

# World Journal of *Gastrointestinal Surgery*

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The primary aim of *World Journal of Gastrointestinal Surgery* (WJGS, *World J Gastrointest Surg*) is to provide scholars and readers from various fields of gastrointestinal surgery with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJGS mainly publishes articles reporting research results and findings obtained in the field of gastrointestinal surgery and covering a wide range of topics including biliary tract surgical procedures, biliopancreatic diversion, colectomy, esophagectomy, esophagostomy, pancreas transplantation, and pancreatectomy, etc.

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Basic Study

## Feasibility and safety of “bridging” pancreaticogastrostomy for pancreatic trauma in Landrace pigs

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### Abstract

#### BACKGROUND

In recent years, we created and employed a new anastomosis method, “bridging” pancreaticogastrostomy, to treat patients with extremely severe pancreatic injury. This surgery has advantages such as short length of surgery, low secondary trauma, rapid construction of shunts for pancreatic fluid, preventing second surgeries, and achieving good treatment outcomes in clinical practice. However, due to the limited number of clinical cases, there is a lack of strong evidence to support the feasibility and safety of this surgical procedure. Therefore, we carried out animal experiments to examine this procedure, which is reported here.

#### AIM

To examine the feasibility and safety of a new rapid method of pancreaticogastrostomy, “bridging” pancreaticogastrostomy.

#### METHODS

Ten Landrace pigs were randomized into the experimental and control groups, with five pigs in each group. “Bridging” pancreaticogastrostomy was performed in the experimental group, while routine mucosa-to-mucosa pancreaticogastrostomy was performed in the control group. After surgery, the general condition, amylase levels in drainage fluid on Days 1, 3, 5, and 7, fasting and 2-h postprandial blood glucose 6 mo after surgery, fasting, 2-h postprandial peripheral blood insulin, and portal vein blood insulin 6 mo after surgery were

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assessed. Resurgery was carried out at 1 and 6 mo after the former one to examine the condition of the abdominal cavity and firmness and tightness of the pancreaticogastric anastomosis and pancreas.

## RESULTS

After surgery, the general condition of the animals was good. One in the control group did not gain weight 6 mo after surgery, whereas significant weight gain was present in the others. There were significant differences on Days 1 and 3 after surgery between the two groups but no differences on Days 5 and 7. There were no differences in fasting and 2-h postprandial blood glucose and fasting and 2-h insulin values of postprandial peripheral blood and portal vein blood 6 mo after surgery between the two groups. One month after surgery, the sinus tract orifice/anastomosis was patent in the two groups. Six months after surgery, the sinus tract orifice/anastomosis was sealed, and pancreases in both groups presented with chronic pancreatitis.

## CONCLUSION

“Bridging” pancreaticogastrostomy is a feasible and safe a means of damage control surgery during the early stage of pancreatic injury.

**Key Words:** Pancreatic trauma; Damage control surgery; “Bridging” pancreaticogastrostomy; Severe pancreatic injury; Safety

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**Core Tip:** This is a basic experimental research paper on the damage control surgery for pancreatic trauma, “bridging” pancreaticogastrostomy. To examine the feasibility and safety of this technique in Landrace pigs, we designed a series of research experiments. We found “bridging” pancreaticogastrostomy can be used to establish rapidly a channel and has similar short- and long-term results compared with the routine mucosa-mucosa pancreaticogastrostomy.

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## INTRODUCTION

In emergency surgery for severe pancreatic trauma, controlling damage and preventing secondary damage is a problem that deserves attention[1-4]. There are not many options for surgeons to deal with this problem. Examples include emergent pancreaticoduodenectomy and pancreatic repair surgery[5-7]. The aims of the surgery are to shunt rationally pancreatic fluid, bile, and digestive juices in addition to hemostasis and to repair organ damage in the cavity. In recent years, we created and employed a new anastomosis method, “bridging” pancreaticogastrostomy, to treat patients with an extremely severe pancreatic injury. This surgery has advantages such as short length of surgery, low secondary trauma, rapid construction of shunts for pancreatic fluid, preventing second surgeries, and achieving good treatment outcomes in clinical practice. However, due to the limited number of clinical cases, there is a lack of strong evidence to support the feasibility and safety of this surgical procedure. Therefore, we carried out animal experiments to examine this procedure, which is reported here.

## MATERIALS AND METHODS

### *Selection and grouping of experimental animals*

Ten healthy Landrace pigs weighing 20–25 kg were selected with no gender restrictions. The pigs were provided by the Experimental Animal Center of Chinese PLA General Hospital. All animals were reared in single cages and periodically fed with refined standard pig feed. Animals were fasted 1 d before surgery and in the first 2 d after surgery but allowed to drink water. Feeding was gradually resumed from Day 3 onwards. Pigs were randomized into the experimental and control groups, with five pigs in each one. “Bridging” pancreaticogastrostomy was performed in the experimental group (Group A), while routine mucosa-to-mucosa pancreaticogastrostomy was performed in the control group (Group B). The operational procedures for the animal experiments were approved by the Institutional Animal Care and Use Committee of PLA General Hospital.

### *Experimental methods and procedures*

**Animal anesthesia:** Sedazine II (xylazine hydrochloride injection) + midazolam injection (volume ratio: 1:1) was used for anesthesia induction by 0.5 mL/kg intramuscular injection. After endotracheal intubation was successful, the ventilator was first connected and then adjusted so that tidal volume was 10 mL/kg, respiratory rate was 16/min, and FIO<sub>2</sub> was 0.4. Positive end-expiratory pressure was maintained at 4 cm H<sub>2</sub>O to maintain good oxygenation in animals. Isoflurane (0.8%) inhalation anesthesia combined with intravenous injection of 2–5 mg/kg fentanyl citrate through the ear vein was used for anesthesia maintenance. Intravenous infusion of rocuronium bromide (20–50 mg/pig) was used as the muscle relaxant. The external jugular vein was dissected to establish venous access. The carotid artery was dissected for connection to the arterial monitoring machine. During surgery, balanced solutions were used to supplement the physiological needs and intraoperative fluid loss in animals. During surgery, blood pressure, heart rate, and temperature were monitored.

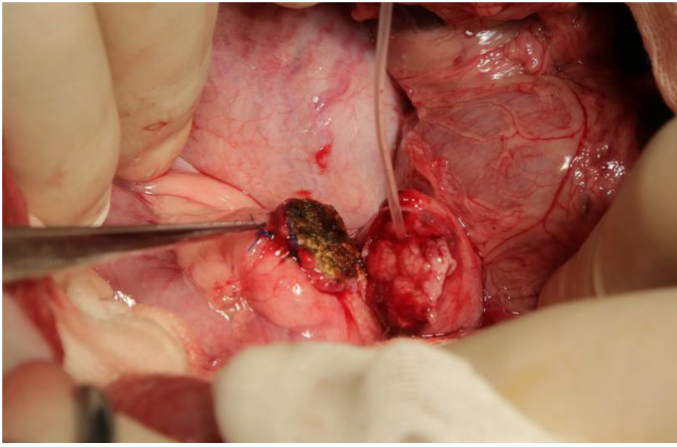
**Surgery procedures:** After anesthesia, an abdominal midline incision was made up to the second row of nipples and down to 5 cm above the navel. The total length was approximately 12 cm, and the abdomen was accessed layer by layer. The duodenum was palpated along the stomach and pylorus, and the duodenum was pulled. A thin pink pancreatic head could be seen to be pulled up. The pancreatic head was dissected, the proximal pancreas was retained, and a cross U-type was made using 5–0 prolene sutures (Figure 1). A 0.6 mm or 0.8 mm pancreatic duct drainage tube was inserted into the distal end.

A “bridging” pancreaticogastrostomy was performed in the experimental group: The gastric wall near the pancreatic stump (generally, the posterior gastric wall at the greater curvature near the pylorus is selected) was used for perforation in an avascular region before the pancreatic duct was inserted into the gastric cavity. At the insertion site, a purse-string suture of the serosa was carried out. Approximately 2 cm of the pancreatic duct was retained between the pancreas and the stomach (Figure 2). A large volume of physiological saline was used to rinse the abdominal cavity. A rubber drainage tube was retained at the abdominal wall and secured. Another hole was made beside the incision for drainage. Approximately 2 cm of drainage tube was retained at the outer end. The pig was carefully examined for the absence of pancreatic fistula and bleeding before the abdomen was closed layer by layer.

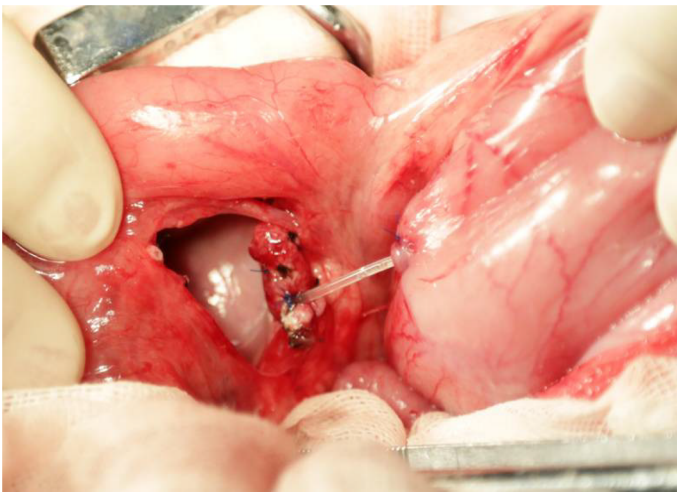
Routine pancreaticogastrostomy was performed in the control group: Mucosa-to-mucosa pancreaticogastrostomy was carried out at the gastric wall at the pancreatic stump side (Figure 3). Other procedures were the same as the experimental group.

### *Observation indicators*

Observation indicators included the general condition of animals, such as feeding, bowel movements, activity, and weight changes. Pancreatic fistula evaluation: Drainage fluid was collected on Days 1, 3, 5, and 7 after surgery to measure amylase levels. The animals were euthanized in two batches: The first batch was euthanized 1 mo after surgery, and two pigs each were randomly selected from the experimental and control groups. The second batch was euthanized 6 mo after surgery, and three pigs each were randomly selected from the experimental and control groups. Resurgery was performed before euthanasia in the animals, and the anesthesia procedure was the same as above. Surgery was performed to examine the abdominal cavity, including the presence/absence of walled-off necrosis, inflammation in the residual pancreas (color, texture), and patency of the sinus tract between the pancreas



**Figure 1** Preparation of pancreatic stumps in all animals in the study.



**Figure 2** “Bridging” pancreaticogastrostomy was performed in the experimental group. The distance between the pancreatic stump and the stomach was approximately 2 cm.



**Figure 3** Routine mucosa-to-mucosa pancreaticogastrostomy was performed in the control group.

and stomach. Fasting and 2-h insulin values of postprandial venous blood were collected before euthanasia for animals that were euthanized 6 mo after surgery. Blood samples were used for blood glucose and insulin measurements. During surgery, portal vein blood was collected to measure insulin levels.



### Statistical analysis

Statistical analysis was performed with SPSS 19.0 (Armonk, NY, United States). Continuous variables were presented as mean  $\pm$  standard error or median and 95% confidence interval and compared by using Student's *t*-test, the Mann-Whitney *U* test, or Wilcoxon's signed-rank test, as appropriate. *P* < 0.05 was considered statistically significant.

## RESULTS

### Postoperative general condition of animals

All animals in both groups survived the surgery, and no perioperative death occurred. Among animals that were continuously observed for 6 mo, one from the control group did not gain weight, which was the same as before surgery. The weight of the remaining animals increased from 30 kg before surgery to 86–90 kg.

### Comparison of postoperative laboratory test markers

From postoperative amylase measurements (Table 1), it can be seen that amylase decreased to normal levels 5 d after surgery in most animals in the experimental and control groups, and only one animal from the control group showed a rebound in amylase level, which increased on Day 7 after surgery. Amylase levels were significantly higher in the experimental group than in the control group on Day 1 after surgery, but there were no differences between the two groups after Day 3. Fasting and 2-h postprandial blood glucose was measured 6 mo after surgery (Table 2). The comparison showed that there was no statistically significant difference between the two groups. Fasting and 2-h peripheral blood insulin and portal vein blood insulin levels were measured 6 mo after surgery (Table 3). The comparison showed that there was no statistically significant difference between the two groups.

### Resurgery status

During the resurgery 1 mo after the surgery, the drainage tube spontaneously fell out. After open abdomen surgery was carried out, we found that there were severe intra-abdominal adhesions. The sinus tract in the experimental group was intact, and the intragastric sinus tract opening was clearly seen (Figure 4). The pancreaticogastric anastomosis in the control group showed good healing, and the intragastric anastomosis was clearly seen (Figure 5).

During resurgery 6 mo after surgery, intra-abdominal adhesions were reduced. Multiple walled-off necroses were present in the abdominal cavity in one from the control group, and no necrotic lesions were present in the abdominal cavity of the other animals. Careful autopsy of the stomach did not find sinus tract opening or anastomosis in the experimental and control groups. The texture of the pancreas in all animals was hard, and the pancreatic duct was significantly dilated, which denotes the presentation of chronic pancreatitis. The pancreas and sinus tract were used for pathological tests. The results were the same between the experimental and the control groups. Hematoxylin and eosin staining showed that the pancreas was filled with large amounts of fibrous tissues and acinar atrophy and there was a drastic decrease in acinar cells and pancreatic islets (Figures 6 and 7).

## DISCUSSION

The drainage of pancreatic fluid while controlling damage during emergent surgical treatment of severe pancreatic trauma (American Association for the Surgery of Trauma grade 4 or 5) is extremely important[8–10]. Even though pancreatic fluid drainage can be achieved in conventional surgeries, such as the Whipple procedure and middle pancreatectomy followed by pancreaticojejunal Roux-en-Y anastomosis, surgical trauma is a factor that cannot be overlooked. How do we solve the problem of pancreatic fluid drainage while complying with the principle of damage control? We innovatively proposed a “bridge” between the pancreas and stomach in which only intubation is carried out, which is not an anastomosis in the traditional sense. We termed this technology “bridging” pancreaticogastrostomy. This procedure can rapidly solve the problem of pancreatic fluid drainage without simultaneously increasing surgical trauma. After we inserted a silicon tube with the same diameter as the pancreatic duct into the pancreatic duct at the damaged site, the silicone tube was

**Table 1 Level of amylase in the abdominal drainage fluid of each animal after operation**

| Day | Experimental group |       |       |       |       | Control group |       |       |       |        | P value |
|-----|--------------------|-------|-------|-------|-------|---------------|-------|-------|-------|--------|---------|
|     | No. 1              | No. 2 | No. 3 | No. 4 | No. 5 | No. 6         | No. 7 | No. 8 | No. 9 | No. 10 |         |
| 1   | 32916              | 11278 | 10557 | 24107 | 13576 | 7653          | 8804  | 2516  | 13865 | 658    | 0.04    |
| 3   | 2329               | 8088  | 3760  | 7089  | 4632  | 591           | 1685  | 2610  | 7538  | 216    | 0.15    |
| 5   | 278                | 200   | 178   | 232   | 485   | 517           | 108   | 955   | 4629  | 58     | 0.31    |
| 7   | 1006               | 14    | 79    |       |       | 23            | 77    | 39256 | 3237  | 16     | 0.35    |

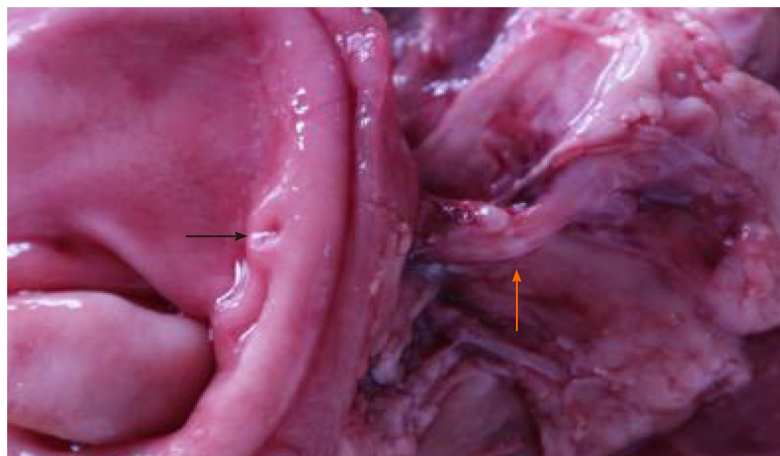
The missing data is due to difficulty in collection or no drainage.

**Table 2 Fasting and 2-h postprandial blood glucose 6 mo after surgery**

|                                | Experimental group |       |       | Control group |       |        | P value |
|--------------------------------|--------------------|-------|-------|---------------|-------|--------|---------|
|                                | No. 5              | No. 6 | No. 7 | No. 8         | No. 9 | No. 10 |         |
| Fasting blood glucose          | 5.57               | 5.2   | 5.88  | 4.49          | 5.23  | 5.41   | 0.21    |
| 2-h postprandial blood glucose | 5.52               | 7.57  | 7.12  | 7.03          | 6.94  | 5.77   | 0.84    |

**Table 3 Fasting, 2-h postprandial peripheral blood insulin and portal vein blood insulin 6 mo after surgery**

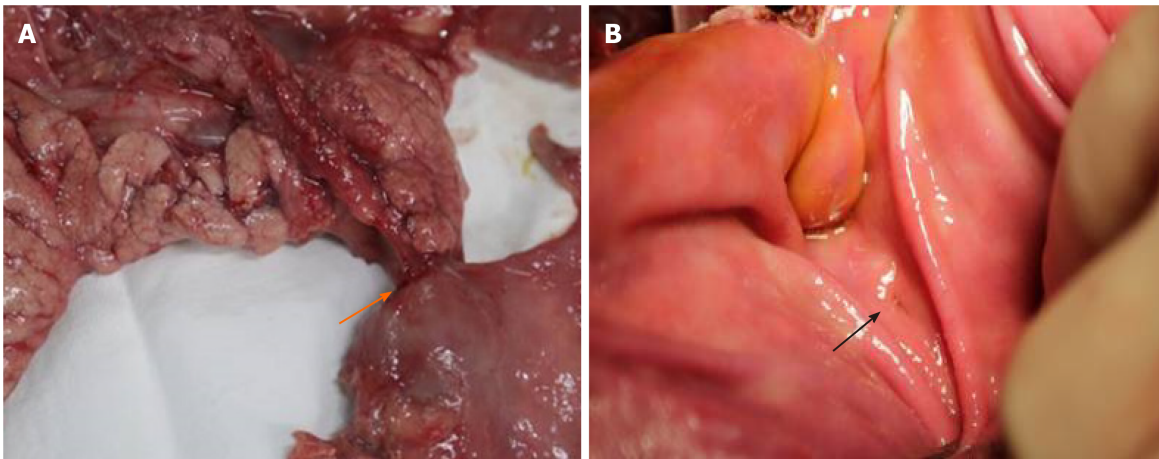
|                                           | Experimental group |       |       | Control group |       |        | P value |
|-------------------------------------------|--------------------|-------|-------|---------------|-------|--------|---------|
|                                           | No. 5              | No. 6 | No. 7 | No. 8         | No. 9 | No. 10 |         |
| Fasting peripheral blood insulin          | 23.6               | 18.6  | 27.4  | 14.3          | 17.3  | 21.3   | 0.16    |
| 2-h postprandial peripheral blood insulin | 31.2               | 25.3  | 31.7  | 26.7          | 37.9  | 35.4   | 0.38    |
| Portal vein blood insulin                 | 74.9               | 54.3  | 62.1  | 57.1          | 52.4  | 51.5   | 0.18    |



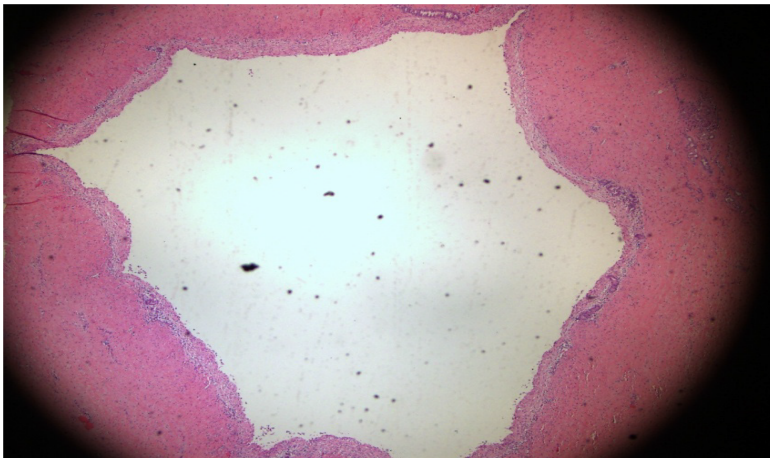
**Figure 4 Sinus tract between the pancreas and stomach.** Orange arrows showed the sinus tract between the pancreas and stomach 1 mo after “bridging” pancreaticogastrostomy. Black arrows showed the sinus tract opening in the stomach.

passed through the posterior gastric wall and the anterior gastric wall to the outside of the body to establish a “bridging” anastomosis. Three to four months after surgery, gastroscopy could be used to cut the drainage tube in the gastric cavity and to pull out the outer part; the connection between the pancreas and the stomach forms a channel.

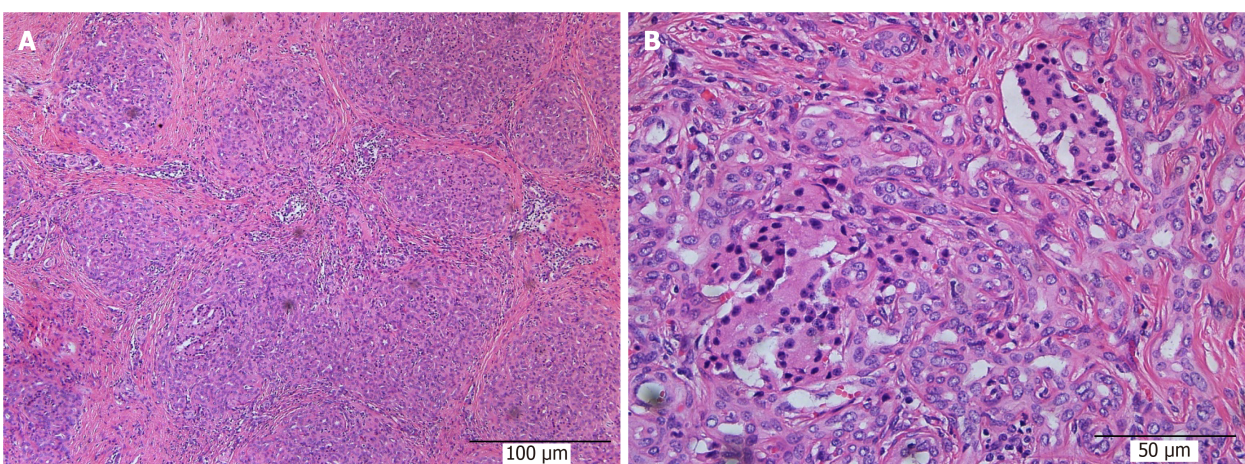
Techniques similar to “bridging” anastomosis have been reported. Xu *et al*[11] used pancreaticoenteric dissection bridge drainage to treat two patients with severe pancreatic fistula and intra-abdominal bleeding after Whipple surgery. During resurgery, the pancreatic stump was resutured, and a drainage tube was inserted into



**Figure 5 Tight connection between the pancreas and stomach.** A: Orange arrows show the tight connection between the pancreas and stomach after routine mucosa-to-mucosa pancreaticogastrostomy; B: Black arrows show the anastomosis.



**Figure 6 Significantly dilated pancreatic duct.**



**Figure 7 The pancreas was filled with large amounts of fibrous tissues and acinar atrophy with a drastic decrease in acinar cells and pancreatic islets.** A:  $\times 100$ ; B:  $\times 400$ .

the pancreatic duct in the distal end. The jejunal loop was sealed, and the drainage tube in the pancreatic duct was inserted through another hole into the jejunal loop. Around 10 cm of the internal drainage tube was present in the abdominal cavity to create internal drainage. After surgery, patients recovered and were discharged. No



related complications occurred during the 18-mo follow-up. In 2010, Kent *et al*[12] used bridging stents to treat seven patients with severe pancreatic fistula after Whipple surgery, of which success was achieved in five patients. Their method was similar to the method of Xu *et al*[11], the aforementioned methods mainly focused on the management of severe pancreatic fistula after Whipple surgery. There are no reports on the treatment of severe pancreatic trauma at present.

“Bridging” pancreaticogastrostomy mentioned in this article has the following strengths: (1) Direct insertion of a tube to create an internal fistula to achieve pancreatic fluid drainage; (2) The drainage tube passing through the posterior gastric wall and anterior gastric wall to the outside of the body to form external drainage to facilitate observation of pancreatic fluid drainage; in the later stage, gastroscopy can be used for resection and removal of the lateral side, and internal drainage is formed in the medial side; (3) Short operation duration and rapid repair, which minimize the length of surgery; (4) Retaining pancreatic function; (5) No traditional anastomosis present; therefore, fistula due to poor anastomosis healing would not occur; and (6) Preventing resurgery for pancreatic fluid sinus tract or pancreaticojejunostomy.

This experiment is a supplement to clinical studies and validates the feasibility of the new method of pancreatic fluid drainage through “bridging.” In particular, we carried out short- and long-term observations of “bridging” pancreaticogastrostomy. From the study results, we found that severe pancreatic leakage did not occur at the early stages of “bridging” anastomosis. In the late stages, the main problem is the detachment of the pancreatic duct drainage tube and drainage sinus tract stenosis, resulting in the pancreatic stump becoming harder and pancreatic atrophy. This is similar to traditional pancreaticogastrostomy. Pancreaticogastric anastomosis was first reported in 1946[13]. Many researchers believed that pancreaticogastrostomy is a simple and safe anastomosis method. The incidence of the early pancreatic fistula for pancreaticogastric anastomosis was lower than that for pancreaticojejunostomy [14,15]. However, long-term follow-up showed that anastomosis stenosis tends to occur at the later stages, and this complication will become more and more severe as time progresses[16,17]. A study showed that glucose tolerance abnormalities tend to occur within 3 years of pancreaticogastrostomy, and problems caused by anastomosis stenosis 10 years after surgery will become more and more remarkable[18]. In this study, no experimental animals developed blood glucose and insulin abnormalities 6 mo after surgery, but sinus tract stenosis became more significant.

## CONCLUSION

In conclusion, “bridging” pancreaticogastrostomy is completely feasible as a means of damage control surgery during the early stage of pancreatic injury. However, it will lead to pancreaticogastric anastomosis stenosis at the late stage, and pancreatic endocrine and exocrine functions are worthy of further examination. The greatest limitations of this study are that pancreatic duct support tubes were all detached in the two groups, strong muscle contractions in the gastric wall resulted in sinus tract/anastomosis closure, and chronic pancreatitis occurred at the late stage.

## ARTICLE HIGHLIGHTS

### Research background

In recent years, a new anastomosis method, “bridging” pancreaticogastrostomy, to treat patients with an extremely severe pancreatic injury was created and employed. This surgery has advantages such as short length of surgery, low secondary trauma, rapid construction of shunts for pancreatic fluid, preventing second surgeries, and achieving good treatment outcomes in clinical practice.

### Research motivation

There is a lack of strong evidence to support the feasibility and safety of this surgical procedure. We carried out an animal experiment to examine this procedure.

### Research objectives

This study aimed to examine the feasibility and safety of a new rapid method of pancreaticogastrostomy, “bridging” pancreaticogastrostomy.



### Research methods

In total, 10 Landrace pigs were randomized into the experimental and control groups. “Bridging” pancreaticogastrostomy was performed in the experimental group, while routine mucosa-to-mucosa pancreaticogastrostomy was performed in the control group. The resurgery was carried out at 1 and 6 mo after the first surgery to examine the condition of the abdominal cavity and firmness and tightness of the pancreaticogastrostomy anastomosis and pancreas.

### Research results

One animal in the control group did not gain weight 6 mo after surgery, whereas significant weight gain was present in the others. There were significant differences on Days 1 and 3 after surgery between the two groups but no differences on Days 5 and 7. One month after surgery, the sinus tract orifice/anastomosis was patent in the two groups. Six months after surgery, the sinus tract orifice/anastomosis was sealed, and pancreases in both groups presented with chronic pancreatitis.

### Research conclusions

“Bridging” pancreaticogastrostomy is completely feasible as a means of damage control surgery during the early stage of pancreatic injury.

### Research perspectives

“Bridging” pancreaticogastrostomy can be used to establish rapidly a channel and has similar short- and long-term results as conventional pancreaticogastrostomy.

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