1. Introduction

As a common condition often associated with symptomatic gastroesophageal reflux disease (GERD), hiatal hernia (HH) refers to abdominal tissue structure other than the esophagus entering the thoracic cavity through the enlarged diaphragm hiatus. Global incidence of the GERD is approximately 10% entering the thoracic cavity through the enlarged diaphragm hiatus. Global incidence of the GERD is approximately 10% to 50%, and 5% to 10% incidence happened in China with hiatus. Hiatal hernia (HH) is associated with significantly reduced length of stay, and a lower mortality in the uncomplicated group compared with outcomes of the open approach. A retrospective study of laparoscopic HH repair in 221 patients found the GERD-health-related quality-of-life (GERD-HRQL) significantly decline from preoperative to 14.5 months follow-up.

Recent studies demonstrated that the use of mesh to enhance esophagectomy can reduce recurrence rates compared to suturing repair at short-term follow-up. Several mesh materials are used for surgery, including synthetic and biological with differing shapes and fixation methods. Biological meshes have superior histocompatibility and decreased foreign body reactions and postoperative rejection. The incidence of postoperative esophageal stenosis, infection, esophageal erosion, and cutting and perforation in biological meshes is significantly lower than that in synthetic meshes. However, the persistence of recurrence rates and mesh-related complications such as mesh erosion or displacement, infection, and development of fibrotic stenosis in biological meshes are maintained. Controversies with outcomes of the open approach. A retrospective study of laparoscopic HH repair in 221 patients found the GERD-health-related quality-of-life (GERD-HRQL) significantly decline from preoperative to 14.5 months follow-up.

Recent studies demonstrated that the use of mesh to enhance esophagectomy can reduce recurrence rates compared to suturing repair at short-term follow-up. Several mesh materials are used for surgery, including synthetic and biological with differing shapes and fixation methods. Biological meshes have superior histocompatibility and decreased foreign body reactions and postoperative rejection. The incidence of postoperative esophageal stenosis, infection, esophageal erosion, and cutting and perforation in biological meshes is significantly lower than that in synthetic meshes. However, the persistence of recurrence rates and mesh-related complications such as mesh erosion or displacement, infection, and development of fibrotic stenosis in biological meshes are maintained. Controversies
the side of the small curvature of the stomach was severed, and the left diaphragm foot was exposed, the omentum tissue on spleen were severed segment by ultrasonic scalpel, the gastrodi-
were placed to grasp the fascia above the esophageal hiatus to was located under the xiphoid process, and Babcock forceps or separated forceps were placed. The third 0.5-cm hole was the secondary surgical hole of the main knife, and grasped and instruments used by assistants. The second 0.5-cm hole was located under the costal margin of the left axilla, (e.g., ultrasonic scalpel) were placed. The first 0.5-cm hole was the main operating hole, and the main surgical instruments was placed through it. The second 1-cm hole was located 2-cm wide; at least 2 stitches were sewn on the muscular esophageal layer) to form a 360° loose fold (Nissen fundus folding), which wrapped the whole circumference of the lower esophagus without tension (Fig. 1C–H).

2. Methods

2.1. Patients

The present retrospective study was conducted on patients undergoing 4K laparoscopic HH repair and Nissen folding in the Minimally Invasive Surgery Department of the Brain Hospital of Hunan Province from August 2019 to August 2020, which was approved by the Ethics Committee of Brain Hospital of Hunan Province (# (2020) LS [K] No.13), and the informed consent was exempted. The inclusion criteria were age > 18 years, GERD and HH diagnosed by clinical manifestations, computed tomography (CT) or magnetic resonance imaging (MRI), endoscopy, upper gastrointestinal angiography, esophageal acid measurement, and manometry; underwent 4K laparoscopic HH repair and Nissen folding. The surgical indications conformed to the international consensus on indications for anti-reflux surgery.[11] Patients in whom surgery was contraindicated; those who had a previous hiatal surgery; and who converted to laparotomy or a combination with other procedures intraoperatively; those with a specific allergic constitution, including severe cardiac and liver insufficiency (cardiac function grade III and above; those with alanine transferase or aspartate aminotransferase >2.5-time the upper limit of normal values) were excluded.

2.2. Surgical technique

Non-crosslinked regenerative biological meshes ( Biosis Healing Biological Technology Co., Ltd., China) composed of multi-layer acellular porcine small intestinal submucosal materials were used to perform a tension-free HH repair under a 4K laparoscope ( Olympus VISERA 4K OTV-S400, Japan). This study adopted a 7-step surgical procedure. After radiography exhibited partial hernia of gastric fundus into esophageal hiatus (Fig. 1A and B), the patient was placed in a supine position with both lower limbs abducted and the head 30-degrees higher than the feet, with the operator standing between the patient's legs. A pneumoperitoneum was established on the umbilicus, with the pneumoperitoneum pressure at 12-mm Hg. Two 1-cm and 3 0.5-cm holes were established in the upper abdomen, and a trocar of the corresponding size was inserted. The first 1-cm hole was located at the junction of the umbilicus and the middle and lower one-third of the xiphoid process, and a 30 endoscope was placed through it. The second 1-cm hole was located 2-cm below the costal margin of the midline of the left clavicle, which was the main operating hole, and the main surgical instruments (e.g., ultrasonic scalpel) were placed. The first 0.5-cm hole was located under the costal margin of the front line of the left axilla, and instruments used by assistants. The second 0.5-cm hole was located under the rib margin of the right clavicular midline and was the secondary surgical hole of the main knife, and grasped forceps or separated forceps were placed. The third 0.5-cm hole was located under the xiphoid process, and Babcock forceps were placed to grasp the fascia above the esophageal hiatus to open the liver and expose the hiatus position.

The HH contents were reduced, the omentum tissue and short gastric blood vessels between the fundus of the stomach and spleen were severed segment by ultrasonic scalpel, the gastrodi-
asphragm and esophageal diaphragm ligament were severed free, the left diaphragm foot was exposed, the omentum tissue on the side of the small curvature of the stomach was severed, and the right diaphragm foot and anterior peritoneum of esophagus were freed. The free esophageal length was increased to ≥5-cm to create the posterior esophageal space. The diaphragm feet on both sides were intermittently sutured with 2-0 propylene silk thread (Ethicon) to reduce the esophageal hiatus, trimmed with a trimmable concave biological mesh, and filled in front of the esophageal hiatus. The diaphragm feet on both sides were intermittently sutured and fixed with 3-0 propylene silk thread (Ethicon). The fundus of the stomach was pulled from the back of the esophagus to the front and sutured with the gastric wall on the left side of the esophagus (2-3 stitches were intermittently sutured with 2-0 silk thread, 2-cm wide; at least 2 stitches were sewn on the muscular esophageal layer) to form a 360° loose fold (Nissen fundus folding), which wrapped the whole circumference of the lower esophagus without tension (Fig. 1C–H).

2.3. Data collection

Baseline characteristics regarding the sex, age, height, weight, body mass index, medical history, and American Society of Anesthesiologists (ASA) score of the patients were collected. HH was divided into the following 4 types according to Barrett classification. Type I: Sliding type. Type II: Paraesophageal type. Type III: Mixed type. Type IV: Multi-organ type.[13]

2.4. Outcome and follow-up

Perioperative indicators, including operating time, intraoperative estimated blood loss, hospitalization time, incidence of intraoperative vagus nerve injury, incidence of postoperative hemorrhage of surgical site, symptom relief rate, VAS score, dysphagia, esophageal stenosis, gastric fistula, esophageal fistula, and mesh infection; and reoperation were collected. Intraoperative vagus nerve injury referred to intraoperatively cut off and thermal injury by appliance. A Visual Analog Scale (VAS) was used to evaluate the degree of pain, and the subjective pain perception of patients was quantified by the VAS scale from 1 to 10. Dysphagia based on Saeed criteria.[14] 0: No swallowing; 1: Swallows liquid difficultly, without pasty nor solids; 2: Swallows normal liquid, pasty difficultly, without swallowing solids; 3: Swallows liquid and pasty normally, with swallowing solids difficultly; 4: Swallows liquid and pasty normally, difficult to swallow solids; 5: Normal swallowing.

The follow-up was performed postoperatively through the outpatient department. The first follow-up was 1 month after surgery, with an interval of 3 months and up to 16 months. All postoperative follow-up symptoms were assessed by gas-
troesophageal reflux disease questionnaire (GerdQ).[15,16] Symptomatic recurrence was defined as patient reports of symp-
toms of GERD. The follow-up also included parameters such as high-resolution esophageal manometry, 24-hours esophageal pH monitoring, CT, gastroscopy, and upper gastrointestinal angiography to determine radiographic recurrence.[17] Radiographic recurrence was defined as evidence of HH.

2.5. Statistical analysis

Statistical analysis was conducted using SPSS 22.0. Variables with normal distribution were presented as mean ± SD, and discordance with normal distribution were expressed as median (range).

3. Results

3.1. Patient demographics

106 patients, 62 (58.4%) men and 44 (41.5%) women underwent 4K laparoscopic HH repair with biologic mesh reinforcement.
The ages of the patients were 52.4 (32–85) years, and the body mass index was 24.8 (18.4–35.1) kg/m². Demographic information and medical history of the patients, including hypertension, diabetes mellitus, hyperlipidemia, history of myocardial infarction, and smoking status, are presented (Table 1).

### 3.2. Operative data

HH was diagnosed intraoperatively in 104 (98.1%) patients, whereas 2 (1.8%) were diagnosed preoperatively. Type I to IV HH was included. The ASA physical status score was calculated that 77 (72.6%), 27 (25.4%), and 2 (1.88%) patients exhibited scores 1, 2, and 3, respectively. The surgical time for all cases was 70.9 ± 8.72 min. The intraoperative blood loss was 30.0 ± 9.89 mL, and length of hospital stay was 4.8 ± 0.76 days. No intraoperative or perioperative complications, including vagus nerve injury, were observed (Table 2).

### 3.3. Postoperative data and follow-up

Postoperative symptom remission rate was 96.5%. The postoperative complications were minor. Ten of 106 (9.43%) patients exhibited dysphagia. The mean VAS score was 1.6 ± 0.71. No symptoms of postoperative complications including hemorrhage, gastric fistula, esophageal fistula, and esophageal stenosis, were observed. The length of clinical follow-up was 11 (1–16) years.

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**Figure 1.** Surgery-related picture A: preoperative magnetic resonance imaging exhibits partial hernia of gastric fundus into esophageal hiatus; B: Barium meal of upper digestive tract indicates hiatal hernia; C: Trocar position layout; D: Restoration of hernia contents; E: Free esophagus and posterior space; F: Intermittent suture of diaphragm foot to reduce esophageal hiatus; G: Placement of biological mesh and fixation with silk thread; H: 360° Nissen fundoplication.
months. No patient exhibited mesh infection and required reoperação and no imaging in the asymptomatic patients displayed the recurrence (Table 2).

### 4. Discussion

This study evaluated the efficacy of the biological mesh in the 4K laparoscopic repair of HH in 106 patients with serious GERD. It had minimal deleterious effects on post-operative dysphagia (9.4%) and was associated with no short-term recurrence rate or complications, such as esophageal stricture, mesh infection, up to 16 months follow-up. Thus, confirming the utility and safety of a biological mesh.

Esophageal HH exhibited an occult onset. Patients exhibited either no clinical symptom or mild symptom, and the degree of symptoms was not proportional to the size of the hernial sac. The diagnosis was difficult in a small hernia, resulted in either no clinical symptom or mild symptom, and the degree of symptoms was not proportional to the size of the hernial sac. In China, the central and western regions remain unaware of this condition, delaying treatment and leading to serious consequences. According to the symptoms, duration, and medication, our center combined examination methods such as gastroscopy, upper gastrointestinal radiography, CT, MRI, esophageal acid measurement, and manometry to make a clear diagnosis and formulate an individualized treatment plan. For patients with mild symptoms, small hernia, and no standard medical treatment, conservative medical treatment, oral proton pump inhibitors, should be administered for 2-3 months. Surgical treatment is adopted for patients with severe symptoms, large hernia, and poor long-term conservative medical treatment.

Additionally, suboptimal treatment effect and serious complications may occur due to differences in diagnosis and treatment opinions. Our results helped to establish the safety of HH repair. Laparoscopic treatment on giant HH is also safe and feasible in elective and emergency settings, even for patients over age of 80.

Patients in our center were treated with 4K laparoscopic transabdominal surgery, and 360 Nissen fundoplication was performed. This study excluded 5 patients who underwent 180° fundoplication due to short esophagus and 3 patients who underwent 270° fundoplication due to a narrow fundus. The patients were discharged from hospital 3 to 5 days postoperatively and were mobilized, could consume liquids at the first day postoperatively. Preoperative gastric tube insertion was not performed routinely, and enhanced recovery after surgery rapid rehabilitation measures were provided. The patients exhibited high comfort and few postoperative complications, with low postoperative recurrence rates. Ultra-clear image quality and local magnification function of the 4K laparoscope made the tissue structure clear and increased the tissue identification degree, enlarging the narrow space of the operation field to avoid damaging blood vessels, esophagus, stomach, and vagus nerve; allow better and safer delineation of the surgical anatomy; ensure decreased intraoperative bleeding, smooth operation process, decrease intraoperative and postoperative complications.

Both the curative effect and nerve protection must be considered. The operators should be familiar with the anatomical course of the vagus nerve and its relationship with the surrounding vascular system. The surgical procedure at our center strictly preserved the hepatic branch of vagus nerve and the trunk of vagus nerve. The incidence of postoperative complications such as abdominal distension, gastric emptying disorder, and bile stasis was low.

#### 4.1. Simple repair

A randomized controlled pilot trial has shown no significant difference in postoperative esophagitis (p = 0.737), gas bloating (p = 0.782), and quality of life (p = 0.992) between HH repair with or without fundoplication in the treatment of GERD, but laparoscopic HH repair combined with a fundoplication to avoid postoperative gastroesophageal reflux and resulting esophagitis.

Several studies confirmed that a laparoscopic 270° Toupet or a laparoscopic 180° Dor fundoplication provided similar control of GORD at follow-up, with no difference in post-fundoplication symptoms, and majority of patients (88%) were satisfied with operation outcomes. A retrospective review of prospectively collected data reported that incidence of recurrent HH increased in direct correlation with the preoperative HH size (No HH: 0%, small HH (<3-cm): 10.1%, large HH (≥3-cm): 16.6%, paraesophageal hernia (PEH): 20%, p = 0.032) after magnetic sphincter augmentation. According to a 5-year observation, patients who underwent laparoscopic repair of large (≥5-cm) type III HH, the 5-year recurrence-free probability was similar, but an earlier failure rate was noted in the non-mesh group at 12 months (p = 0.299). For patients with esophageal hiatus <5-cm, simple repair could be attempted. However, given the increasing risks of long-term recurrence, we chose to place meshes and use tension-free repair. No consolidated standard

### Table 1

Patient demographics.

| Variable               | Total (n = 106) |
|------------------------|-----------------|
| Age, yrs              | 52.4 (32–85)    |
| Sex                    |                 |
| Male                  | 62 (58.4%)      |
| Female                | 44 (41.5%)      |
| Body mass index, kg/m²| 24.8 (18.4–35.1)|
| Type of hiatal hernia  |                 |
| I                     | 65 (61.3%)      |
| II                    | 23 (21.6%)      |
| III                   | 15 (14.1%)      |
| IV                    | 3 (2.8%)        |
| Hiatal hernia diagnosis|                |
| Intraoperative        | 2 (1.8%)        |
| Preoperative          | 104 (98.1%)     |
| Hypertension          | 56 (52.8%)      |
| Diabetes mellitus     | 38 (35.8%)      |
| Hyperlipidemia        | 23 (21.6%)      |
| Active smoker         | 55 (51.8%)      |
| History of myocardial infarction | 2 (1.8%) |

Continuous data summarized as mean ± SD. Categorical data are expressed as n (%).

### Table 2

Perioperative data and complications.

| Variable                             | Total (n = 106) |
|--------------------------------------|-----------------|
| Surgical time, min                   | 70.9 ± 8.72     |
| Estimated blood loss, mL             | 30.0 ± 9.80     |
| Length of hospital stay, days        | 4.8 ± 0.76      |
| Postoperative symptom remission rate (%)| 96.5%          |
| Intraoperative complications/injury of vagus nerve | 0 (0%) |
| Postoperative complications          |                 |
| Hernorrhage                          | 0 (0%)          |
| Gastric fistula                      | 0 (0%)          |
| Esophageal fistula                   | 0 (0%)          |
| Esophageal stenosis                  | 0 (0%)          |
| Dysphagia                            | 10 (9.43%)      |
| VAS score                            | 1.6 ± 0.71      |
| Reoperation                          | 0 (0%)          |
| Hernia recurrence                    | 0 (0%)          |

Continuous data summarized as median (range). Categorical data are expressed as n (%).

VAS = visual analog scale.
existed yet on whether the hernia sac must be removed and the size of the hernia sac to be removed. Haze suggested that there was no need to forcibly remove the hernial sac to avoid damaging the vagus nerve. Enough space was present for strengthening the diaphragm and placing a mesh.

4.2. Artificial synthetic mesh repair

Materials for artificial synthetic mesh repair include non-absorbable synthetic materials such as polypropylene, polyester, polytetrafluoroethylene, and polysiloxane. Absorbable synthetic materials such as polyactic acid and polycaprolactone, composite materials, animal-derived materials, and allogeneic materials. Since artificial synthetic hernia meshes have been applied in the clinical setting, significant progress has been made in approaches to treat hernia repair. However, with the extension of its application time, the problem of poor histocompatibility of nondegradable synthetic materials has become increasingly prominent, and increased cases of mesh infection after operation require reoperation to remove the mesh. The synthetic mesh, represented by the polypropylene mesh, directly comes into contact with internal organs and can not only cause serious abdominal adhesion but also long-term contact and friction between the mesh and gastric wall and esophagus when used to repair HH due to the rough surface of the mesh. Thus, it may easily damage the gastric wall and esophagus and erode the esophagus and gastric wall in severe cases, causing gastric and esophageal fistulas. Presently, the disadvantages of synthetic mesh such as permanent residue and scar after 3 months in clinical practice have become increasingly prominent. The pain, discomfort, and foreign body sensation caused by scar tissue sclerosis are difficulties that synthetic mesh cannot overcome. A systematic reviewed the application of a mesh in the HH repair during Nissen fundoplication for both GERD and HH, suggesting that the recurrence rate in the synthetic mesh group was 6.8% compared to 16.1% in the biological mesh group \( (P < .05) \), and the complication rate was 5.1% and 4.6% \( (P > .694) \), respectively.\(^{10} \) Additionally, once infection and recurrence occur after the synthetic mesh is implanted into the human body, a secondary operation is required to extract the mesh, which not only increases pain but also the economic burden on the patient. Thus, in-depth research is required on collagen-based biomaterials when scientists are constantly exploring, improving, and developing composite materials.

4.3. Biological mesh repair

Biological mesh repair is based on biological materials and has been approved by FDA. The use of biological mesh can not only reduce the postoperative recurrence rate of HH but also overcome. A systematic reviewed the application of a mesh in the HH repair during Nissen fundoplication for both GERD and HH, suggesting that the recurrence rate in the synthetic mesh group was 6.8% compared to 16.1% in the biological mesh group \( (P < .05) \), and the complication rate was 5.1% and 4.6% \( (P > .694) \), respectively.\(^{10} \) Additionally, once infection and recurrence occur after the synthetic mesh is implanted into the human body, a secondary operation is required to extract the mesh, which not only increases pain but also the economic burden on the patient. Thus, in-depth research is required on collagen-based biomaterials when scientists are constantly exploring, improving, and developing composite materials.

5. Conclusion

The use of the biological mesh in tension-free HH repair under the 4K laparoscope is safe and effective, and is associated with fewer adverse reactions and an obvious short-term effect.

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