Original Article

Application of a specialist nurse-led multidisciplinary team model in the perioperative care of patients undergoing simultaneous pancreas and kidney transplantation: randomized controlled trial

Weiting Zhang, Xiuli Feng, Xuanying Deng, Min Jin, Jiali Li, Jiahui Xu, Jiali Fang, Caiqin Pan, Yuhe Guo

Organ Transplantation Department, the Second Affiliated Hospital of Guangzhou Medical University, Guangzhou, China

Contributions: (I) Conception and design: W Zhang; (II) Administrative support: X Feng; (III) Provision of study materials or patients: X Deng, M Jin; (IV) Collection and assembly of data: J Li, J Xu, J Fang; (V) Data analysis and interpretation: C Pan, Y Guo; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Xiuli Feng, BS. Organ Transplantation Department, the Second Affiliated Hospital of Guangzhou Medical University, No. 63, Yayun South Road, Panyu District, Guangzhou 511447, China. Email: 379894875@qq.com.

Background: Simultaneous pancreas and kidney transplantation (SPKT) is an effective treatment option for individuals who suffer from both diabetes mellitus and renal failure. However, experiments exploring nurse-led multidisciplinary team management during the perioperative management of patients undergoing SPKT are currently limited. This study aims to explore the clinical performance of a transplant nurse-led multidisciplinary team (MDT) in the perioperative management of SPKT patients.

Methods: A total of 218 patients who underwent SPKT were randomly assigned to either a control group (n=116) receiving conventional care or an intervention group (n=102) managed through a transplant nurse-led MDT approach. The incidence of postoperative complications, hospital stay, total hospitalization cost, readmission rate, and postoperative nursing quality were compared between these 2 groups.

Results: The intervention and control groups showed no significant differences in age, gender, and body mass index. Compared with the control group, the intervention group had a significantly lower incidence of postoperative pulmonary infection and gastrointestinal (GI) bleeding (27.6% *vs.* 14.7% and 31.0% *vs.* 15.7%, respectively, both P<0.05). Compared to the control group, the intervention group had significantly lower hospitalization costs, length of hospital stay, and readmission rate 30 days after discharge (32.98±9.10 *vs.* 36.78±15.36, 26.47±13.4 *vs.* 31.03±11.61 and 31.4% *vs.* 50.0%, respectively, all P<0.05). Additionally, the intervention group had significantly better quality of postoperative nursing care than the control group (11.61±0.69 *vs.* 9.64±1.42, P<0.01), the availability of infection control and prevention measures (11.74±0.61 *vs.* 10.53±1.11, P<0.01), the effectiveness of health education (11.73±0.61 *vs.* 10.41±1.06, P<0.01), the effectiveness of rehabilitation training (11.77±0.54 *vs.* 10.37±0.96, P<0.01), and the patient satisfaction with nursing care (11.83±0.42 *vs.* 10.81±1.08, P<0.01).

Conclusions: The nurse-led MDT model for transplant patients can reduce complications, shorten hospital stays, and save costs. It also provides clear guidelines for nurses, improving care quality and aiding patient recovery

Trial Registration: Chinese Clinical Trial Registry ChiCTR1900026543.

Keywords: Specialist nurse; multidisciplinary team; simultaneous pancreas and kidney transplantation; perioperative management

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Introduction

Simultaneous pancreas and kidney transplantation (SPKT) is an effective treatment for individuals suffering from both diabetes mellitus and renal failure, helping patients to eliminate dependence on exogenous insulin and renal replacement therapy (1). In 2021, the International Diabetes Federation (IDF) released new epidemiological survey data showing that 537 million adults worldwide between the ages of 20 and 79 were living with diabetes. with a prevalence rate of 10.5%, among which China had 140 million individuals with diabetes, the highest number of individuals with diabetes globally (2). Diabetic kidney disease (DKD) has been the primary cause of end-stage renal disease (ESRD) for a considerable period., and the prevalence of DKD has increased proportionally with the significant rise in the prevalence of diabetes (3).

Since multiple departments are involved during the perioperative management of SPKT, the multidisciplinary team (MDT) approach has become one of the important medical modes globally as it can integrate medical resources and contribute to improved outcome (4). Nurses are essential in all aspects of SPKT management, providing disease-related information, health education, and patient engagement to improve adherence to guidelines and promote positive health outcomes. However, most of the currently available studies on perioperative care of SPKT patients are case reports from single centers, and most of them have focused on the nursing of specific complications and thus were still at the stage of experience accumulation. To date, no systematic and evidence-based mode for nursing management throughout the spectrum of perioperative care has been available (5). In our current study, a pre-, intra-, and post-operative (PIP) care model for patients undergoing SPKT that was led by specialist nurses for organ donation (hereafter referred as "transplant nurses") and involved nurses from the anesthesiology department, nutrition department, rehabilitation department, endocrinology department, nephrology department, hemodialysis department, and pharmacy department, as well as follow-up nurses, was developed and applied in clinical settings to integrate multiple resources. We present this article in accordance with the CONSORT reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-116/rc).

Highlight box

Key findings

- The MDT model facilitates perioperative recovery of patients undergoing simultaneous pancreas and kidney transplantation (SPKT).

What is known and what is new?

- There is a lack of research on multidisciplinary, patient-centered management approaches by specialist nurses during the perioperative care of pancreas-kidney transplant patients.
- This study tested a comprehensive multidisciplinary approach, led by nurses, to manage patients undergoing SPKT.

What is the implication, and what should change now?

- The MDT model saves health care expenditures, and larger sample sizes are needed to better evaluate the model.

Methods

Participants

In this prospective parallel study, patients who underwent SPKT at our center from September 2016 to December 2021 were enrolled if they met the inclusion (*Figure 1*). To be eligible for inclusion, Inclusion criteria for patients were: (I) age between 18 and 80 years; (II) meeting the SPKT criteria stipulated by the indications and contraindications for SPKT in the *Chinese Guidelines on Kidney Transplantation* and *Chinese Guidelines on Pancreatic Transplantation* and having been approved by the ethics committee; (III) being able to tolerate surgery, as assessed by preoperative organ function tests; (IV) having signed informed consent forms. In relation to withdrawal and exclusion, patients were excluded from the investigational treatment: (I) at the request of the investigator himself/herself or his/her legal representative; (II) if in the opinion of the investigator or designee, participation in the study could be detrimental to the patient; (III) upon the death of the patient. The reasons for withdrawal were recorded for all patients who withdrew from the study.

A total of 218 eligible patients were divided into 2 groups using a random number table. Participants were randomly assigned to either the intervention or control group in a 1:1 ratio. There were 102 patients in the intervention group, and 116 in the control group. This parallel study complied with the Declaration of Helsinki (as revised in 2013), and was approved by the Ethics Committee of the Clinical Research Center of the Second Affiliated Hospital of Guangzhou Medical University (No. 2023-hg-ks-11). All the patients signed informed consent forms.

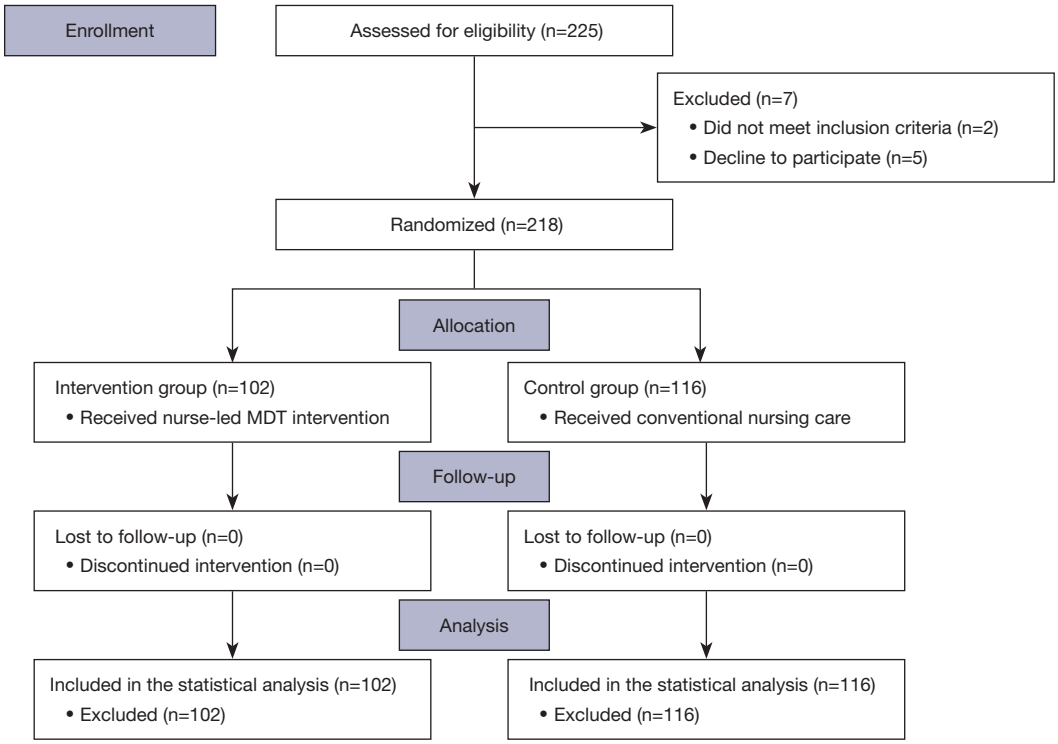

Figure 1 Flow chart of patient grouping and screening. MDT, multidisciplinary team.

Intervention group

During the perioperative management period, the intervention group received both the conventional care described above and a nurse-led MDT approach, while the control group only received conventional care.

Building a transplant nurse-led MDT

With a transplant nurse as the team leader, the MDT comprised a transplant surgeon, anesthesiologist, dialysis physician, nutritionist, pharmacist, rehabilitation physician, hemodialysis nurse, diabetes specialist nurse, and follow-up nurse.

Developing PIP care protocols for patients undergoing SPKT

Based on nursing practice and clinical nursing management experience in China and internationally (6,7), the MDT developed a PIP care model for patients undergoing SPKT, with its main content including preoperative assessment and preparation, intraoperative anesthesia management, postoperative fluid management, blood glucose management, nutrition management, infection control and prevention, identification and observation of complications, early rehabilitation, psychological care, health education, follow-up management, and specialist nurse-guided nursing management continuum.

Implementation of an MDT approach

The implementation steps included the following: (I) establishment of an SPKT MDT. (II) Assessment of nursing problems: the transplant nurse collected patient data and facilitated the assessment of major nursing problems. (III) Multidisciplinary bedside rounds: members of the MDT were invited to attend morning bedside rounds every Monday, during which the transplant nurse reported the disease conditions and provided reasonable insights from the perspective of nursing. (IV) MDT meetings: during the weekly meetings, the transplant surgeon reported on the disease condition and treatment plan and the transplant nurse reported on early-warning nursing problems; accordingly, the intervention plan was developed. (V) Implementation of the intervention plan: the specialist nurse checked the implementation of the nursing plan daily, so as to identify any possible problem during the implementation of the plan and revise the nursing plan in a timely manner. Specialist nurses were invited to

address the relevant specialist problems encountered in the implementation process. (VI) Evaluation of quality control performance: MDT records of the discharged patients were regularly compiled by follow-up nurses; for patients experiencing special or complex nursing problems, a continuous improvement program was developed.

Control group (conventional nursing care group)

Patients received conventional nursing care after SPKT: after the surgery, the primary nurse closely monitored the disease conditions and offered mental health support, with special attention to the prevention of complications; health education was provided throughout the peri-operative period; nursing problems were promptly assessed, and consultations with other specialists were arranged when needed.

The transplant nurse-led multidisciplinary collaborative nursing protocol is shown in the Appendix 1.

Survey tools

A quality control questionnaire for post-transplantation nursing was developed, which covered 5 domains including the implementation rate of basic nursing care, the availability of infection control and prevention measures, the effectiveness of health education, the effectiveness of rehabilitation training, and the patient satisfaction with nursing care. The questionnaire included 15 items, and the total score of each domain was 12. A higher score indicated better quality control.

Follow up

Baseline data such as age, gender, and BMI were collected. Data were collected at the perioperative period after SPKT, and mainly focused on the postoperative complication incidence, hospital stay, total hospitalization cost and readmission rate, and postoperative nursing quality scores. Two independent researchers who were blinded to the allocation of participants collected and analyzed the aforementioned data. The primary endpoint was gastrointestinal (GI) bleeding during the peri-operative period.

Statistical analysis

Sample size

We performed a conservative sample size calculation based on the incidence of GI bleeding observed in our study. We determined that 99 patients in both groups would be required to detect an expected decrease from 31% to 15% with a two-tailed alpha of 0.05 and a power of 0.80.

Data analysis

We conducted statistical analysis using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). *T*-tests and analysis of variance (ANOVA) were used to analyze the measurement data, which were reported as mean ± standard deviation (SD). The qualitative data were compared using chi-square test on rows and columns; for data with an expected frequency of <1, the Fisher's exact probability test was performed. The Kolmogorov-Smirnov method was used to examine the normality of data distributions, and a P value of <0.05 was considered statistically significant. Statistical analysis was performed using SPSS 25.0 software.

Results

Baseline characteristics

A total of 218 patients who underwent SPKT in our center during the period from September 2016 to December 2021 were enrolled (*Figure 1*). The intervention group (n=102) and control group (n=116) showed no statistical differences in general information including age, gender, and BMI (*Table 1*). Thus, these two groups were comparable.

Post-operative complications

The intervention group had a significantly lower incidence of pulmonary infection compared to the control group in terms of medical complications (P=0.021), and a significantly lower incidence of GI bleeding in terms of surgical complications (P=0.008), whereas there was no statistical difference in the incidence rates of intestinal obstruction, intestinal fistula, pancreatic fistula, pancreas graft thrombosis, and poor incision healing (*Table 2*).

Total hospitalization cost, length of hospital stay, and readmission within 30 days after discharge

The intervention group had significantly lower hospitalization days, total hospitalization cost, and 30-day post-discharge readmission rate compared to the control group. The number of hospitalization days and total hospitalization cost (direct medical cost) were significantly

Table 1 Baseline data in two groups

Main measures	Control group (n=116)	Intervention group (n=102)	P value
Age, years	47.5±10.3	50.8±8.8	0.082
Gender (males/females)	94/22	91/11	0.093
BMI, kg/m^2	23.5±3.16	23.7±2.78	0.249
Number of HLA mismatches	3.6±1.0	3.6±1.1	0.702
Pre-operative glycosylated hemoglobin, %	6.5±1.5	6.8±1.9	0.242
Age of donors, years	32.7±11.0	35.1±12.5	0.292

Data are presented as either numerical values or mean ± standard deviation. BMI, body mass index; HLA, human leukocyte antigen.

Table 2 Incidence rates of complications in two groups (n=218)

Item	Control group (n=116)	Intervention group (n=102)	P value
Gastrointestinal bleeding, n (%)	36 (31.0)	16 (15.7)	0.008
Intestinal obstruction, n (%)	4 (3.4)	1 (0.9)	0.374
Pulmonary infection, n (%)	32 (27.6)	15 (14.7)	0.021
Intestinal fistula, n (%)	3 (2.6)	2 (2.0)	1.0
Pancreatic fistula, n (%)	1 (0.9)	1 (0.9)	1.0
Pancreas graft thrombosis, n (%)	4 (3.4)	5 (4.9)	0.737
Poor incision healing, n (%)	20 (17.2)	16 (15.7)	0.758

Table 3 Total hospitalization cost and length of hospital stay in two groups

Item	Control group (n=116)	Intervention group (n=102)	P value
Length of hospital stay (days)	36.78±15.36	32.98±9.10	0.023
Total hospitalization cost (10,000 yuan)	31.03±11.61	26.47±13.4	<0.01
Readmission rate within 30 days after discharge	58 (50.0)	32 (31.4)	0.005

Data are presented as either numerical values or mean ± standard deviation.

lower in the intervention group than in the control group (P<0.05), as shown in *Table 3*.

Quality of postoperative care

According to the survey, the quality of postoperative nursing care was significantly better in the intervention group compared to the control group in all 5 domains including the implementation rate of basic nursing care, the availability of infection control and prevention measures, the effectiveness of health education, the effectiveness of rehabilitation training, and the patient satisfaction with nursing care (all P<0.01) (*Table 4*).

Discussion

SPKT is a complex surgical procedure that simultaneously involves 3 organs including pancreas, duodenum, and kidneys. Its perioperative care is extremely challenging, and a variety of complications may occur. The major concerns during PIP care of patients undergoing SPKT include the following: (I) fluid management: excessive fluid intake can easily lead to heart failure, pulmonary edema, and other complications, whereas low fluid intake can cause dehydration and insufficient graft perfusion. (II) Nutrition management: there is limited evidence on the application of early enteral nutrition following SPKT. In fact, early

Table 4 Core competencies of specialist nurses in two groups

Item	Control group (n=116)	Intervention group (n=102)	P value
Implementation rate of basic nursing care	9.64±1.42	11.61±0.69	<0.01
Effectiveness of health education	10.41±1.06	11.73±0.61	<0.01
Effectiveness of rehabilitation training	10.37±0.96	11.77±0.54	<0.01
Availability of infection control and prevention measures	10.53±1.11	11.74±0.61	<0.01
Patient satisfaction with nursing care	10.81±1.08	11.83±0.42	<0.01

Data are shown as mean ± standard deviation.

nutritional management often includes 3 phases: TPN, transition from parenteral to enteral nutrition, and enteral nutrition, with daily caloric supply adjusted by nursing staff in an individualized manner. (III) Infection prevention and control: patients undergoing SPKT are predisposed to infections due to the placement of multiple indwelling catheters and the use of high-dose immunosuppressants, and the infections may be aggravated in diabetic patients because these patients are intolerant to it. (IV) Rejection identification: SPKT is a transplant of multiple organs, during which the diagnosis and treatment of rejection is particularly complicated and difficult. Most acute-rejection episodes occur insidiously, and the confirmation of pancreas rejection relies on biopsy. (V) Complication identification and observation: the high incidence of complications after SPKT is an important factor affecting the short-term patient and graft survivals. Reducing the incidence of postoperative complications is the key to improving the short-term survival rates of patients and grafts and preventing graft failure. (VI) Psychological care and health education: multiple catheterizations, long fasting time, and pain and discomfort at the operation site may lead to decreased compliance behavior and anxiety/depression. Timely mental assessment, psychological support, and health education are especially important for the recovery and prognosis of the recipients.

In our current study, the MDT model had the following advantages and thus optimized management, reduced the occurrence of postoperative complications, and promoted the early recovery of patients.

Specialist nurse-led MDT model improves nursing quality and reduces postoperative complications

In the present study, the specialist nurse-led MDT perioperative management model was effective in lowering the incidence of pulmonary infection, intestinal obstruction, and GI bleeding in patients undergoing SPKT. It has been reported that the incidence of complications after SPKT ranges from 23% to 65.5% (8,9). In our center, pulmonary infection and GI bleeding are the 2 major complications with the highest incidence rates, and their occurrence is closely related to the use of immunosuppressive drugs. Oversuppression of the immune system by immunosuppressive drugs is a risk factor for pulmonary infection after organ transplantation (9), whereas the common causes of GI bleeding after SPKT include anastomotic bleeding, mucosal necrosis/bleeding due to intestinal ischemia, and pancreaticoduodenal graft bleeding due to rejection (10). Therefore, in our specialist nurse-led MDT model, the transplant nurse exerts leadership in patient care and plays a key role in the prevention, identification, and detection of complications. Early pulmonary infection requires refined care by nursing staff, including the addition of early rapid rehabilitation interventions (to encourage patients to exercise in bed and become ambulatory early) and the provision of scientific guidance (to reduce hypostatic pneumonia caused by long-duration bed rest). Our results also showed that the transplant nurse-led MDT increased MDT specialist consultations, which effectively reduced the incidence of pneumonia, highlighting the key role of the transplant nurse in preventing complications. Intestinal bleeding is another major complication, and effective and feasible nursing measures can reduce the trauma caused by GI bleeding. In this study, the incidence of GI bleeding was significantly lower in the intervention group than in the control group (P=0.008), suggesting the effectiveness of the transplant nurse-led MDT model in preventing this condition. Intestinal obstruction is a common complication after pancreatic surgeries and is also known to occur after SPKT (11). The occurrence of early intestinal obstruction

after SPKT is associated with the history of preoperative peritoneal dialysis, insufficient postoperative ambulation, and premature consumption of solid foods. The implementation of our specialist nurse-led MDT model, in which the specialist nurse developed the individualized rehabilitation plans and dietary regimens together with the rehabilitation physician and nutritionist, reduced the incidence of intestinal obstruction (0.9% *vs.* 3.4%), although there was no statistical difference between these 2 groups.

Specialist nurse-led MDT model shortens hospital stay and lowers hospital costs

In our current study, perioperative management based on a specialist nurse-led MDT shortened hospital stay, reduced hospital costs, and lowered readmission rates in patients undergoing SPKT. According to a study conducted outside of China (12), the hospitalization costs ranged from $75,200 to $87,800 and the laboratory testing costs were $23,600–$11,200 for patients undergoing SPKT, and the above expenditures did not include the organ acquisition costs. The high hospitalization expenses pose a huge financial challenge to SPKT patients (13). In addition, bleeding, thrombosis, and infections after SPKT are the main causes of prolonged hospitalization, and the incidence of readmission reached 74.2% in SPKT patients due to various infections (14). In our current study, the specialist nurse-led MDT model reduced the incidence of common complications such as pulmonary infections and GI bleeding, thereby promoting early recovery and improving health outcomes, which ultimately shortened the length of hospital stay and lowered the readmission rate, showing great economic benefits.

The specialty nurse-led MDT model improves nurses' professional competencies and increases patient satisfaction

In the present study, the transplant nurse-led MDT model promoted the increase in the specialist nurses' core competencies and promoted the continuous improvement of nursing quality. Nursing staff participate in the whole course of treatment and rehabilitation and provide direct care for the patients; thus, they play key role in multidisciplinary collaboration (5,15). Among them, specialist nurses participate in MDT as nursing experts. They can act as consultants, educators, and multidisciplinary coordinators for physicians, nurses, and patients, thus playing a pivotal role in the MDT (16). Some international MDT models have proposed the health problem-oriented professional support (6,7). In our present study, the specialist nurse served as an MDT leader in assessing patients' symptoms and demands and invited professionals from relevant disciplines to provide professional support. This model effectively enhanced the nurse' management skills, critical thinking, professional development skills, and other core competences, which is conducive to the development of core competencies of specialist nurses.

Effective communication and information sharing facilitate MDT management

Multidisciplinary information-sharing platforms and communication channels are important for MDT management. In our center, we have realized real-time communication and information sharing through the hospital's information sharing platform, which will be further used for the performance assessment of various MDTs. In particular, it will be used to optimize the management policies, work processes, and performance incentives of the transplant nurse-led MDT model.

The main limitation of this study was the small number of cases included, in the future, larger sample sizes are needed to better evaluate the model.

Conclusions

In summary, SPKT is a difficult procedure with high incidence of postoperative complications, complex perioperative management, and multiple challenges in postoperative care. In this article, we summarized our experience in offering postoperative clinical nursing for SPKT patients, especially the application of a transplant nurse-led MDT model that has effectively reduced perioperative complications. This new model proposes clear clinical pathways and guidelines for nursing staff and improves the quality of nursing services and therefore warrants further investigations and application in in clinical practice.

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Footnote

Reporting Checklist: The authors have completed the CONSORT reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-116/rc

Trial Protocol: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-116/tp

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-116/dss

Peer Review File: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-116/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-116/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study complied with the Declaration of Helsinki (as revised in 2013), and was approved by the Ethics Committee of the Clinical Research Center of the Second Affiliated Hospital of Guangzhou Medical University (No. 2023-hg-ks-11). All the patients signed informed consent forms.

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Appendix 1

Details of the MDT model

The transplant nurse-led multidisciplinary collaborative nursing protocol was developed as follows.

The MDT members' responsibilities

The transplant nurse was responsible for nursing team building, nursing protocol development and quality control, and cross-disciplinary coordination; the transplant surgeon was responsible for treatment protocol decision-making and recommendation; the anesthesiologist was responsible for choosing the anesthesia mode, formulating an anesthesia plan, offering precise anesthesia, implementing intraoperative fluid management, and identifying and handling anesthesia emergencies; the hemodialysis physician was responsible for assessing volume status and maintaining volume balance; the hemodialysis nurse was responsible for maintaining vascular access ports, assessing patients' response to hemodialysis treatment (including the vital signs, fluid balance, and circulation stability), and providing feedback to the transplant nurse; the nutritionist was responsible for formulating personalized nutrition management plans; the rehabilitation physician, diabetes specialist nurse, and pharmacist offered consultations for difficult problems in their own specialty areas; and the follow-up nurse was responsible for post-discharge follow-up management and data collection.

Preoperative assessment and preparation

Members included a transplant surgeon, a transplant nurse, an anesthesiologist, operating room nurses, and a hemodialysis nurse. (I) The transplant surgeon strictly evaluated the surgical indications, preoperative general conditions, and cardiopulmonary function according to the requirements in the *Clinical Technical Specification for Simultaneous Pancreas and Kidney Transplant* and formulated the preoperative dialysis plan together with the dialysis physician based on the patient's water, electrolytes, and acid-base balance. (II) The anesthesiologist and the theatre nurses thoroughly assessed the patient's anesthesia risk. (III) The transplant nurse offered preoperative preparation and psychological care for the patients based on the results of preoperative assessment performed by the MDT.

Intraoperative management

Intraoperative management was participated by a transplant surgeon, an anesthesiologist, and operating room nurses. The transplant nurse handed over the patient's preoperative assessment and preparation conditions to the operating room nurses, focusing on the special medical histories and the MDT's preoperative assessment results (including cardiopulmonary function and dialysis status), so as to enable the operating room nurses to monitor and maintain effective circulation and carry out fluid management, thus ensuring the intraoperative safety.

Postoperative management

(I) Condition observation

Monitoring was performed by the transplant team-directed MDT. (i) Changes in disease conditions were close monitored. The vital signs and central venous pressure were monitored on an hourly basis, with special attention to changes in blood pressure, heart rate, and heart rhythm. Post-transplant hypotension increases the risk of arterial graft thrombosis. The post-operative blood pressure should not be too low, and the systolic blood pressure should be maintained at 120–160 mmHg to ensure effective perfusion of the kidney and pancreas grafts and prevent oliguria secondary to hypotension or even delayed recovery of renal function and thrombosis. (ii) The wound dressings were observed, and the presence (or absence) of tenderness, distension, and/or tension in the transplantation area were assessed. The perirenal drainage tube, posterior pancreatic head drainage tube, vesicorectal pouch drainage tube (pouch of Douglas drainage tube in women), and gastric tube were placed after surgery for gastrointestinal (GI) decompression. All the tubes were fixed and in good condition. The drainage should be sufficiently patent. The volume, color, and properties of drained fluids were observed. (iii) During the daily medical and nursing integrated ward rounds, the transplant nurse performed 3-level quality control. Solutions to the major nursing issues were proposed according to changes in the disease conditions, which provided clear nursing guidance for clinical nurses.

(II) Fluid management

Goal-directed fluid therapy was applied to minimize cardiac workload, maintain effective circulating volume, and ensure tissue and organ perfusion. Fluid infusion was guided by the real-time, accurate, and continuous hemodynamic and volume

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monitoring. (I) The 24-hour fluid intake and output were accurately recorded after surgery. (II) The individualized fluid therapy protocols were developed on a daily basis based on the preoperative dialysis type, age, body weight, cardiac function, urine output, blood pressure, central venous pressure, and intraoperative fluid intake and output. Fluid management was dynamically adjusted when necessary. (III) The infusion of daily target ordered volume was required to be completed in each shift. (IV) The specialist quality indicators for fluid management were developed for each post-transplant patient, with an attempt to achieve optimal volume management through indicator-based quality control.

(III) Blood glucose management

Blood glucose is an important monitoring indicator after SPKT and can be used to intuitively assess the function of the pancreas. The postoperative blood glucose management program was jointly developed by the transplant nurse and the diabetes specialist nurse: (i) an instantaneous scanning glucose monitoring system was used for painless, rapid, accurate, continuous, and dynamic blood glucose monitoring. (ii) The blood glucose was monitored every hour from the day of surgery to the second postoperative day and then every 2–3 h on the third postoperative day. Then, the monitoring frequency was changed to before meals and 2 h after meals after the patients resumed eating by mouth. (iii) Special attention was paid to the occurrence of hyperglycemia or hypoglycemia: Postoperative emergency and high-dose hormone use may lead to stress-triggered elevation of blood glucose in a small number of patients. The possibility of delayed pancreatic graft function should be considered if there is refractory hyperglycemia. Thrombosis of the transplanted pancreas and/or graft pancreatitis should be ruled out, and early identification and early intervention are required if such conditions are present. Since the endocrine drainage method used in the surgery was based on systemic circulation and insulin does not circulate through the liver, some patients may experience hypoglycemia. Thus, the blood glucose needs to be closely monitored and managed in time.

(IV) Nutrition management

Personalized and phased nutritional support programs were developed for patients. (i) After SPKT, a gastric tube was placed for GI decompression for 5–7 days, and total parenteral nutrition (TPN) [25–30 kcal/(kg·d)] was offered. (ii) After the removal of the gastric tube, TPN was gradually transited to a full liquid diet and then a normal diet. (iii) The transplant surgeon, transplant nurse, and nutritionist closely cooperated to conduct a comprehensive nutritional assessment based on the patient's body mass index (BMI), total serum protein, and hemoglobin and according to the *Nutritional Risk Screening 2000* (NRS 2000). The nutritional programs were dynamically adjusted. TPN should be transited to a combination of enteral and parenteral nutrition. When transoral feeding could meet 60% of the target caloric requirement, parenteral nutrition was stopped and total enteral nutrition was offered. (iv) During the period when the patient resumed transoral feeding, the nursing priorities were changed to abdominal signs and GI reactions; blood and urine amylase, serum lipase, electrolytes, and blood glucose should be monitored, and any possible complications such as GI bleeding and intestinal infarction should be observed.

(V) Optimization of immunosuppressive regimen

Immunosuppression after SPKT must be individualized as much as possible under the premise of good function of the transplanted pancreas and kidney. (i) The immunosuppression regimen shall be customized according to the body weight, age, and metabolic type. (ii) An immunosuppression regimen based on tacrolimus + mycophenolate mofetil + hormones was used, and rabbit anti-human thymoglobulin and interleukin 2 (IL-2) inhibitors were used for immune induction. (iii) Drugs were administered via gastric tube during gastric tube placement, and GI decompression was continued after the gastric tube was clamped for 2 hours after drug administration. (iv) The blood concentration of tacrolimus was measured twice weekly. The immunosuppressant dosages were promptly adjusted according to drug concentration to maintain blood concentration at 5–15 ng/mL. (v) Priority was given to ensure proper drug administration, optimize patients' awareness and behavior, and broaden patients' drug knowledge.

(VI) Infection control and prevention

Strict infection control and prevention measures were applied. (i) Adequate preoperative bowel preparation was conducted to reduce abdominal contamination during intestinal surgery. (ii) After the surgery, the patients were transferred to the intensive care unit (ICU) for protective isolation, and the sheet and clothes were sterilized by using pressurized steam. (iii) 2% chlorhexidine wipes were applied to bath the patients; during the placement of the gastric tube, the mouth was rinsed with 0.9% saline and 5% sodium bicarbonate injection in an alternating manner; perineal wiping was per during the placement of indwelling urinary catheter, and skin cleanser was used to prevent incontinence-associated dermatitis. (iv) potential pathogens

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in the patients' secretions, drainage fluids, and excretions were regularly detected, and any abnormalities detected were intervened promptly. (v) Antimicrobials were rationally used.

(VII) Management of complications

The transplant surgeon and the specialist nurses were the key members of the complication management team. Evidence-based integrated prevention strategies for pulmonary infection, urinary tract infection, and abdominal infection were developed. The common complications and their management were as follows: (i) rejection: distension and tenderness in the transplantation area were investigated and the tension was observed; changes in body temperature, blood sugar, blood and urine amylase, lipase, and other indicators were monitored; changes in stool form were observed; and auxiliary examinations such as color ultrasound of pancreas graft, abdominal computed tomography (CT), and pancreas puncture biopsy were performed if necessary. (ii) Postoperative bleeding: The main causes of intra-abdominal bleeding after SPKT are abnormal coagulation function in uremic patients, routine postoperative anticoagulation therapy, graft pancreatitis, and local infection. The patients' blood pressure and heart rate should be closely monitored, and the color and volume of drainage fluids should be observed. The anticoagulant drugs should be rationally used, and any bleeding tendency should be observed. (iii) Pancreatic fistula and intestinal fistula: pancreatic fistula is characterized by changes in color and nature of drainage fluid and significant elevation of amylase and lipase levels, along with increased body temperature in patients with infection. Intestinal fistula is characterized by severe abdominal pain, abdominal distension, peritoneal irritation, and other manifestations of peritonitis, accompanied by fever, elevated white blood cell count, and drainage of fecal residue-like fluid (drainage fluid obtained by abdominal puncture is brown and has a fecal odor). Free gas can be seen on imaging. Immediate surgical intervention should be offered once a diagnosis of pancreatic fistula or intestinal fistula is confirmed. (iv) Pancreas graft thrombosis: It has insidious early manifestations, including elevated blood glucose as well as elevated blood and urine amylase and lipase levels. In the more advanced stages of pancreas graft thrombosis, the blood and urine amylase and lipase levels sharply decrease, along with pain or tenderness in the transplantation area. The diagnosis can generally be confirmed by Doppler ultrasonography, although CT or magnetic resonance imaging (MRI) angiography can also be valuable. (v) Graft pancreatitis: The typical signs and symptoms include pain in the abdominal wall at the transplant site, abdominal distension, tenderness, and significantly elevated blood and urine amylase levels. Graft pancreatitis should be distinguished from pancreatic fistula; a drainage fluid amylase level of up to 10,000 U often suggests pancreatic fistula. (vi) Intestinal obstruction: Intestinal obstruction is related to long operative time, severe edema of the intestinal wall, history of preoperative peritoneal dialysis complicated by peritonitis, GI dysfunction, and unreasonable diet. Its clinical manifestations include nausea, vomiting, abdominal distension, and delayed defecation. The transplant nurse should preemptively identify potential nursing problems. In this study, the transplant nurse organized joint rounds by the MDT to achieve the early diagnosis, treatment, and nursing of these complications, so as to lower the incidence of complications and increase the survival rates of both grafts and patients.

(VIII) Early rehabilitation and functional exercises

In order to promote early rehabilitation and prevent pulmonary infections, individualized physical and mental preparation was completed according to patients' cognitive ability and psychological status (11) and rehabilitation exercise plans were developed and implemented: (i) preoperatively, patients were instructed on respiratory function exercise and bed bowel training. (ii) At post-surgical 2 h, the patients were assisted to turn over, to perform bed extremity extension and flexion exercises, to do ankle pumps, and to receive pneumatic therapy. Patients were also instructed how to cough and spit effectively. (iii) On post-operative day 3–4, the patients began to perform ambulatory activities including respiratory function exercise and limb exercise. (iv) All the exercises were carried out stepwise and individualized. The activities were stopped when the patient experienced discomfort. (v) Through joint rounds, the transplant nurse and the rehabilitation physician comprehensively assessed the postoperative condition of patients, asked the rehabilitation department to assist in rehabilitation exercises according to their conditions, and to jointly formulate rehabilitation exercise prescriptions to promote early postoperative recovery.

(IX) Psychological care

The team aimed to establish a good doctor-patient relationship and learn the psychosocial needs of the patients and their families. Psychological interventions and services were tailored in the different stage of the surgery. For patients with anxiety and/or depression, targeted psychological counseling was offered according to their gender, age, and literacy level. Patients' mental status and emotional reactions were regularly observed, and the postoperative pain, sleep problems, and irritability

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were promptly managed. The patients were also instructed to identify and cope with stress and achieve self-relaxation, and their family members were taught how to provide appropriate mental and somatic care to the patients, thus helping the patients to gain confidence in fighting the disease during the perioperative period.

(X) Health education

Health education empowers patients to take responsibility for their own care and improves their compliance with treatment. In our center, health education was carried out throughout the perioperative period: (i) a clinical nursing pathway for SPKT was established, which covered preoperative awareness raising and postoperative education on infection prevention, functional exercise, medications, diets, observation of complications, self-management, and life- and work-related activities. (ii) The clinical nursing pathway was carried out on a daily basis by the transplant nurse, who conducted the whole-course health education from the preoperative period to the 15th postoperative day. (iii) Health promotion leaflets and popular science videos were created and distributed to improve patients' self-management ability after discharge.

(XI) Continuity of care

The long-term postoperative follow-up visits were arranged. (i) The "Follow-up Management Policies for Simultaneous Pancreas and Kidney Transplant" were established, and dedicated follow-up nurses were designated. (ii) The follow-up frequencies were as follows: within 3 months after surgery: once a week; 3–6 months after surgery: every 2 weeks; and more than 6 months after surgery: monthly. (iii) The content of the follow-up visits included the general condition of the patient, laboratory tests, and color ultrasound findings of the pancreas and kidney grafts. (iv) Both outpatient follow-up and telephone follow-up were applied. In addition, outpatient follow-up by specialist nurses was adopted to provide postoperative evaluation and health education for patients. (v) Health education was also offered with the help of WeChat and other social media and by giving regular health education lectures.

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