time, SD (hours)	12.3, 6.2	12.2, 5.8	0.9
Received Induction Therapy, %	78.8	80.6	0.2
Delayed Graft Function, %	10.3	11.7	0.2
Exocrine Drainage			0.06
Enteric	87.2	84.7	
Bladder	9.1	11.5	
Unknown	3.7	3.8	

Table 2

Reason for early hospital readmission after simultaneous pancreas kidney transplantation, n=2,021.

Reason	SPK Recipients Experiencing EHR, n (%)	Required Medical Management, n (%)	Required Surgical/ Procedural Management, n (%)
Infection	466 (23.1)	389 (83.5)	77 (16.5)
Kidney/Urinary Tract Disorder	328 (16.2)	294 (89.7)	34 (10.4)
Alimentary Tract Disorder	316 (15.6)	289 (91.5)	27 (8.5)
Pancreatic/Hepatobiliary Disorder	226(11.1)	150 (66.4)	76 (33.6)
Electrolyte/Nutritional Disorder	209 (10.3)	209 (100)	0 (0)
Hematologic/Immunologic Disorder	91(4.5)	89 (97.8)	2 (2.2)
Neurologic Disorder	86 (4.3)	86 (100)	0 (0)
Unspecified Operative Procedure	59 (2.9)	0 (0)	59 (100)
Rehabilitation	47 (2.3)	47 (100)	0 (0)
Unknown Diagnosis	47 (2.3)	-	-
Cardiac	41 (2.0)	37 (90.2)	4 (9.3)
Other			
Diagnosis unrelated to SPK	34 (1.7)	12 (35.3)	22 (64.7)
Vascular Disorder	24 (1.2)	13 (54.2)	11 (45.8)
Respiratory Disorder	14 (0.7)	8 (57.1)	6 (42.9)
Wound/Skin Breakdown	12 (0.7)	5 (41.7)	10 (83.3)
Diabetes/Endocrine Disorder	8 (0.4)	7 (87.5)	1 (12.5)
Scheduled Follow-up	5 (0.3)	5 (100)	0 (0)
Musculoskeletal/Connective Tissue Disorder	4 (0.2)	4 (100)	0 (0)
Drug Complications	3 (0.2)	3 (100)	0 (0)
Psychiatric Disorder	1 (0.1)	1 (100)	0 (0)

Table 3

Relative risk of early hospital readmission after simultaneous pancreas-kidney transplantation, n=3,643.

Factors	Adjusted Relative Risk (95% CI)	p-value
Age (per decade)		
18 to 40 years	0.88 (0.82, 0.97)	0.005
Greater than 40 years	1.05 (0.97, 1.15)	0.2
Recipient African American Race	1.07 (0.98, 1.16)	0.1
Recipient BMI (kg/m_2)		
Underweight (<18.5)	1.09 (0.94, 1,28)	0.3
Normal (18.5–25)	REF	-
Overweight (25–30)	0.96 (0.87, 1.06)	0.4
Obese (>30)	0.90 (0.68, 1.19)	0.5
Peripheral Vascular Disease	1.10 (0.99, 1.23)	0.07
Donor African American Race	1.13 (1.04, 1.23)	0.005
Donor Asian Race	1.06 (0.97, 1.16)	0.2
Donor BMI (kg/m_2), %		
Underweight (<18.5)	0.91 (0.78, 1.06)	0.2
Normal (18.5–25)	REF	-
Overweight (25–30)	1.12 (1.04, 1.22)	0.004
Obese (>30)	1.04 (0.92, 1.19)	0.5
Lack of Induction	1.06 (0.98, 1.16)	0.2
Length of stay (per day)		
First 14 days	1.02 (1.01, 1.04)	<0.001
Greater than 14 days	0.99 (0.98, 0.99)	<0.001

Table 4

Relative risk of early hospital readmission after simultaneous pancreas-kidney transplantation by center-level factors, n=3,643.

Factors	Adjusted Relative Risk (95% CI)	p-value
Total volume		
1–11	REF	-
12–27	1.18 (0.85, 1.63)	0.3
29–122	0.98 (0.73, 1.33)	0.7
Average length of stay (days)		
4.8–11.1	REF	-
11.1–14.6	0.99 (0.79, 1.23)	0.9
14.7–47.7	1.04 (0.82,1.33)	0.7
Percent African American recipients		
0–7.7%	REF	-
8.1–21.4%	1.06 (0.84,1.34)	0.5
22.2–100%	1.06 (0.82, 1.36)	0.5
Median time to transplant (years)		
0.1–0.7	REF	-
0.7–1.3	1.21 (0.97, 1.49)	0.09
1.3–3.7	1.11 (0.89, 1.39)	0.3
Percent Preemptive Transplant		
0–4.5%	REF	-
4.6–13.3%	0.94 (0.75, 1.19)	0.6
13.8–66.7%	1.12 (0.88, 1.43)	0.3