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The utility of robotic assisted pancreas transplants – a single center retrospective study

Mario Spaggiari, Kiara A. Tulla, Obi Okoye, Caterina Di Bella, Pierpaolo Di Cocco, Jorge Almario, Pearl Ugwu-Dike, Ivo G. Tzvetanov & Enrico Benedetti

Division of Transplantation, Department of Surgery, University of Illinois at Chicago, Chicago, IL, USA

Correspondence
Mario Spaggiari MD, Division of Transplant, Department of Surgery, University of Illinois at Chicago, 840 South Wood Street, Clinical Sciences Building, Suite 522, Chicago, IL 60612, USA.
Tel.: 312-996-6771;
fax: 312-413-3483;
e-mail: mspaggia@uic.edu

SUMMARY

The prevalence of obesity within the diabetic population is on the rise. This development poses unique challenges for pancreas transplantation candidates as obese individuals are often denied access to transplant. The introduction of robotic approach to transplant has been shown to improve outcomes in obese patients. A single center retrospective review of pancreas transplant cases over a 4-year period ending December 2018 was performed. Patients undergoing robotic surgery were compared to their counterparts undergoing open transplant. 49 patients (10 robot, 39 open) received pancreas transplants over the study period. Mean age was 43.1 ± 7.5 vs. 42.8 ± 9.7 years. There were no significant differences in demographics except body mass index (33.7 ± 5.2 vs. 27.1 ± 6.6, $P = 0.005$). Operative duration (7.6 ± 1.6 vs. 5.3 ± 1.4, $P < 0.001$), and warm ischemia times [45.5 (IQR: 13.7) vs. 33 (7), $P < 0.001$] were longer in the robotic arm. There were no wound complications in the robotic approach patients. Graft (100% vs. 88%, $P = 0.37$) and patient survival (100% vs. 100%, $P = 0.72$) after 1 year were similar. Our findings suggest that robotic pancreas is both safe and effective in obese diabetic patients, without added risk of wound complications. Wide adoption of the technique is encouraged while long term follow-up of our recipients is awaited.

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Introduction

The incidence of both type 1 (T1DM) and type 2 diabetes mellitus (T2DM) is increasing globally [1], however the utilization of pancreas transplantation has been declining over the past decade. Candidates listed for transplantation has decreased from 2067 patients in 2004 to 961 in 2015 and proportionally, the number of patients transplanted has also declined from 1500 to 947 during this time period [2]. In the past, this was used primarily as a treatment for T1DM, but T2DM as an indication for pancreas transplantation is increasing (11.7% in 2016 from 10.5% in 2015). This is a direct result of a change in the pancreas transplant allocation selection criteria introduced in 2014. The current guidelines require a candidate to be an insulin dependent diabetic, with either a fasting C-peptide of >2 ng/ml and a BMI < 30 kg/m^2 or C-peptide of ≤2 ng/ml with no BMI restriction. These cutoffs are designed to screen for patients with beta cell mass dysfunction rather than isolated insulin resistance [3,4].

At the same time, more T1DM and T2DM patients are presenting with significant obesity, making them

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suboptimal transplant candidates at most centers [5,6]. These patients are often passed on the waiting lists until an "ideal" body mass index (BMI) for transplantation is reached, increasing the long-term consequences of end-organ failure.

Elevated BMI $\geq$ 30 kg/m^2 has been associated with up to a 6-fold increase in rates of all cause post-operative complications, including wound infections [7]. Wound infections, especially deep ones, have been noted to warrant graft removal due to high risk of patient mortality after pancreas transplantation [8]. Obese patients have a higher risk of wound dehiscence, ventral hernias, intra-abdominal infections, gangrene, necrotizing infections, graft loss, and mortality, which may explain the reluctancy by some centers to list these patients for pancreas transplantation [7,9,10]. Strategies that reduce surgical complication rates in obese patients would theoretically bypass the bottleneck and grant access to pancreas transplantation in this underserved population [11].

Robotic pancreas transplantation in obese transplant candidates is a novel technique with potential to address the surgical complication risk. The traditional approach to pancreas transplantation involves a midline abdominal incision, with its attendant risk of incisional hernias. On the contrary, the robotic approach mitigates wound complications across BMI categories with a short sub-xiphoid incision. Favorable reduction in wound complication rates have been reported by our group, utilizing robotics in kidney transplant recipients [12]. Building on that experience, we developed a laparoscopic, robotic-assisted approach to perform pancreas transplants in a predominantly obese cohort. This article explores our experience with this technique, while comparing outcomes to patients undergoing the traditional open approach.

Methods

Study design and patient population

After institutional review board (IRB) approval, a retrospective analysis of all pancreas transplant cases performed between January 2015 and December 2018 was conducted.

Per protocol, patients meeting UNOS eligibility criteria were evaluated by a multidisciplinary transplant team, and assessed for peripheral vascular disease, hypoglycemic unawareness [13], presence of autonomic neuropathy (i.e. neurogenic bladder, gastroparesis) and renal function for proper listing and surgical planning purposes. These patients were subsequently listed for simultaneous pancreas-kidney transplantation (SPK), pancreas after kidney transplantation (PAK), or pancreas transplantation alone (PTA) where applicable.

Graft back-bench preparation

Donor grafts are evaluated for suitability by reviewing laboratory test results, donor characteristics and visual inspection of the organ upon procurement. Meticulous backbench preparation is performed to ensure the pancreas capsular integrity and suture-ligate potential sources of bleeding. A single arterial inflow is created using the donor iliac artery Y-graft, by connecting it to the proximal splenic artery and superior mesenteric artery. Venous outflow derives from the portal vein.

Surgical technique

Conventional pancreas transplant was performed through a midline abdominal approach. Upon entry into the abdomen, the right colon is mobilized, and the distal inferior vena cava (IVC) and right common iliac artery (RCIA) are exposed. The Y-graft is then anastomosed to the RCIA, while the donor portal vein anastomosed to the distal IVC, both performed in an end-to-side fashion. Pancreas drainage is achieved through a two-layered end-to-side anastomosis between the duodenum and the distal jejunum.

Robotic pancreas transplant at our institution is performed with the da Vinci® Robot Si (Intuitive Surgical Inc, Sunnyvale, CA, USA), using the same technique previously described by our group [14]. Briefly, three robotic arms (including the camera port) and one laparoscopic assistant port were utilized. The organs are inserted into the abdominal cavity through a 7 cm supra-umbilical midline incision with a GelPort (Applied Medical, Rancho Santa Margarita, CA, USA; Fig. 1). The portal vein of the pancreas is anastomosed in an end-to-side fashion to the left external iliac vein, and the arterial Y-graft is anastomosed to the left external iliac artery with 5-0 expanded polytetrafluoroethylene (e-PTFE) continuous suture (Fig. 2a,b). Pancreas drainage is achieved via a duodeno-ileal anastomosis (Fig. 2a–c) or a duodeno-cystostomy if a tension-free enteric drainage is not feasible. In the former, the donor duodenum and recipient ileum (>120 cm from the ileocecal valve) are anastomosed using a stapler or robotic hand-sewn technique. In the latter, a side-to-side duodeno-cystostomy is performed between the duodenum of the allograft and the recipient's bladder with an end-to-end anastomosis (EEA) circular stapler (Covidien, Mansfield, MA, USA).

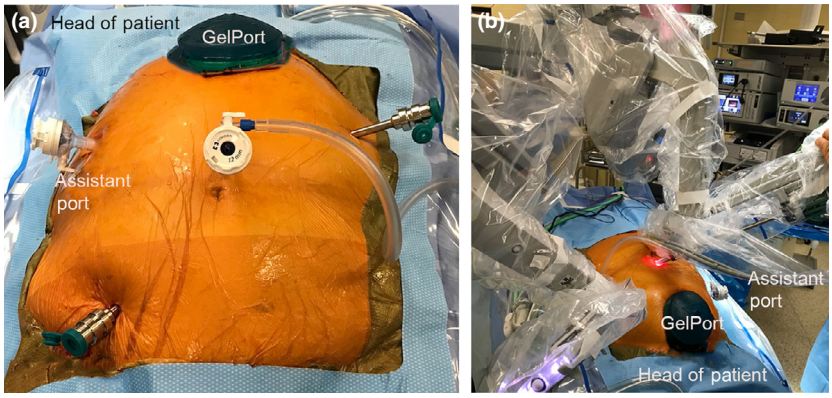

Figure 1 Robotic pancreas transplant port placement and robot. (a) The robotic ports are placed as follows: the gel port is a 7 cm incision below the xyphoid, the camera port is supra-umbilical while the two additional robotic ports are placed in the left upper quadrant and right lower quadrant lateral to the rectus abdominus. The assistant port is placed in the right upper quadrant. (b) The robot is docked on the patient's left side near the feet, while the patient is in 30-degree Trendelenburg.

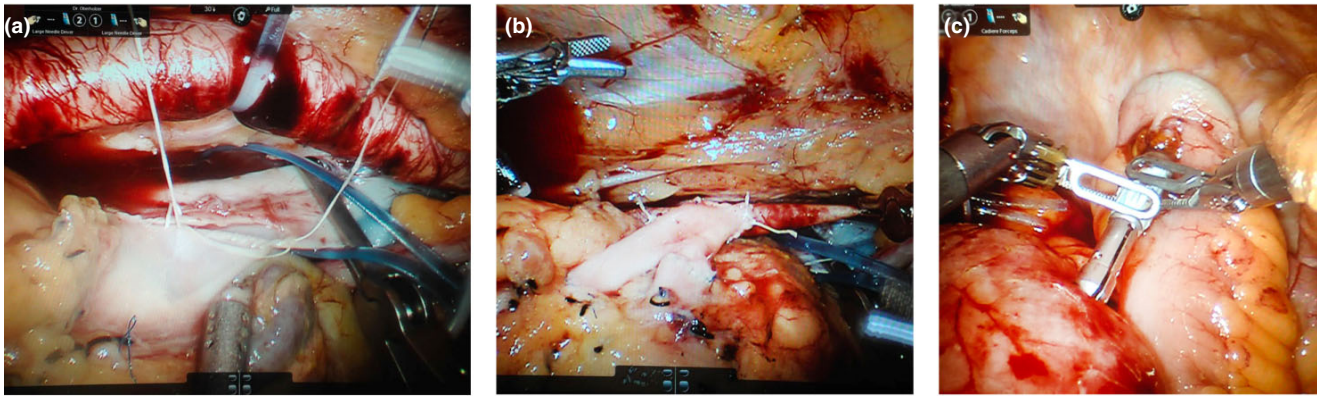

Figure 2 Robotic anastomoses for pancreas transplant. (a) The venous anastomosis is completed in an end to side between the graft portal vein and the left external iliac vein first because of its inferior-posterior position. It is completed with a 5-0 Gortex sutured. (b) The arterial Y conduit is anastomosed in an end to side fashion in the left external iliac artery. (c) The end-to-end anastomosis stapler anvil in placed in the ilium and the circular stapler is threaded through the duodenal stump to provide an end to side anastomosis, with subsequent closure of the duodenal stump.

The technical aspects of robotic kidney technique have been previously published [12]. Briefly, a 30° robotic endoscope is inserted through a 12-mm umbilical trocar, while two 7-mm robotic trocars are inserted in the right subcostal region and left iliac fossa. A 12-mm assistant port is placed between the umbilicus and the trocar positioned in the left iliac fossa. GelPort access for abdominal organ manipulation is through a 7-cm upper-midline incision. The assistant port is strategically positioned to allow insertion of a robotic arm for renal transplant after pancreas implantation in SPK cases.

Per institutional protocol, immunosuppression induction included steroids and daily rabbit anti-thymocyte globulin 1.5 mg/kg given on postoperative days (POD) 0–4. All patients received maintenance immunosuppression with tacrolimus in combination with mycophenolic acid and a rapid, 5-day steroid taper. Tacrolimus therapy was started by POD 2 at 0.025 mg/kg every 12 h with a target trough level of 10–15 ng/ml for the first 2 months and 5–10 ng/ml thereafter. Maintenance immunosuppression after day 5 was steroid-free.

Statistical analysis

Patient demographics, donor information, intra-operative details and post-operative course were obtained from the electronic medical records, and UNOS DonorNet®. Donors were matched to recipients in the standard fashion and recipients were selected for the robotic approach if they had a BMI $\geq$ 30 kg/m^2, in the absence of iliac artery atherosclerosis.

The primary outcome variables studied were procedural complications, graft loss and mortality. Secondary

outcomes analyzed were operative time, blood loss, and graft survival. Post-operative graft function was monitored using glycated hemoglobin measurements (HbA1c) at scheduled intervals. Univariate comparisons were performed between open approach and robotic approach recipients. Continuous variables were tested for normality using the Shapiro-Wilk test. Categorical variables were described as proportions of the denominator population and reported as percentages. Normally distributed continuous variables were reported as mean ± standard deviation, while non-normally distributed data were presented as median (interquartile range). Univariate analyses were performed using Fisher's exact test for categorical variables, and the Mann-Whitney *U* test for continuous variables. Graft and patient survival were explored using Kaplan Meier statistics. Patients were considered to have graft failure if the graft was excised, if the patient re-registered for a pancreas, if the patient returned to insulin requirements 0.5 units/kg/day for 90 consecutive days, or if the patient died [15]. A P value <0.05 was considered significant. All statistical analyses were performed using IBM SPSS Statistics for Macintosh, Version 25.0 (IBM Corp., Armonk, NY, USA).

Results

Over the study period, a total of 49 pancreas transplants were performed at our institution. The mean age was 42.8 ± 9.2 years, with even gender spread (49% male), and mean BMI of 28.4 ± 6.9 kg/m^2. Majority of patients (77.6%) had type 1 Diabetes, while 69.4% had a history of End-Stage Renal Disease (ESRD) requiring dialysis. The median HbA1C at the time of surgery was 7.5%, while hypertension (85.7%) and retinopathy (53.1%) were the most commonly reported associated comorbidities. Of the study population, 10 patients (20.4%) underwent a robotic assisted approach, while the remaining 39 (79.6%) were transplanted using the open technique. Patients undergoing robotic surgery had a significantly higher BMI than those in the open approach (33.7 ± 5.2 vs. 27.1 ± 6.6, $P = 0.005$). Recipient demographic data stratified by procedure type are presented in Table 1.

The mean age for donors was 21.5 ± 10.2 years, and the mean BMI was 21.9 ± 4.9 kg/m^2. All the organs were sourced from brain-dead donors. Majority of donors were Caucasian (40.8%), male (69.4%), and the most common cause of death was anoxia (36.7%). The median HbA1C was 5.4 (0.4). With the exception of gender, there were no significant differences between donors for patients in the open versus the robotic populations. The donor demographics are summarized in Table 2.

Thirty-seven patients (75.5%), including three patients with ESRD not yet on dialysis underwent SPK transplant, eight patients (16.3%) had PTA, and four patients (8.2%) had PAK procedures. In the robotic group, eight of the patients underwent SPK, while the remaining two patients had PAK, and PTA. In the open approach group, SPK was performed in 29 patients (74.4%), PTA in 7 (17.9%) PTA, and PAK in three patients (7.7%).

Drainage of the pancreas was achieved through the bowel in 46 (93.9%) cases, while the remaining three patients (6.1%) were drained through the urinary bladder. All of the open approach patients had enteric diversion of the pancreas, while seven in the robotic cohort had enteric drainage. The mean operative time was 5.8 ± 1.7 h, while the estimated blood loss was 200 (250) ml. Operative time was significantly longer in the robotic approach (7.6 ± 1.6 vs. 5.3 ± 1.4 h, $P < 0.001$), while the estimated blood loss was lower in the robotic [150 (63) vs. 200 (350), $P = 0.042$]. The length of hospitalization was shorter in the robotic arm, though this finding did not reach statistical significance. Additional operative details are reported in Table 3.

There were seven cases of graft loss, six in the open approach group, and 1 in the robotic arm. One case was due to the patient's death from encephalitis secondary to primary CNS B-cell lymphoma. Four cases were due to graft removal for various reasons, and two patients developed insulin requirements >0.5 μ/kg/day. Additional details on these patients are presented in Table 4.

One of the patients in the robotic arm developed an incisional hernia at the epigastric incision site, while another patient in the open approach group also had an incisional hernia. Two open approach patients had duodenal stump leaks, which required re-operation. In one of these patients, the graft could not be salvaged, and the other was managed with a Roux-en-Y duodeno-jejunostomy. One patient in the robotic arm presented with an acute abdomen, and elevated pancreatic enzymes in the effluent from the closed-suction drain. Given the concerns for a pancreatic leak, she underwent exploratory laparoscopy which was turned out to be non-diagnostic. An abdominal lavage was performed, and the patient had an uneventful recovery from presumed pancreatitis. Other post-operative complications are presented in Table 5. There were no statistically significant differences in the incidence of post-operative

Table 1. Patient demographics

Patient characteristics	All patients (*N* = 49)	Robotic (*N* = 10)	Standard (*N* = 39)	*P*
Age (years), mean ± SD	42.8 ± 9.2	43.1 ± 7.5	42.8 ± 9.7	0.817
Male gender, *n* (%)	24 (49%)	6 (60%)	18 (46.2%)	0.496
Ethnicity and race, *n* (%)				
African-American	15 (30.6%)	6 (60%)	9 (23.1%)	0.099
Caucasian	17 (34.7%)	1 (10%)	16 (41%)	
Hispanic	15 (30.6%)	3 (30%)	12 (30.8%)	
Other	2 (4.1%)	0	2 (5.1%)	
BMI (kg/m^2), mean ± SD	28.4 ± 6.9	33.7 ± 5.2	27.1 ± 6.6	0.005
Type 1 DM, *n* (%)	38 (77.6%)	6 (60%)	32 (82.1%)	0.201
ESRD on dialysis, *n* (%)	34 (69.4%)	8 (80%)	26 (66.7%)	0.702
ABO blood type, *n* (%)				
A	14 (28.6%)	3 (30%)	11 (28.2%)	0.815
AB	1 (2%)	0	1 (2%)	
B	9 (18.4%)	1 (10%)	8 (20.5%)	
O	25 (51%)	6 (60%)	19 (48.7%)	
Pre-op laboratory values, median (IQR)				
Hemoglobin A1C	7.5 (2.5)	6.9 (2.9)	7.6 (2.4)	0.651
C-peptide	0.2 (1.6)	0.5 (1.8)	0.1 (1.4)	0.205
Co-morbidities, *n* (%)				
Hypertension	42 (85.7%)	9 (90%)	33 (84.6%)	1.000
Hyperlipidemia	15 (30.6%)	2 (20%)	13 (33.3%)	0.702
Coronary artery disease	7 (14.3%)	3 (30%)	4 (10.3%)	0.140
Previous cerebrovascular accident	3 (6.1%)	1 (10%)	2 (5.1%)	0.504
Thyroid disease	8 (16.3%)	3 (30%)	5 (12.8%)	0.333
Obstructive sleep apnea	4 (8.2%)	1 (10%)	3 (7.7%)	1.000
Peripheral neuropathy	16 (32.7%)	6 (60%)	10 (25.6%)	0.060
Retinopathy	26 (53.1%)	7 (70%)	19 (48.7%)	0.299
Gastroparesis	7 (14.3%)	1 (10%)	6 (15.4%)	1.000

A1C, glycated hemoglobin; BMI, body mass index; DM, diabetes mellitus; ESRD, end stage renal disease, IQR, interquartile range; SD, standard deviation.

complications when comparing the two groups. Graft function evaluated using A1C showed a gradual decline over a 3-month period and remained stable over a 12-month period (Fig. 3). Graft and patient survival were explored using Kaplan-Meier analyses. One-year graft survival estimates were 100% for robotic cases, and 88% for the open approach. Patient 1-year survival estimates were 100% for the robotic approach, and 100% for the open surgery.

Discussion

This single institution's report on a new technique in an underserved population confirms the feasibility of robotic pancreas transplantation in the obese diabetic patient. Patients undergoing the robotic approach had a significantly higher BMI, and longer operative times. The reported blood loss was less, and surgical complication rates were similar to the open approach. It is important to note that only one patient in the robotic cohort developed a surgical site infection, which resolved after a course of oral antibiotics. Patient and graft survival in the robotic approach were also similar to patients in the open cohort.

The first robotic pancreas transplant cases were reported by Boggi *et al.* [16]. The authors included three normal BMI patients and demonstrated the feasibility of the technique. Our center performs a large number of robotic kidney transplants in obese patients without vascular disease, and this served as a platform to develop our pancreas technique [12,17]. Our variation of the robotic pancreas transplant is tailored to obese patient anatomy by changing the graft insertion site to a short upper midline incision and intra-abdominal completion of the enteric anastomosis [14]. These modifications, as seen in other patient cohorts, avoid the lower abdominal incision and minimize the risk of skin infections from groin contamination [18].

Table 2. Donor characteristics

	All patients (*N* = 49)	Robotic (*N* = 10)	Standard (*N* = 39)	*P*
Age (years), mean ± SD	21.5 ± 10.2	20.7 ± 8.4	21.8 ± 10.7	0.771
Male gender, *n* (%)	34 (69.4%)	10 (100%)	24 (61.5%)	0.021
Ethnicity and race, *n* (%)				
African-American	15 (30.6%)	3 (30%)	12 (30.8%)	0.550
Caucasian	20 (40.8%)	3 (30%)	17 (43.6%)	
Hispanic	12 (24.5%)	4 (40%)	8 (20.5%)	
Other	2 (4.1%)	0	2 (5.1%)	
BMI (kg/m^2), mean ± SD	21.9 ± 4.9	21.8 ± 5.4	22 ± 4.8	0.915
Cause of death, *n* (%)				
Anoxia	18 (36.7%)	3 (30%)	15 (38.5%)	0.213
Blunt head trauma	16 (32.7%)	3 (30%)	13 (33.3%)	
Cerebrovascular hemorrhage	6 (12.2%)	0	6 (15.4%)	
GSW head	9 (18.4%)	4 (40%)	5 (12.8%)	
Peak pre-donation laboratory				
Creatinine (mg/dl), median (IQR)	1.04 (0.7)	1.45 (1)	1 (0.6)	0.214
Hemoglobin A1C (%), median (IQR)	5.4 (0.4)	5.2 (0.3)	5.4 (0.4)	1.000
KPDI (%), mean ± SD	30.4 ± 17.8	29.5 ± 15.4	30.6 ± 18.6	0.876

A1C, glycated hemoglobin; BMI, body mass index; GSW, gunshot wound; IQR, interquartile range; KDPI, kidney donor profile index; SD, standard deviation.

Table 3. Operative details and outcomes

	All patients (*N* = 49)	Robotic (*N* = 10)	Standard (*N* = 39)	*P*
Type of transplant				
Pancreas after kidney	4 (8.2%)	1 (10%)	3 (7.7%)	
Pancreas transplant alone	8 (16.3%)	1 (10%)	7 (17.9%)	0.821
Simultaneous pancreas-kidney	37 (75.5%)	8 (80%)	29 (74.4%)	
Enteric diversion	46 (93.9%)	7 (70%)	39 (100%)	0.007
Estimated blood loss (ml)	200 (250)	150 (63)	200 (350)	0.042
Operative time (h)	5.8 ± 1.7	7.6 ± 1.6	5.3 ± 1.4	<0.001
CIT pancreas (h)	9.2 (7.7)	7.5 (3.5)	9.8 (8.8)	0.079
WIT pancreas (min)	164 (264.5)	48.5 (13.7)	33 (7)	<0.001
CIT kidney (h)	11.4 (5.9)	11.8 (2.6)	10.5 (8)	0.780
WIT kidney (min)	40.5 (10)	45 (32)	39.5 (9)	0.092
Length of hospital stay (days)	8 (5)	6.5 (6)	8 (5)	0.129
Graft loss	7 (14.3%)	1 (10%)	6 (15.4%)	1.000
Mortality	1 (2%)	0	1 (2.6%)	1.000
Duration of follow-up (months)	20.3 (25.4)	13.1 (18.3)	21.2 (28.5)	0.243

CIT, cold ischemia time; WIT, warm ischemia time.

A recent analysis of the International Pancreas Transplant Registry (IPTR) showed an increasing trend of overweight and obese pancreas transplant recipients over the last decades (46% in 2002–2008 to 63% in 2009–2015, $P < 0.0001$) [19]. Robotic surgery, with reduced abdominal wall trauma would be a technically viable option in the obese subset of pancreas transplant recipients. This concept has been successfully demonstrated in obese kidney transplant recipients [12].

From the patient perspective, receiving a pancreas graft is associated with years of life gained, regardless of the BMI [20]. This survival benefit is attributed to improved metabolic control, which in turn translates to a reduction in cardiovascular risk. Evidence of this risk reduction is demonstrated by a decline in carotid intimal thickness of post-pancreas transplant patients almost to the level of healthy control subjects [21]. Obese diabetic candidates are often overlooked for

Table 4. Characteristics of patients with graft loss

Surgical approach	Etiology of graft loss	Time to graft loss (days)
Open	Graft necrosis	3
Open	Duodenal stump leak, graft pancreatitis and peripancreatic abscess formation	39
Open	Acute rejection	145
Open	Poor compliance	298
Open	Graft venous thrombosis	509
Open	Patient death	720
Robotic	Poor compliance	846

Table 5. Complications

Classification	All patients (N = 49, %)	Robotic (N = 10)	Standard (N = 39, %)	P
Surgical	8 (16.3)	1 (10%)	7 (17.9)	1.000
Wound	1 (2)	0	1 (2.6)	1.000
Vascular	3 (6.1)	0	3 (7.7)	1.000
Graft	6 (12.2)	1 (10%)	5 (12.8)	1.000
Other	3 (6.1)	2 (20%)	1 (2.6)	0.102

*Surgical complications include incisional hernias (2), stump leaks (2), pelvic abscesses (3), and bowel obstruction (1); wound complications – seromas (1); vascular complications – hematomas requiring evacuation (2), graft vein thrombosis (1), iliac pseudoaneurysm (1); graft complications – pancreatitis (4), acute rejection (1), graft necrosis (1); other complications; community acquired pneumonia (1), bacteremia (1), primary CNS B-cell lymphoma (1).

transplantation and advised to adopt lifestyle modifications for weight loss and improved glycemic control. However, medical weight loss programs have low long-term success rates and poor patient compliance [22,23].

There is conflicting data regarding the effects of obesity on graft outcomes. Sampaio *et al.* [9] analyzed T1DM patients treated with SPKs, stratified by pre-transplant BMI from the UNOS database between 2000 and 2007. In their analysis, obese patients had a greater number of complications such as pancreas graft thrombosis [odd ratio (OR) 1.38; 95% CI: 1.15–1.68]. In addition, obesity was associated with a 35% increased mortality risk and a 41% higher risk of graft loss. Early graft failure was found to explain the difference in 3-year graft survival between obese and non-obese transplant recipients. Bedat *et al.* [10] evaluated short term (90 days) and long-term patient (90 days to 5 years) outcomes in obese pancreas graft recipients using 25 years of Scientific Registry of Transplant Recipients data. Again, progressive increase in BMI was found to be an independent predictor of pancreatic graft loss and patient death in the short term ($P < 0.001$). Obesity was associated with a higher risk of graft failure after the first 90 days ($P = 0.01$).

However, single centers evaluating modern pancreas transplant data disagree with those conclusions regarding patient and graft outcomes. Hanish *et al.* [10] demonstrated that a BMI $\geq$ 30 kg/m^2 was an independent predictor of overall complications following surgery (OR 6.8, $P < 0.001$). However, there was no difference identified between groups with regards to allograft failure, posttransplant insulin resistance, and death. Similarly, Afaneh *et al.* [24] reported that after 139 consecutive pancreas transplants, there was a significant association between higher BMI and perioperative morbidity, but no differences in patient and graft outcomes. Laurence *et al.* [18] analyzed 368 patients divided into two BMI groups (BMI < 30 kg/m^2 or BMI $\geq$ 30 kg/m^2) and reported that the obese population ($n = 60$) had a higher incidence of wound complications and acute rejection. In their analysis, graft and patient survival were comparable between obese and normal weight recipients. These findings suggest that BMI may not influence long-term outcomes if post-operative wound complications can be minimized.

As more T2DM patients are added to the transplant list, it is important to recognize the data supporting their candidacy. Patient survival improves significantly in T2DM recipients compared to T2DM patients who have not received transplantation, especially if they have ESRD [19]. Excellent results have been achieved in patients regardless of pre-transplant C-peptide levels, although the donor pancreas beta cells will theoretically be overstimulated and lead to beta cell exhaustion with subsequent graft loss if patients with T2DM are transplanted without proper screening [25–27]. Although studies have shown positive outcomes for T2DM transplant candidates, these patients are infrequently transplanted [28]. Our series comprised of mainly T1DM patients, but we anticipate a more even proportion of T2DM patients as the program expands.

The study limitations include the retrospective design, relatively low population of patients in the robotic cohort, and shorter follow up duration. Regarding benefits of the approach, the duration of post-operative ileus, or use of narcotic medication could not reliably obtained, however patients undergoing robotic

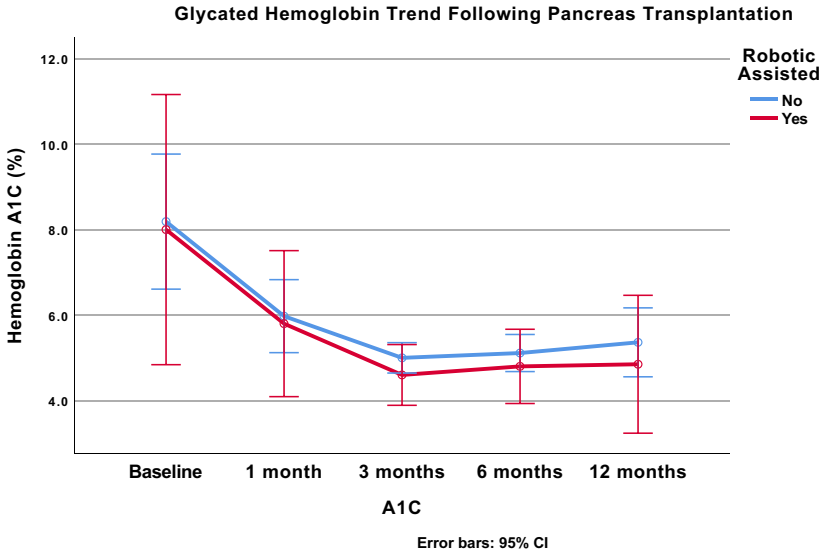

Figure 3 Glycated hemoglobin trend following Pancreas Transplant. The mean HbA1C declined from a preoperative value of 8.2 ± 2.0 and 8.0 ± 1.4 to 6.0 ± 1.1 and 5.8 ± 0.7 in the open and robotic arms respectively 1-month post-transplant. The lower A1C level persisted over time at 3 months (5.0 ± 0.4 and 4.6 ± 0.3), 6 months (5.1 ± 0.6 and 4.8 ± 0.1) and 12 months (5.4 ± 1.0 and 4.8 ± 0.1). (Error bars are set for the 95% confidence interval of the mean).

transplant were discharged earlier than their open counterparts, though this finding was not statistically significant. Our series was conducted at single center with a high-volume robotic transplant program, with more than 1000 robotic donor nephrectomies and 200 robotic kidney transplants to date. This procedure was developed after garnering experience from other robotic transplant procedures in morbidly obese recipients and explains the absence of wound complications in the robotic cohort. Although, the acquisition and maintenance of the robot is expensive, the utility of the technology in transplantation has allowed for obese transplant recipients to be safely listed and successfully transplanted [29]. Wide adoption of robotic-assisted pancreas transplantation could potentially increase access to transplantation for obese diabetic patients. Further long-term and larger volume studies will be integral in addressing how this technique influences longer term graft and patient survival.

Authorship

MS and IT: participated in research design, performance of the research, data analysis, critically reviewing the manuscript. KAT, CDB and OO: participated in writing the paper, data collection and data analysis. PDC and PU-D: participated data collection and critical review of the manuscript. EB and IT: participated in research design, performance of the research, critical review of the manuscript. All authors have read and approved the manuscript.

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Conflicts of interest

The authors have declared no conflicts of interest.

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