ORIGINAL ARTICLE

Impact of graft implantation order on graft survival in simultaneous pancreas–kidney transplantation

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SUMMARY

The optimal order of revascularization for pancreas and kidney grafts in simultaneous pancreas–kidney transplantation has not been established. In this study, we investigate the influence of graft implantation order on graft survival in SPK. 12 700 transplantations from the Scientific Registry of Transplant Recipients were analyzed retrospectively. Graft implantation order was determined based on the reported ischemia times of pancreas and kidney grafts. Pancreas and kidney graft survivals were analyzed depending on graft implantation order at 3 months and 5 years using Kaplan–Meier plots. Significance was tested with log-rank test and Cox regression model. In 8454 transplantations, the pancreas was implanted first (PBK), and in 4246 transplantations, the kidney was implanted first (KBP). The proportion of lost pancreas grafts at 3 months was significantly lower in PBK (9.4% vs. 10.8%, $P = 0.011$). Increasing time lag (>2 h) between kidney and pancreas graft implantation in KBP accentuated the detrimental impact on pancreas graft survival (12.5% graft loss at 3 months, $P = 0.001$). Technical failure rates were reduced in PBK (5.6 vs. 6.9%, $P = 0.005$). Graft implantation order had no impact on kidney graft survival. In summary, although observed differences are small, pancreas graft implantation first increases short-term pancreas graft survival and reduces rates of technical failure.

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Key words
graft implantation order, graft survival, registry study, Simultaneous pancreas–kidney transplantation

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Introduction

The incidence of type 1 diabetes mellitus is increasing worldwide [1]. Advances in insulin therapy (new synthetic insulins, sensors, pump delivery) have markedly improved blood glucose control in these patients, with an ensuing decrease in secondary macro- and microangiopathic complications [2]. In spite of this, some patients still progress to diabetic nephropathy and end-stage kidney disease. Pancreas transplantation is currently the only therapeutic approach to type 1 diabetes able to consistently achieve euglycemia. Pancreas transplantation is mostly performed as a simultaneous pancreas–kidney transplant (SPK) procedure and is the treatment of choice for patients with end-stage diabetic nephropathy. To date, 20 715 SPKs have been reported to the Organ Procurement and Transplantation Network (OPTN) in the United States of America [3]. Transplantation of the pancreas in patients with type 1 diabetes mellitus in need of a kidney transplant improves patient survival, kidney graft function and survival, and quality of life in comparison with kidney

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transplantation alone [4–7]. Recently, Khairoun *et al.* [8] have described a reversion of systemic microvascular structural abnormalities in diabetic nephropathy patients in the first year after SPK. On the flipside, the risk of pancreas graft loss is about 10–15% during the first year after SPK [9]. Early graft loss is mainly a result of technical rather than immunological causes [10]. Both large single-center and registry studies have revealed that prolonged preservation time was a risk factor for technical graft failure [10,11].

The preferred order of revascularization during implantation of pancreas and kidney grafts in SPK is not established and is largely dictated by personal preference of the surgeon. There is little literature available on this topic. In a single-center study of 151 SPK recipients, a higher 3-month pancreas graft survival was observed when kidney was implanted first [12]. In spite of this report, we hypothesize that implantation of the kidney first would result in longer pancreas cold ischemia time, which could in turn have a detrimental impact on the occurrence of technical complications and on pancreas graft survival. Accordingly, using data from the Scientific Registry of Transplant Recipients (SRTR), we have investigated the influence of graft implantation order in SPK on short- and long-term pancreas and kidney graft survival.

Materials and methods

This study used data from the SRTR. The SRTR data system includes data on all donors, wait-listed candidates, and transplant recipients in the United States, submitted by the members of the OPTN, and has been described elsewhere. The Health Resources and Services Administration, U.S. Department of Health and Human Services, provides oversight to the activities of the OPTN and SRTR contractors.

We performed a retrospective analysis of 17 264 SPKs performed in the United States and reported to the SRTR. Transplantations were done between October 1987 and August 2011. All pancreas and kidney grafts derived from brain-dead multi-organ donors. Our analysis included 184 transplantations from donors after cardiac death. All analyzed transplantations derived each from a single donor.

Venous vascular management was realized by either systemic or portal drainage. Exocrine pancreas secretion was drained either enterically, with or without Roux-en-Y, or into the bladder.

Graft implantation order was determined using ischemia times reported for the pancreas and kidney transplantations. In the SRTR registry, kidney cold (h) and warm (min) ischemia time and total pancreas preservation time (h) were given. Kidney cold ischemia time is defined as time the kidney spent in cold preservation solution after recovery from the donor. Kidney warm ischemia time includes ischemia during organ recovery, from the time of cross-clamping until cold perfusion, and ischemia during implantation, from removal of the organ from ice until reperfusion including anastomotic time. Total pancreas preservation time includes both cold ischemia and warm ischemia time including anastomotic time. Graft implantation order was determined by subtracting total pancreas preservation time from the sum of kidney cold and warm ischemia time. A positive resulting value indicated that the pancreas was implanted before the kidney and a negative value indicated that the kidney was implanted before the pancreas. We excluded 4564 transplantations because there was no difference between ischemia times (n = 604) or because data of ischemia times were missing (n = 3960). In 1398 transplantations, data of kidney warm ischemia time were missing, but total pancreas preservation time was shorter than kidney cold ischemia time. Since this implies that the pancreas was implanted before the kidney, these were included in our analyses.

We determined graft survival depending on graft implantation order at 3 months and 5 years after transplantation using Kaplan–Meier plots. All statistical analyses were performed using IBM SPSS Statistics 20.0 (IBM Corporation, Armonk, NY, USA). Significance of difference in graft survival was tested with log-rank test and Cox regression model. Log-rank test was performed to assess differences in Kaplan–Meier estimates. Cox proportional hazard regression model was used to fit a multivariate model with graft implantation order and all confounders as independent variables and with the event considered being graft failure. A P-value <0.05 was considered significant.

Technical failure was defined as pancreas graft failure within the first 3 months after transplantation due to thrombosis, infection, bleeding, anastomotic leak, or pancreatitis.

We analyzed donor, graft, transplant, and recipient characteristics as well as causes of graft failure depending on graft implantation order. Continuous values were expressed as mean ± standard error of the mean (SEM). For comparison between two groups, Student's t-test was performed for continuous values and chi-square test was performed for categorical values. A P-value <0.05 was considered significant.

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Results

We analyzed 12 700 SPKs reported to the SRTR registry. In 8454 transplantations, the pancreas was implanted first (pancreas before kidney, PBK), and in 4246 transplantations, the kidney was implanted first (kidney before pancreas, KBP).

Mean follow-up time was slightly but significantly longer when pancreas was implanted first (6.6 ± 0.3 vs. 6.3 ± 0.1 years for PBK vs. KBP, $P < 0.001$). Kidney cold ischemia time was longer when pancreas was implanted first (14.8 ± 0.1 vs. 11.0 ± 0.1 h for PBK vs. KBP, $P < 0.001$). Kidney warm ischemia time was longer for pancreas implanted first (35.8 ± 0.3 vs. 33.1 ± 0.3 min for PBK vs. KBP, $P < 0.001$). As expected, total pancreas preservation time was shorter when pancreas was implanted first (12.2 ± 0.1 vs. 14.3 ± 0.1 h for PBK vs. KBP, $P < 0.001$). Portal venous drainage was used in 11% of PBK and in 17.4% of KBP, whereas systemic venous drainage was used in 88.9% of PBK and in 82.5% of KBP ($P < 0.001$). Enteric exocrine drainage was used in 53.4% of PBK and in 60.6% of KBP while bladder exocrine drainage was used in 44.7% of PBK and in 37.1% of KBP ($P < 0.001$).

Donor and recipient characteristics are shown in Table 1. There were small but significant differences in donor age, donor gender, recipient age, and recipient BMI between the two groups. Differences in donor cause of death were significant, as well. No significant difference was observed in donor BMI, recipient gender, and number of patients under dialysis before transplantation.

Kidney graft survival (Fig. 1) was similar at 3 months (3.5 vs. 3.5% graft loss for PBK vs. KBP, $P = 0.931$) and 5 years (13.7 vs. 12.7% graft loss for PBK vs. KBP, $P = 0.213$) after transplantation for pancreas or kidney implanted first.

Pancreas graft survival at 3 months after transplantation (Fig. 2a) was significantly higher when pancreas was implanted first (9.4 vs. 10.8% graft loss for PBK vs. KBP, $P = 0.011$). No significant difference was observed in pancreas graft survival at 5 years after transplant (18.5 vs. 19.3% graft loss for PBK vs. KBP, $P = 0.187$) (Fig. 2b).

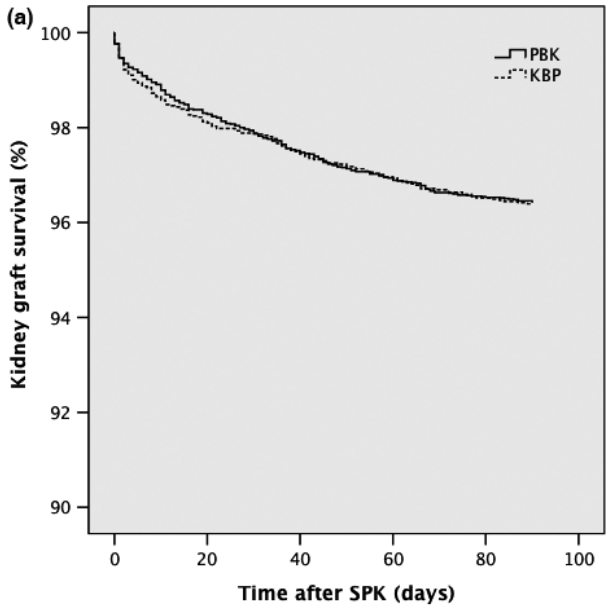
We then analyzed whether graft implantation order had the same effect on pancreas graft survival at 3 months depending on venous drainage. While there was no significant difference for portal drainage ($n = 1{,}664$; 10.3 vs. 8.2% graft loss for PBK vs. KBP, $P = 0.116$; Fig. 3a), graft survival was significantly higher when pancreas was implanted first for systemic drainage ($n = 11\,020$; 9.3 vs. 11.2% graft loss for PBK vs. KBP, $P = 0.002$; Fig. 3b).

In view of changes of practices and technical advances over the study period, pancreas graft survival at 3 months was analyzed for two distinct eras (1987–1999, 2000–2011). Graft survival was significantly higher when pancreas was implanted first from 1987 until 1999 ($n = 6301$, 10.7 vs. 12.6% graft loss for PBK vs. KBP, $P = 0.027$, Fig. 4a). No significant difference was observed in graft survival from 2000 until 2011 ($n = 6399$, 8.1 vs. 9% graft loss for PBK vs. KBP, $P = 0.202$, Fig. 4b). We therefore analyzed separately systemic and portal drainage from 2000 until 2011. Graft survival was higher when pancreas was implanted first for systemic drainage ($n = 5227$, 8

Table 1. Donor and recipient characteristics

	PBK	KBP	*P*-value
Total number (*n*)	8454	4246	
Donor age (years)	26.9 ± 0.1	26.4 ± 0.2	0.026
Donor gender (male/female, %)	5613/2841, 66/34	2896/1350, 68/32	0.041*
Donor BMI (kg/m^2)	23.8 ± 0.05	23.8 ± 0.1	0.617
Donor cause of death (anoxia/stroke/head trauma/CNS tumor/other, *n*)	745/1910/4992/64/743	364/883/2676/12/311	0.000*
Recipient age (years)	39.0 ± 0.1	39.7 ± 0.1	0.000
Recipient gender (male/female, %)	3329/5125, 39/61	1703/2543, 40/60	0.427*
Recipient BMI (kg/m^2)	24.2 ± 0.05	24.4 ± 0.1	0.004
Dialysis before transplantation (yes/no, %)	6408/1989, 76/24	3204/1021, 76/24	0.574*

Donor and recipient characteristics are shown for pancreas before kidney (PBK) and kidney before pancreas (KBP). Values represent mean ± SEM or number (*n*/*n*) and percentage (%/%). Significances were tested by Student's *t*-test or by *Pearson chi-square test. $P < 0.05$ was considered significant.



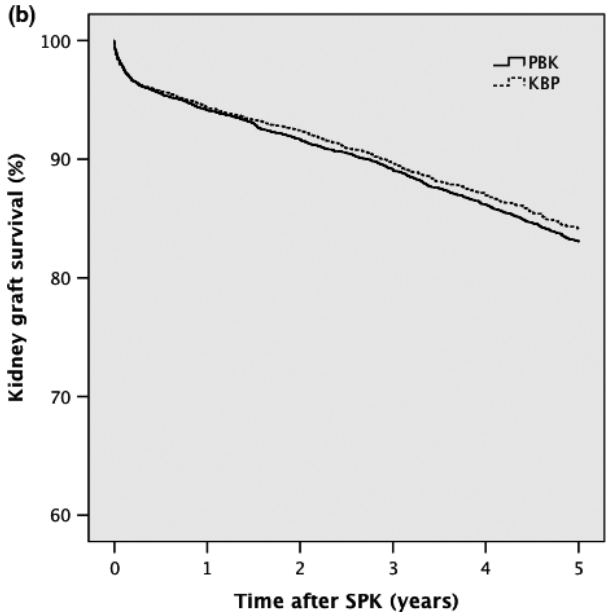
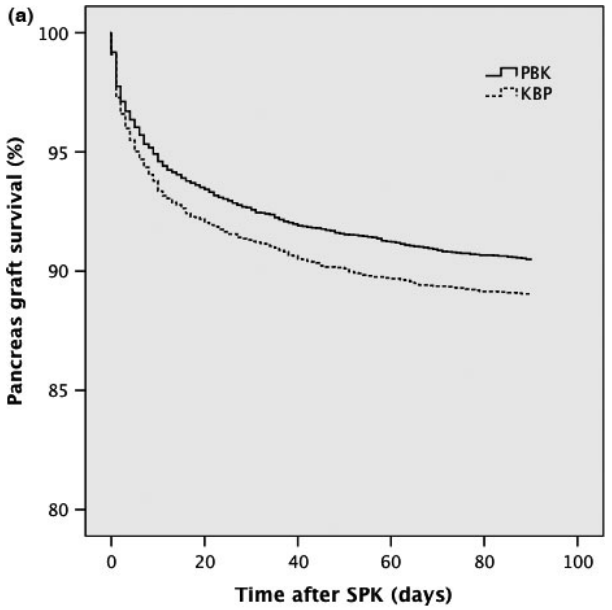


Figure 1 Kidney graft survival according to graft implantation order (PBK = pancreas before kidney, KBP = kidney before pancreas). (Panel a): Short-term graft survival at 3 months after SPK. (Panel b): Long-term graft survival at 5 years after SPK. No significant differences between the two groups are observed (3.5 vs. 3.5% graft loss, $P = 0.931$ (a); 13.7 vs. 12.7% graft loss, $P = 0.213$ (b) for PBK vs. KBP, respectively).



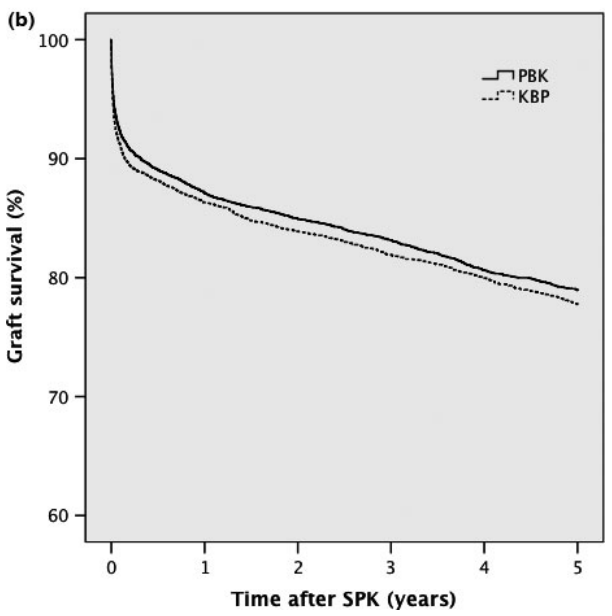


Figure 2 Pancreas graft survival according to graft implantation order (PBK = pancreas before kidney, KBP = kidney before pancreas). (Panel a): Short-term graft survival at 3 months after SPK. (Panel b): Long-term graft survival at 5 years after SPK. Significantly higher pancreas graft survival is observed at 3 months when pancreas is implanted first (9.4 vs. 10.8% graft loss for PBK vs. KBP, $P = 0.011$ (a)). No significant difference is observed at 5 years (18.5 vs. 19.3% graft loss for PBK vs. KBP, $P = 0.187$ (b)).

vs. 9.6% graft loss for PBK vs. KBP, $P = 0.046$, Fig. 4c), while there was a trend toward lower graft survival when pancreas was implanted first for portal drainage ($n = 1158$, 8.6 vs. 7.2% graft loss for PBK vs. KBP, $P = 0.346$, Fig. 4d).

We thereupon performed Cox regression analysis of pancreas graft survival at 3 months and 5 years depending on graft implantation order and confounding donor and recipient variables (donor age, donor gender, donor cause of death, recipient age, and recipient BMI), and type of venous and exocrine drainage. Results of Cox regression analysis are shown in Table 2. Cox multivariate analysis at 3 months revealed that graft implantation

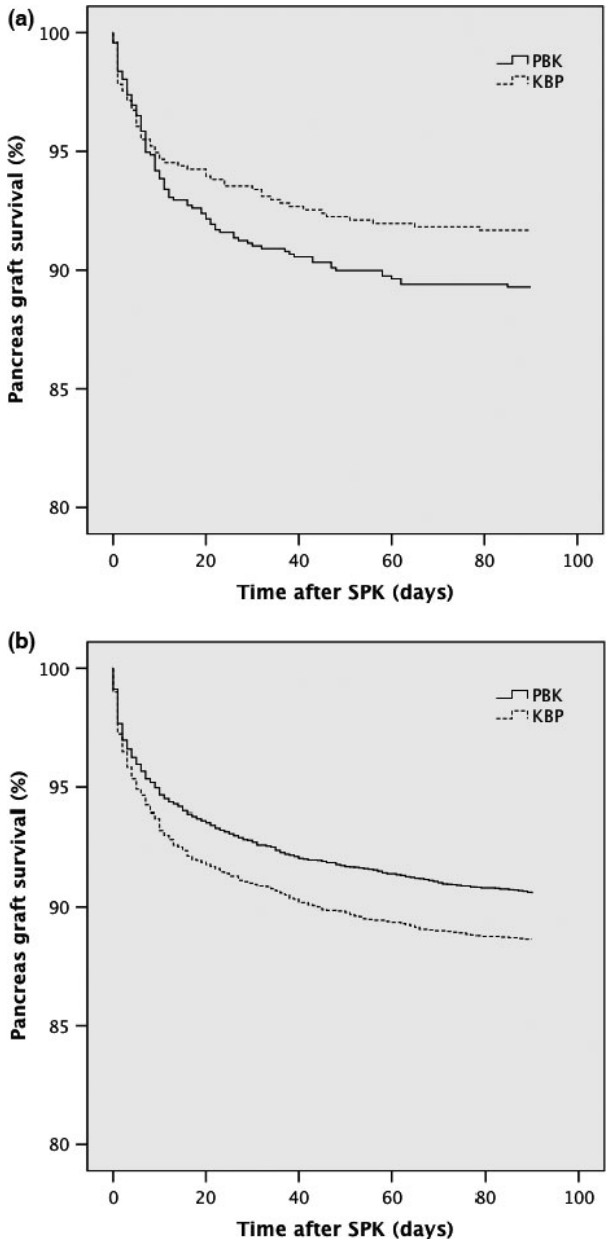


Figure 3 Short-term pancreas graft survival at 3 months according to graft implantation order (PBK = pancreas before kidney, KBP = kidney before pancreas) and subgroups of venous drainage. (Panel a): Graft survival for portal drainage. (Panel b): Graft survival for systemic drainage. No significant difference is observed for portal drainage (10.3 vs. 8.2% graft loss for PBK vs. KBP, $P = 0.116$ (a)). Significantly higher pancreas graft survival is observed when pancreas is implanted first for systemic drainage (9.3 vs. 11.2% graft loss for PBK vs. KBP, $P = 0.002$ (b)).

order, donor age, recipient age, and recipient BMI had independently significant impact on pancreas graft survival. Donor gender, donor cause of death, type of venous drainage as well as type of exocrine drainage had no significant impact on pancreas graft survival at 3 months. Cox regression analysis at 5 years revealed that graft implantation order, donor age, recipient age, recipient BMI, and type of exocrine drainage were independent risk factors for pancreas graft survival, while donor gender, donor cause of death, and type of venous drainage had no significant impact on pancreas graft survival at 5 years.

Cox regression analysis also revealed that total pancreas preservation time was highly associated with pancreas graft survival at 3 months ($P < 0.001$), independently from graft implantation order.

We then analyzed pancreas graft survival at 3 months depending on graft implantation order and increasing time lag (<1 h, 1–2 h and >2 h) between kidney and pancreas graft implantation in KBP. Increasing time between graft implantation was associated with decreased pancreas graft survival in KBP (10.2%, 9.4%, and 12.5% graft loss for <1 h, 1–2 h, and >2 h) compared to PBK (9.4% graft loss, $P = 0.001$) (Fig. 5a). This analysis was also performed at 5 years and revealed essentially similar findings, that is, decreased pancreas graft survival at 5 years in KBP (18.1%, 18%, and 21.3% graft loss for <1 h, 1–2 h, and >2 h) compared to PBK (18.5% graft loss, $P = 0.026$) (Fig. 5b).

Total numbers of pancreas graft failures were 798 for PBK and 455 for KBP, respectively (9.4 vs. 10.7%, $P = 0.006$). Graft failure for technical reasons occurred significantly less in PBK compared to KBP (5.6 vs. 6.9% of total transplant number, $P = 0.005$). Rejection rates were similar for PBK and KBP (1.0 and 1.1% of total transplant number, $P = 0.682$). Causes of technical failure are shown in Table 3. There was no difference in types of technical failure between the two groups.

Discussion

Unlike other types of solid organ transplantation, the pancreas continues to be plagued by a significant rate of technical complications [13]. Previous studies have shown the negative impact of prolonged preservation time on pancreas graft survival [10,11]. More recently, preservation time above 20 h was identified as a risk factor for technical failure in pancreas transplantation [14]. Technical complications are for the main cause of pancreas graft loss up to 3 months [10] and often require repeat laparotomy [15]. The impact of increased pancreas preservation time on short-term graft survival was unsurprisingly confirmed in this dataset.

This made us hypothesize that the order of graft implantation might have an impact on pancreas graft survival in SPK, because implanting the kidney first

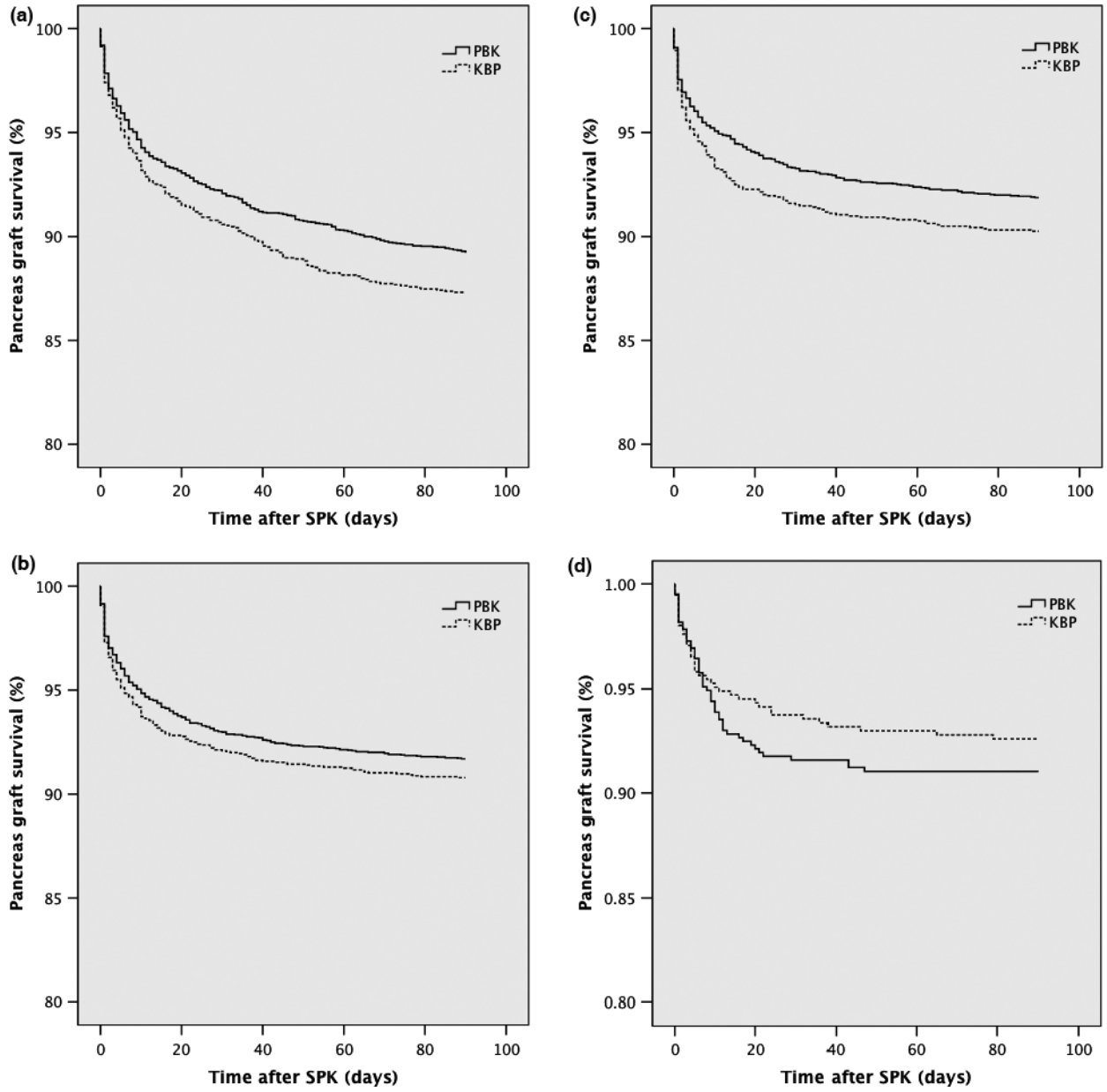


Figure 4 Short-term pancreas graft survival at 3 months according to graft implantation order (PBK = pancreas before kidney, KBP = kidney before pancreas) and 2 transplant eras (1987–1999, 2000–2011). (Panel a): Graft survival in 1987–1999. (Panel b): Graft survival in 2000–2011. (Panel c): Graft survival in 2000–2011 for systemic drainage. (Panel d): Graft survival in 2000–2011 for portal drainage. Significantly higher graft survival is observed when pancreas is implanted first in 1987–1999 (10.7 vs. 12.6% graft loss for PBK vs. KBP, $P = 0.027$ (a)). No significant difference is observed in 2000–2011 (8.1 vs. 9% graft loss for PBK vs. KBP, $P = 0.202$ (b)). Significantly higher graft survival is observed in 2000–2011 for systemic drainage (8 vs. 9.6% graft loss for PBK vs. KBP, $P = 0.046$ (c)). No significant difference is observed in 2000–2011 for portal drainage (8.6 vs. 7.2% graft loss for PBK vs. KBP, $P = 0.346$ (d)).

would imply a longer cold ischemia time for the pancreas.

Scientific Registry of Transplant Recipients data do not include reasons for selecting a particular graft implantation order. In all likelihood, this choice was dictated in most cases by nothing else than personal surgeon preference. The statistically significant differences observed between the PBK and KBP groups (Table 1) are so small that they are unlikely to be of any clinical relevance, nor to have dictated surgeon's choice of order of implantation.

We did observe a small but significant difference in short-term pancreas graft survival depending on graft implantation order. Beyond 3 months, no significant

Table 2. Cox regression analysis of pancreas graft survival.

	Pancreas graft survival – 3 months			Pancreas graft survival – 5 years		
Variable	HR*	95% CI†	*P*-value	HR*	95% CI†	*P*-value
Graft implantation order	1.146	1.015–1.295	0.028	1.095	1.003–1.196	0.044
Donor age	1.027	1.022–1.032	<0.001	1.02	1.016–1.024	<0.001
Donor gender	0.911	0.802–1.034	0.148	0.969	0.885–1.061	0.5
Donor cause of death	1	1.000–1.000	0.184	1	1.000–1.000	0.272
Recipient age	0.991	0.984–0.999	0.019	0.982	0.976–0.987	<0.001
Recipient BMI	1.041	1.028–1.054	<0.001	1.027	1.017–1.037	<0.001
Type of venous drainage	1.071	0.896–1.280	0.451	1.129	0.991–1.287	0.069
Type of exocrine drainage	1.026	0.964–1.093	0.42	1.065	1.018–1.114	0.007

*Hazard ratio (HR) estimated from Cox proportional hazard regression model.

†Confidence interval of the estimated HR.

difference was observed. This corresponds to a decreased rate of technical failure observed at 3 months when pancreas was implanted first. Interestingly, increasing the time lag between kidney and pancreas implantation accentuated the observed difference, raising the proportion of lost grafts in KBP from 10.8% to 12.5%, that is, a 16% increase.

Analysis of graft survival depending on type of venous drainage showed that this effect was only observed for systemic drainage of the pancreas. For portal drainage, a trend toward lower pancreas graft survival was even observed when pancreas was implanted first.

Analysis of graft survival depending on transplant era confirmed the advantage of implanting pancreas first. In the more recent era, we observed an advantage for pancreas transplanted first with systemic venous drainage. Again, pancreas graft survival tended to be lower in portally drained pancreases when they were implanted first. This might be explained by a higher incidence of technical complications such as venous thrombosis in portal drainage when pancreas is implanted first. Reasons may include mechanical factors, such as vessel twist or organ compression, or delayed heparin therapy due to subsequent implantation of the kidney. In this study, graft implantation order did not affect long-term pancreas graft survival. As shown by Tai *et al.*, [13] pancreas graft loss beyond 1 year is foremost due to rejection. In our data, rejection rate was expectedly similar in both groups, independent from graft implantation order. Accordingly, Niederhaus *et al.* [16] previously reported that longer pancreas cold ischemia time was not a risk factor for rejection. Increasing time between kidney and pancreas implantation led to a small, but significant difference at 5 years after transplant, raising the proportion of lost grafts in KBP from 19.3% to 21.3%. Similar slopes in all groups indicate that this observation is largely a reflection of the early graft losses and corresponds mainly to technical failures.

From another standpoint, we did not observe any influence of graft implantation order on short- or long-term kidney graft survival. Increasing cold ischemia time within reasonable limits has been shown to have no significant effect on long-term kidney graft survival [17]. Former studies have shown that cold ischemia time in renal transplants is strongly associated with delayed graft function [18]. However, the effects of delayed graft function are limited to the first year post-transplant [19]. More recently, Kayler *et al.* [20,21] have shown that, despite higher rates of delayed graft function, there was no effect of cold ischemia time on kidney graft survival.

To our knowledge, only one, single-center report has previously looked at the impact of graft implantation order on pancreas graft survival. A group from Brazil [12] observed a higher thrombosis rate in pancreas grafts when pancreas was implanted before kidney. They concluded that kidneys should be implanted first in SPK when retractor replacement is needed with intent to avoid damage to pancreas grafts during the surgical procedure. In their center, SPK involved two different teams and two different surgical sites, implantation being performed intraperitoneally for the pancreas and extraperitoneally for the kidney. This procedure required retractor replacement during surgery with possible pancreas damage during kidney implantation when pancreas was implanted first. There are no detailed data describing the step-by-step transplant procedure in the SRTR, but we can assume that in most US centers, the

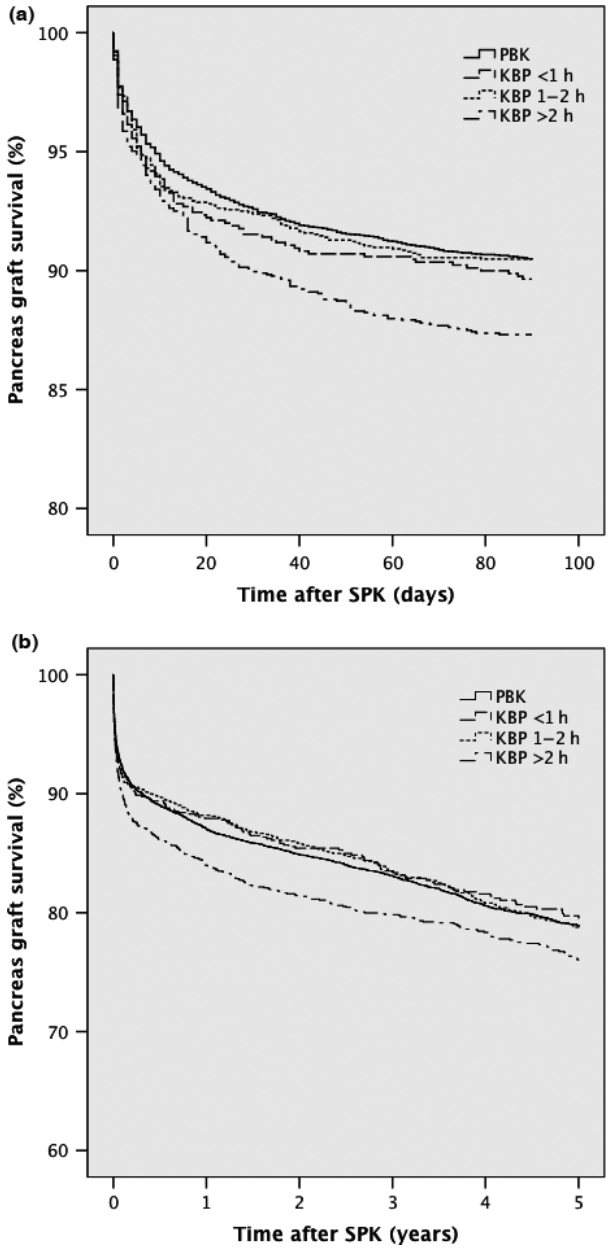


Figure 5 Pancreas graft survival according to time lag between kidney and pancreas graft implantation in KBP (<1 h, 1–2 h, >2 h) and in comparison with PBK. (Panel a): Short-term graft survival at 3 months after SPK. (Panel b): Long-term survival at 5 years after SPK. Lower pancreas graft survival is observed at 3 months (a) with increasing time lag in KBP (10.2, 9.4, 12.5% graft loss for <1 h, 1–2 h, >2 h) compared to PBK (9.4% graft loss, $P = 0.001$). Lower pancreas graft survival is also observed at 5 years (b) with increasing time lag in KBP (18.1, 18, 21.3% graft loss for <1 h, 1–2 h, >2 h) compared to PBK (18.5% graft loss, $P = 0.026$).

same surgical team implants both pancreas and kidney via a single midline surgical incision. These technical issues may explain the discordance between the Brazilian and this US registry study.

Table 3. Technical graft failure type.

	PBK	KBP	*P*-value
Technical graft failure n	476	293	
Thrombosis *n* (%)	389 (81.7)	241 (82.2)	0.495
Infection *n* (%)	31 (6.5)	24 (8.2)	0.332
Bleeding *n* (%)	16 (3.4)	4 (1.4)	0.103
Anastomotic leak *n* (%)	27 (5.7)	10 (3.4)	0.180
Pancreatitis *n* (%)	13 (2.7)	14 (4.8)	0.118

Different types of technical graft failure are shown for pancreas before kidney (PBK) and kidney before pancreas (KBP). Values represent number *n* and percentage (%) of total number of technical graft failure. Significances were tested by Pearson chi-square test. $P < 0.05$ was considered significant.

Our study carries the power, but also the typical limitations of a large registry study. A number of SPK transplants were excluded from the study due to missing data. It also has the known limitations of a retrospective study. There are also potential confounding variables, and a potential confounding center effect was not possible to rule out. Finally, the decision to implant the pancreas first might be a surrogate marker of surgical complexity.

In summary, this study shows that in SPK, implanting the pancreas first decreases the risk of early graft loss significantly, even if the observed differences are small. A vast majority of short-term graft failures are secondary to technical complications. The rate of early graft failure is accentuated by the time lag between kidney and pancreas implantation. Therefore, this large registry study allows to recommend implantation of the pancreas before the kidney in an SPK procedure, especially when cold ischemia time is prolonged or time lag between kidney and pancreas revascularization is expected to be extended, because of foreseeable technical difficulties, for example. When the surgeon chooses to implant the kidney first, time lag between graft revascularization should not exceed 2 h.

Authorship

NN, BB, PM, and TB: participated in research design. NN, BB, and CT: participated in data management and analysis. NN, AA, CT, and TB: participated in writing of the paper.

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Conflicts of interest

The data reported here have been supplied by the Minneapolis Medical Research Foundation as the contractor for the SRTR. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of or interpretation by the SRTR or the U.S. Government. The authors declare no conflict of interests.

REFERENCES

1. Patterson CC, Dahlquist GG, Gyürüs E, Green A, Soltész G. Incidence trends for childhood type 1 diabetes in Europe during 1989–2003 and predicted new cases 2005–20: a multicentre prospective registration study. *Lancet* 2009; **373**: 2027.
2. The Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993; **329**: 977.
3. http://optn.transplant.hrsa.gov/. Last accessed: May 14, 2015.
4. Wiseman AC. The role of kidney-pancreas transplantation in diabetic kidney disease. *Curr Diab Rep* 2010; **10**: 385.
5. Mohan P, Safi K, Little DM, *et al.* Improved patient survival in recipients of simultaneous pancreas-kidney transplant compared with kidney transplant alone in patients with type 1 diabetes mellitus and end-stage renal disease. *Br J Surg* 2003; **90**: 1137.
6. Israni AK, Feldman HI, Propert KJ, Leonard M, Mange KC. Impact of simultaneous kidney-pancreas transplant and timing of transplant on kidney allograft survival. *Am J Transplant* 2005; **5**: 374.
7. Lindahl JP, Hartmann A, Horneland R, *et al.* Improved patient survival with simultaneous pancreas and kidney transplantation in recipients with diabetic end-stage renal disease. *Diabetologia* 2013; **56**: 1364.
8. Khairoun M, de Koning EJ, van den Berg BM, *et al.* Microvascular damage in type 1 diabetic patients is reversed in the first year after simultaneous pancreas-kidney transplantation. *Am J Transplant* 2013; **13**: 1272.
9. McCullough KP, Keith DS, Meyer KH, Stock PG, Brayman KL, Leichtman AB. Kidney and pancreas transplantation in the United States, 1998–2007: access for patients with diabetes and end-stage renal disease. *Am J Transplant* 2009; **9**: 894.
10. Humar A, Ramcharan T, Kandaswamy R, Gruessner RW, Gruessner AC, Sutherland DE. Technical failures after pancreas transplants: why grafts fail and the risk factors – a multivariate analysis. *Transplantation* 2004; **78**: 1188.
11. Gruessner AC, Sutherland DE. Pancreas transplant outcomes for United States (US) and non-US cases as reported to the United Network for Organ Sharing (UNOS) and the International Pancreas Transplant Registry (IPTR) as of June 2004. *Clin Transplant* 2005; **19**: 433.
12. Salzedas-Netto A, Linhares M, Lopes-Filho G, *et al.* Simultaneous pancreas-kidney transplantation: which organ should be transplanted first? *Transplant Proc* 2010; **42**: 2647.
13. Tai DS, Hong J, Busuttil RW, Lipshutz GS. Low rates of short- and long-term graft loss after kidney-pancreas transplant from a single center. *JAMA Surg* 2013; **148**: 368.
14. Finger EB, Radosevich DM, Dunn TB, *et al.* A composite risk model for predicting technical failure in pancreas transplantation. *Am J Transplant* 2013; **13**: 1840.
15. Reddy KS, Stratta RJ, Shokouh-Amiri MH, Alloway R, Egidi MF, Gaber AO. Surgical complications after pancreas transplantation with portal-enteric drainage. *J Am Coll Surg* 1999; **189**: 305.
16. Niederhaus SV, Leverson GE, Lorentzen DF, *et al.* Acute cellular and antibody-mediated rejection of the pancreas allograft: Incidence, risk factors and outcomes. *Am J Transplant* 2013; **13**: 2945.
17. Shoskes DA, Cecka JM. Effect of delayed graft function on short- and long-term kidney graft survival. *Clin Transplant* 1997; **1997**: 297.
18. Ojo AO, Wolfe RA, Held PJ, Port FK, Schmouder RL. Delayed graft function: risk factors and implications for renal allograft survival. *Transplantation* 1997; **63**: 968.
19. McLaren AJ, Jassem W, Gray DW, Fuggle SV, Welsh KI, Morris PJ. Delayed graft function: risk factors and the relative effects of early function and acute rejection on long-term survival in cadaveric renal transplantation. *Clin Transplant* 1999; **13**: 266.
20. Kayler LK, Magliocca J, Zendejas I, Srinivas TR, Schold JD. Impact of cold ischemia time on graft survival among ECD transplant recipients: a paired kidney analysis. *Am J Transplant* 2011; **11**: 2647.
21. Kayler LK, Srinivas TR, Schold JD. Influence of CIT-induced DGF on kidney transplant outcomes. *Am J Transplant* 2011; **11**: 2657.