

Comparison of a modified one-piece mechanical and double-layer hand-sewn anastomosis in McKeown esophagogastrectomy: A single-institute retrospective study

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Received July 30, 2020; Accepted April 21, 2021

DOI: 10.3892/mco.2021.2296

Abstract. The present study aimed to introduce a novel method of cervical esophagogastric anastomosis, so-called 'modified one-piece mechanical anastomosis' (MOMA) in McKeown esophagogastrectomy and to compare its feasibility, efficacy and safety with those of 'conventionally double-layer hand-sewn anastomosis' (CDHA). Between March 2016 and March 2018, 80 consecutive patients with thoracic esophageal squamous cell carcinoma undergoing McKeown esophagogastrectomy with a curative intent were included in the present study. Among them, 40 received MOMA and the other 40 received CDHA. Their medical records, including operation time, anastomotic time, estimated blood loss, post-operative complications within 30 days, as well as survival rate, were retrospectively reviewed, analyzed and compared. Total operation time, anastomotic time and estimated blood loss in the MOMA group were significantly decreased compared with those in the CDHA group (207.73±2.66 vs. 225.40±3.43 min; 10.95±0.44 vs. 23.03±0.47 min; 144.50±21.14 vs. 241.75±23.75 ml; all $P<0.01$). Anastomotic leakage was present in 1 patient in the CDHA group, but no patients in the MOMA group ($P=1.000$). Anastomotic stenosis was documented in 4 and 2 patients in the MOMA and CDHA group, respectively ($P=0.392$). The 30-day operative mortality was 0% and no significant difference was demonstrated in post-operative complications within groups ($P>0.05$). Furthermore, the disease-free and overall survival was compared by means

of Kaplan-Meier survival estimates and log-rank tests and no statistical difference was determined ($P=0.5114$ and $P=0.7875$, respectively). McKeown esophagogastrectomy with MOMA may be a feasible, effective and reproducible alternative with relatively satisfactory postoperative outcomes for the treatment of TE-SCC, providing shorter operation and anastomosis times, and less estimated intraoperative blood loss.

Introduction

Carcinoma of the esophagus is one of the most lethal neoplasms worldwide (1,2). In China, however, it ranks among the top 3 most common malignancies, demonstrating an incidence of nearly 5 million and claiming a cancer-related death of around 4 million per year, turning out a major health threat (3,4). Quite different from the situation in western countries that most esophageal cancer evolving from Barrett's esophagus and demonstrating a major histology of adenocarcinoma, situation in China is that squamous cell carcinoma predominates in more than 95% EC patients. However, accounting for nearly 95% of all cases in China, most esophageal squamous cell carcinoma (ESCC) locates in the intrathoracic portion and surgical resection remains the preferred modality of radical treatment, especially for the early- or mid-staged lesions (5). After esophagectomy, reconstruction using a gastric conduit is the most common procedure (6), although various other anastomotic techniques have been demonstrated (7-10). However, reconstruction surgery following resection of the esophagus is frequently associated with occurrence of anastomotic leakage. Once it occurs, patients suffered decreased quality of life, protracted hospitalization or even death. This is why there were many innovations and modifications in reconstructive surgery including functional end-to-end stapling, triangulating stapling, T-shaped linear stapling, pre-embedded stapling, and so forth (11-15).

Although efficacy of mechanical anastomosis had been reported previously (12,16,17), much effort had still been tried to better off the clinical outcome and simplify the procedure (18,19). Chen *et al* (20) reported that use of pleural flaps in the upper mediastinum would reduce the incidence of

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Key words: thoracic esophageal squamous cell carcinoma, modified one-piece mechanical anastomosis, conventionally double-layer hand-sewn anastomosis, McKeown esophagogastrectomy

cervical subcutaneous emphysema and anastomotic leakage into pleural cavity. Sugimura *et al* (8) introduced a modified Collard anastomosis which would be more effective in the reduction of anastomotic stenosis. Sun *et al* (21) demonstrated an embedded three-layer esophagogastric anastomotic manœuvre which would facilitate the reduction of morbidity as well as improvement of short-term outcomes. In the present study we introduced a novel method of cervical esophagogastric anastomosis, so-called ‘modified one-piece mechanical anastomosis (MOMA)’ in McKeown esophagogastric resection and compared its feasibility, efficacy and safety with conventionally double-layer hand-sewn anastomosis (CDHA). We made a minor modification based on the traditional mechanical anastomosis (TMA). We hypothesized non-inferiority when comparing MOMA to CDHA, and in our early practical experience MOMA had been proven feasible, and would significantly speed up the surgical procedure in abdominal phase and cervical anastomosis.

Patients and methods

Study design and patients. From March 2016 to March 2018, 96 consecutive patients with thoracic esophageal squamous cell carcinoma in the Department of Thoracic Surgery of Fujian Cancer Hospital and Fujian Medical University Cancer Hospital were hospitalized and preoperatively evaluated for the eligibility for surgical resection. As a result, 80 of them met the criteria and were enrolled. All patients were diagnosed by gastroscopy and pathologically proven, no surgical contraindications had been demonstrated and no patient had suffered from a double cancer. The surgical criteria for thoracic esophageal cancer is cT1-4aN0-1M0. Forty patients received a modified anastomotic (MOMA) and the other 40 conventionally hand-sewn maneuver (CDHA). Resections were carried out by 2 different surgical teams (MOMA by X. Chen, J. Zhang and G. Weng and CDHA by K. Zhu, S. Lin and Y. Cai), while patients were treated with the same perioperative regimen in process of hospitalization. The screening items included: Complete blood count (CBC), comprehensive chemistry profile, esophageal barium swallow, upper gastrointestinal (GI) endoscopic ultrasonography (EUS) and biopsy and chest/upper abdomen computed tomography (CT) with intravenous (IV) contrast. The histopathologic features of cancerous specimens were classified in accordance with the 8th AJCC (American Joint Committee on Cancer) criteria on esophageal cancer (22,23), and the TNM staging system as well (24). Patients receiving induction chemotherapy, however, would not undergo surgery until down-staging was achieved and surgical indication was met. Clinicopathologic parameters including age, gender, smoking status, Brinkman index, ECOG score, history of gastric surgery, cellular histology, preoperative weight loss, body mass index (BMI), preoperative albumin, preoperative BUN, tumor location, American Society of Anesthesiology (ASA) classification, Charlson comorbidity index (CCI) (25), pathologic TNM stage, follow-up data and history of neoadjuvant therapy and postoperative therapy were collected. Intraoperative characteristics like thoracic duct ligation, pyloric emptying procedure, jejunostomy, length of hospital stay, total operation time, time of anastomosis, estimated blood loss, total chest/gastric tube

retention time, total chest/gastric tube drainage volume and number of resected/metastasized lymph nodes (r/m LNs). Patients' surgical outcome information included resection margin, blood transfusion, postoperative pneumonitis, anastomotic leakage/stenosis, postoperative arrhythmia, bleeding, gastric conduit palsy/tearing, recurrent laryngeal nerve palsy, chylothorax, 30-day re-admission and mortality. The final follow-up date was September 24, 2019. The study protocol was approved by the Human Ethics Review Committee of Fujian Cancer Hospital and Fujian Medical University Cancer Hospital, and a signed informed consent was obtained from each patient.

Surgical approaches. The operation began with a thoracic phase by open right thoracotomy, in which resection of the tumor together with lymphadenectomy was carried out. An open abdominal phase followed, in which the stomach was prepared and then brought up through the chest into the neck for a circular end-to-end stapled anastomosis, with the proximal stomach conduit at the apex of the pleural cavity.

Dissection of the esophagus was initiated from the mediastinal visceral pleura at the inferior margin of arch of azygos vein with ultrasonic shears, moving down from the posterior and then to the anterior wall of the esophagus. After the azygos vein was transected, the dissection was continued up into the upper mediastinum, carefully preserving both sides of the bronchial arteries and thoracic duct, and keeping from injuring both sides of recurrent laryngeal nerves (RLNs) while dissecting the suspicious metastatic lymph nodes nearby.

At the end of esophagectomy, the patient was repositioned to supine position. Gastric mobilization as well as preparation of gastric conduit was then carried out in an open manner. For MOMA group, gastric mobilization was initiated from the middle at the greater curvature of stomach on the greater omentum, with a distance of ≥ 2 cm from the arch of gastroepiploic vessels (Fig. 1A, arrow ①), firstly moving clockwise to the starting point of the right gastroepiploic artery, then anti-clockwise to dissect the left gastroepiploic, splenogastric, short gastric and retrogastric vessels. After removal of No. 18 and 19 LNs, the left gastric vessels together with No. 17 LN were then dissected. The omental bursa was opened, with the lesser curvature of the stomach and the esophagogastric conjunction well dissected and fully released. Then the right gastric vessels were ligated at the level of 3rd or 4th branch from the rightmost (Fig. 1A, arrow ② and 1B, arrow ①), the stomach was then cut from the ligation/start point (Fig. 1A, arrow ② and 1B, arrow ②) along with the lesser curvature (Fig. 1C and D) to the endpoint (Fig. 1A, arrow ③ and 1E, arrow) at ≤ 3 cm (Fig. 1A, arrow ④, marked as yellow thick line) to the cardia without full transection at the esophagogastric junction with endocutter, making the stomach a thin gastric conduit of around 3.5 cm in diameter (Fig. 1F, arrow) and ensuring the adequate length for the replacement of resected esophagus. Then some stitches were placed to ensure the security of the gastric conduit, and the uppermost stitch (Fig. 1E, arrow) was used as a landmark to indicate the cutting margin of remnant gastric conduit later.

A straight incision was made in front of the sternocleidomastoid muscle in the left neck, after removal of 1L LNs, the cervical esophagus was freed. The gastric conduit, together with the dissected esophagus and cut lesser curvature of

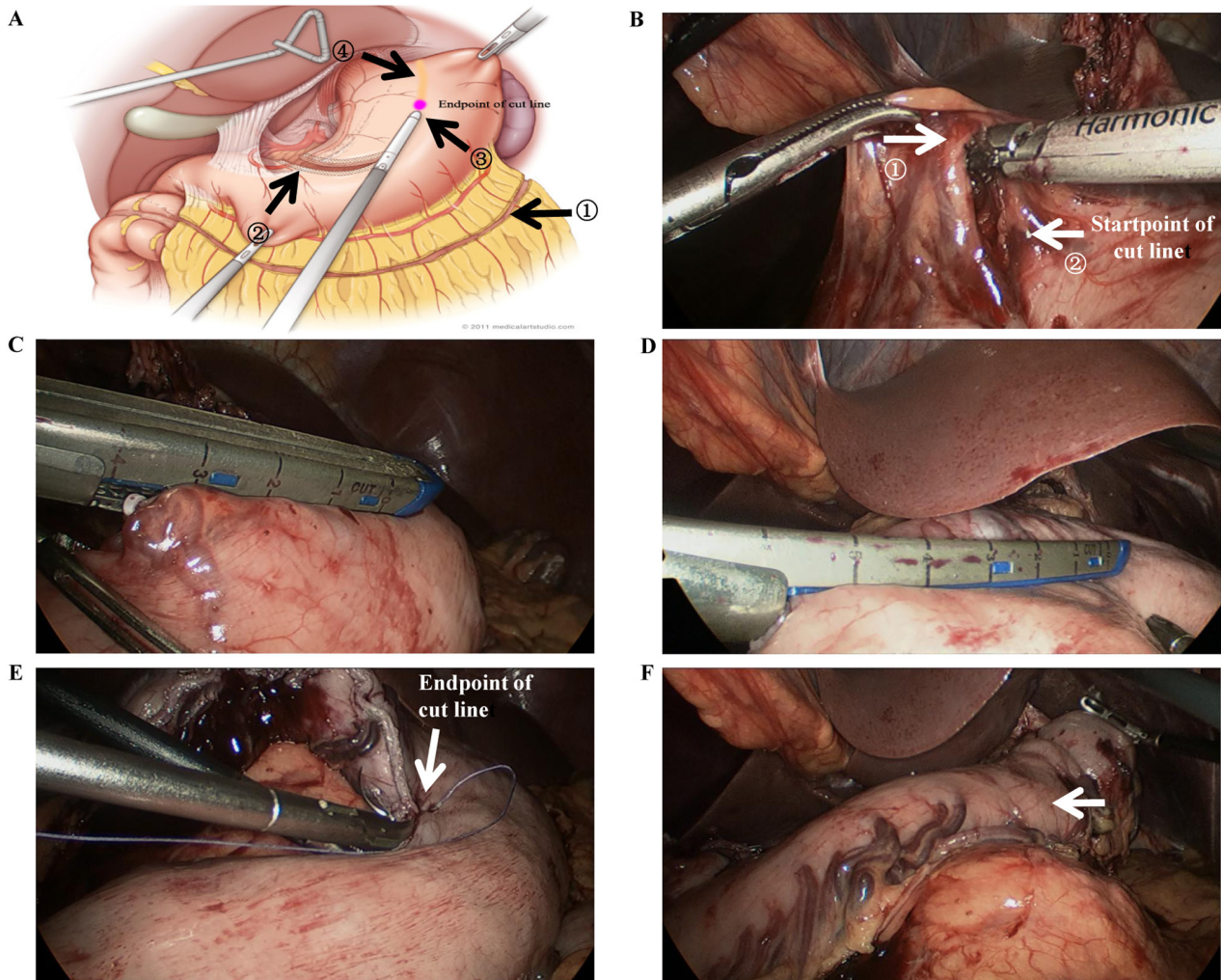


Figure 1. Illustration of gastric mobilization and gastric conduit preparation. (A) Arrow ① indicating cut line of greater omentum along the greater curvature of the stomach; arrow ② indicating startpoint of cut line of lesser curvature of the stomach; dot in pink [arrow ③] indicating endpoint of cut line of lesser curvature of the stomach; thick yellow line [arrow ④] indicating leftover part of esophagogastric junction. (B) Arrow ① indicating the branches of right gastric vessels; arrow ② indicating the startpoint of cut line of lesser curvature of the stomach. (C) Cutting of lesser curvature of the stomach by endocutter; (D) fulfillment of gastroplasty of lesser curvature of the stomach; (E) and a marking stitch was made to indicate the endpoint of cut line (arrow); (F) arrow indicating the accomplished gastric conduit at a diameter of 3 cm.

the stomach, was pulled up from the abdomen into the neck through hiatus, esophageal bed in the retromediastinum and then inlet of thoracic cage, carefully not to have it torn. After an appropriate size of anvil (all Johnson & Johnson, and size of stapler used was as followed: no. 21 in 23 patients and no. 25 in 17 patients) was inserted and well placed (Fig. 2A, arrow ①), an incision was made at the lesser curvature site on the esophagogastric junction for the entrance of stapler shaft (Fig. 2A, site of ultrasonic shears cut). Then a circular end-to-end stapled anastomosis was accomplished (Fig. 2B, arrow showing the anastomosis) with the anastomotic site on the posterior wall of gastric conduit and close to the greater curvature to ensure better blood flow. The remnant gastric conduit was transected at least 3 cm afar off from the anastomotic line, i.e., along with the line of marked stitch (Fig. 2C, arrow showing the marking stitch), ensuring the adequate blood supply (Fig. 2D, arrow ① for anastomosis and ② for transecting line, distance within them should be ≥ 3 cm).

For the CDHA group, all the other procedures were identical except that during the preparation of gastric conduit, the

lesser curvature of the stomach was fully transected without preserving the remnant part of the lesser curvature (Fig. 1A, arrow ④, marked as yellow thick line), then the gastric conduit was pulled up to the neck and a conventional double-layer hand-sewn anastomosis was carried out with 4-0 Mersilk in an interrupted manner in both layers.

In the patients without jejunostomy, a nasojejunal feeding tube were inserted to ensure that enteral alimentation was started in the early postoperative period.

Definition of postoperative complications and follow-up. Patients routinely underwent postoperative gastrointestinal endoscopy at 12 months if complaints of symptoms such as dysphagia arise. In this study, anastomotic stricture is defined as a condition that requires balloon dilation at the stenotic anastomosis within 90 postoperative days (PODs), with endoscopic proof of a stenosis through which a 9-mm endoscope cannot be passed. Anastomotic leakage is defined as the presence of extraluminal contrast by postoperative CT after swallowing contrast medium, endoscopic visualization

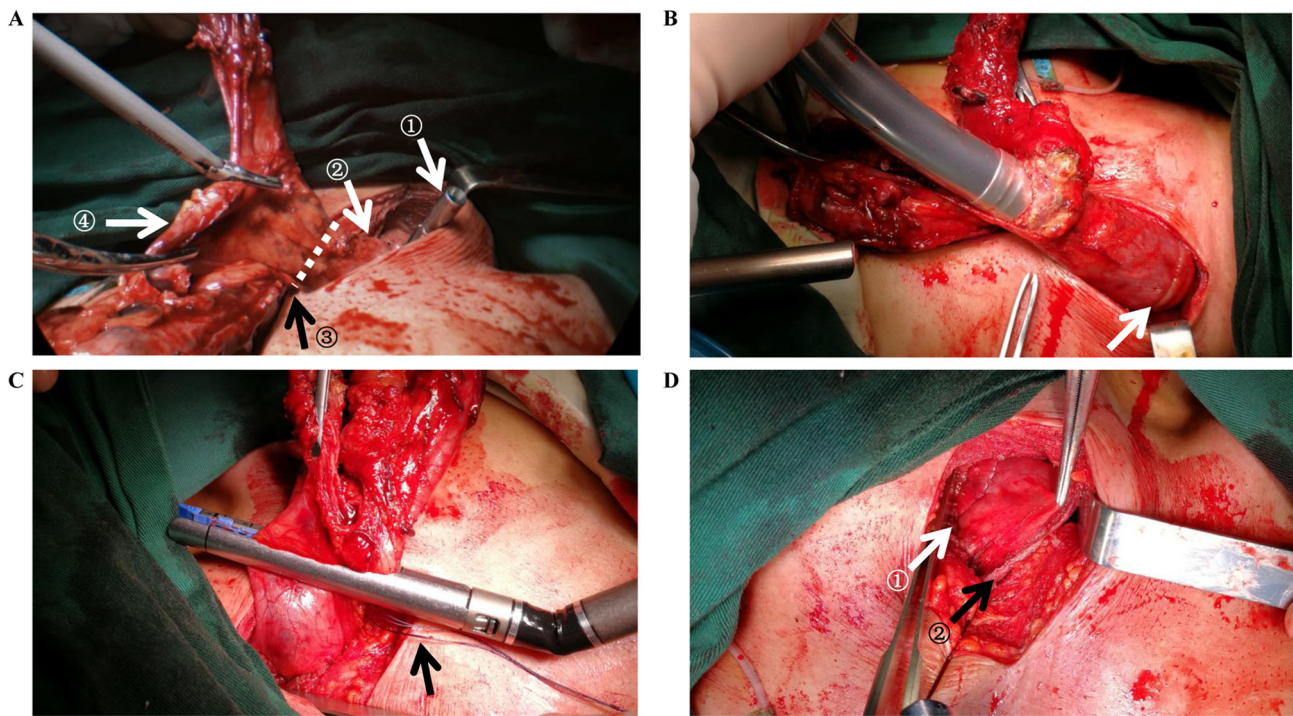


Figure 2. Cervical circular end-to-end stapled esophagogastric anastomosis. (A) Arrow ① indicating the anvil of stapler and dotted line indicating the transecting line [arrow ③]; arrows ② and ④ indicate the greater and lesser curvature of the stomach, respectively. Stapler shaft entering through the spot where ultrasonic shears cut. (B) Anastomosis was accomplished and the arrow indicates the anastomotic line. (C) Remnant part of gastric conduit was transected by endocutter at the level of marking stitch (arrow). (D) Fulfillment of end-to-end stapled esophagogastric anastomosis, arrow ① indicates the anastomotic line and arrow ② indicates the transecting line of remnant gastric conduit, and the distance between the two arrows should surpass 3 cm.

of dehiscence or fistula, or flow of saliva or pus through the cervical wound within 30 PODs. If pus was discovered from the cervical wound with uncertain anastomotic leakage found, patients undergo a contrast medium swallow study and a CT study after open drainage of the cervical wound to confirm the existence of anastomotic leakage. Other overall postoperative morbidities are redefined as greater than grade II by the Clavien-Dindo classification. Follow-up appointments for all patients took place at 1, 3, 6, 12 and then every 6 months following surgery at Fujian Medical University Cancer Hospital. All patients would be followed up to 5 years or until death.

Statistical analysis. All data were analyzed by SPSS 23.0 (SPSS, Inc.). The quantitative data were expressed as the mean \pm standard deviation (SD) and compared using the unpaired Student's t-test. The counting data were expressed by frequency or rate, and the comparison between groups was carried out by Pearson's χ^2 or Fisher's exact test as appropriate. All patients received a follow-up. The Kaplan-Meier method with log-rank test was used for estimating and comparing probability of unadjusted disease-free survival (DFS) and overall survival (OS) within groups. A P-value <0.05 was considered statistically significant.

Results

Basic characteristics of study population. Ninety-six consecutive patients were screened and 80 patients with thoracic esophageal cancer were enrolled and received surgery

from April 2016 through March 2018 (Table I). The average age for CDHA and MOMA groups was 63.53 ± 1.14 and 61.58 ± 0.85 years old, respectively ($P=0.173$). Except for preoperative albumin ($P=0.029$), no statistical difference had been demonstrated in the items of gender, smoker, Brinkman index, ECOG score, preoperative BUN, BMI, preoperative weight loss, tumor location, ASA classification, Charlson comorbidity index, induction therapy, postoperative radiotherapy, postoperative chemotherapy, pathologic TNM staging, nerve involvement or vascular invasion (Table I, all $P>0.05$).

Intraoperative characteristics. All patients received Mckeown procedure with different anastomotic ways. As shown in Table II, all patients in both groups received open thoracotomy and laparotomy. Although number of patients receiving thoracic duct ligation (8 vs. 17, $P=0.030$) and jejunotomy (14 vs. 31, $P<0.001$) in the CDHA and MOMA groups was various, no significant difference had been demonstrated in the following items: Pyloric emptying procedure, length of hospital stay (25.35 ± 1.29 vs. 24.40 ± 1.16 days, $P=0.586$), chest tube retention time (9.80 ± 0.68 vs. 11.15 ± 0.52 days, $P=0.119$), total chest tube drainage (2517.90 ± 469.05 vs. 2715.35 ± 298.77 ml, $P=0.724$), gastric tube retention time (10.35 ± 0.39 days vs. 11.58 ± 0.51 d, $P=0.059$), total gastric tube drainage (1568.55 ± 182.01 vs. 1738.70 ± 170.54 ml, $P=0.497$), average resected LNs (22.43 ± 1.75 vs. 24.83 ± 1.62 , $P=0.317$) or metastasized LNs (0.93 ± 0.28 vs. 0.95 ± 0.25 , $P=0.946$). It's of note that in comparison to the CDHA group, total operation time (207.73 ± 2.66 vs. 225.40 ± 3.43 min, $P<0.001$) and time of anastomosis (10.95 ± 0.44 vs. 23.03 ± 0.47 min, $P<0.001$) were

Table I. Basic characteristics of study population (n=80).

Variables	CDHA (n=40)	MOMA (n=40)	t/ χ^2	P-value
Age, years (mean \pm SD)	63.53 \pm 1.14	61.58 \pm 0.85	1.375	0.173
Sex, n			0.853	0.356
Male	27	23		
Female	13	17		
Smoker, n			2.452	0.117
Yes	24	17		
No	16	23		
Brinkman index (mean \pm SD)	435.00 \pm 60.29	305.00 \pm 64.05	1.478	0.143
Average follow-up, months	24.70	18.58	/	NA
ECOG, n			/	>0.999
≤ 1	40	40		
>1	0	0		
BMI, kg/m ² (mean \pm SD)	21.34 \pm 0.41	22.33 \pm 0.48	1.554	0.124
Preoperative albumin, g/l (mean \pm SD)	38.03 \pm 0.53	40.04 \pm 0.73	2.219	0.029
Preoperative BUN, g/l (mean \pm SD)	5.21 \pm 0.24	5.17 \pm 0.24	-0.141	0.888
Preoperative weight loss, n ^a			0.734	0.392
>0, ≤ 5 kg	36	38		
>5, ≤ 10 kg	4	2		
Tumor location, n			2.040	0.361
Upper	6	4		
Middle	28	25		
Lower	6	11		
ASA classification, n			0.392	0.531
II	35	33		
III	5	7		
CCI, n			0.251	0.617
≤ 3	12	10		
>3	28	30		
Induction therapy, n ^a			3.127	0.077
Yes	39	35		
No	1	5		
Postoperative RT, n ^a			3.127	0.077
Yes	5	1		
No	35	39		
Postoperative CT, n			1.867	0.172
Yes	11	6		
No	29	34		
pTNM staging, n			0.487	0.485
0-II	24	27		
III	16	13		
Nerve involvement, n			0.000	>0.999
Yes	7	7		
No	33	33		
Vascular invasion, n			2.990	0.084
Yes	15	8		
No	25	32		

^aUsing Fisher's exact test. Continuous data are presented as the mean CDHA, conventionally double-layer hand-sewn anastomosis; MOMA, modified One-piece mechanical anastomosis; ASA, American Society of Anesthesiologists; CCI, Charlson comorbidity index; LNs, lymph nodes; RT, radiotherapy; CT, chemotherapy; NA, not available.

Table II. Intraoperative characteristics (n=80).

Parameters	CDHA (n=40)	MOMA (n=40)	t/χ^2	P-value
TD ligation, n			4.713	0.030
Yes	8	17		
No	32	23		
Pyloric emptying procedure, n			/	NA
None	40	40		
Balloon dilation	0	0		
Jejunostomy, n			14.679	<0.001
Yes	14	31		
No	26	9		
Length of hospital stay, days (mean \pm SD)	25.35 \pm 1.29	24.40 \pm 1.16	0.547	0.586
Total operation time, min (mean \pm SD)	225.40 \pm 3.43	207.73 \pm 2.66	4.067	<0.001
Time of anastomosis, min (mean \pm SD)	23.03 \pm 0.47	10.95 \pm 0.44	18.781	<0.001
Estimated blood loss, ml (mean \pm SD)	241.75 \pm 23.75	144.50 \pm 21.14	3.059	0.003 ^a
Chest tube retention time, days (mean \pm SD)	9.80 \pm 0.68	11.15 \pm 0.52	1.575	0.119
Total chest tube drainage, ml (mean \pm SD)	2517.90 \pm 469.05	2715.35 \pm 298.77	0.355	0.724
Gastric tube retention time, days (mean \pm SD)	10.35 \pm 0.39	11.58 \pm 0.51	1.917	0.059
Total gastric tube drainage, ml (mean \pm SD)	1568.55 \pm 182.01	1738.70 \pm 170.54	0.682	0.497
Average resected LNs (mean \pm SD)	22.43 \pm 1.75	24.83 \pm 1.62	1.007	0.317
Metastasized LNs (mean \pm SD)	0.93 \pm 0.28	0.95 \pm 0.25	0.067	0.946

CDHA, conventionally double-layer hand-sewn anastomosis; MOMA, modified One-piece mechanical anastomosis; TD, thoracic duct; LN, lymph node; NA, not available.

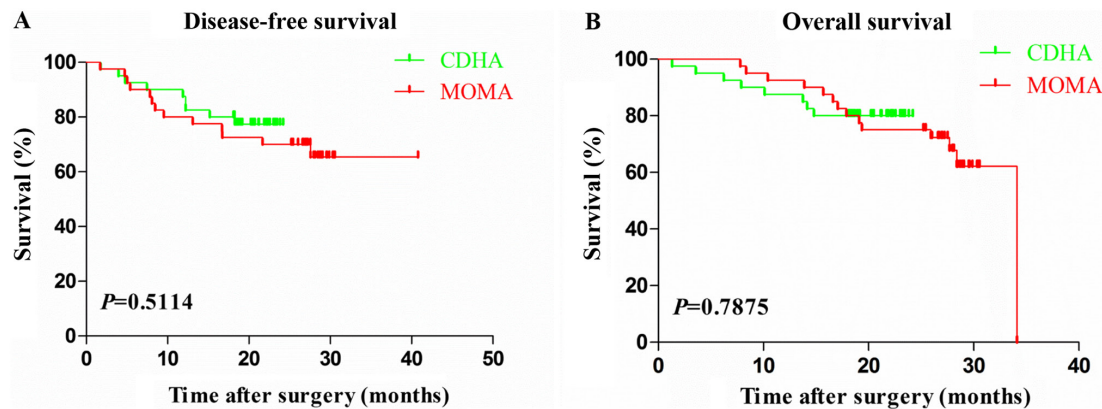


Figure 3. Survival analysis for patients receiving McKeown esophagogastrectomy with different anastomotic manners using the Kaplan-Meier method and a log-rank test. (A) No statistically significant difference was observed for disease-free survival between MOMA and CDHA groups ($P=0.5114$); (B) No statistically significant difference was observed for overall survival between MOMA and CDHA groups ($P=0.7875$). CDHA, conventionally double-layer hand-sewn anastomosis; MOMA, modified one-piece mechanical anastomosis.

significantly shorter and the estimated blood loss was obviously less (144.50 \pm 21.14 ml vs. 241.75 \pm 23.75 ml, $P=0.003$). The average follow-up time in CDHA and MOMA groups was 24.70 and 18.58 months, respectively, both longer than one year.

Patients' surgical outcome. The perioperative surgical outcomes of patients within 30 PODs were indicated in Table III. Briefly, in the CDHA and MOMA groups, 37 and 39 patients achieved R0 resection margin ($P=0.294$), 11 and 10 patients received blood transfusion ($P=0.799$), 9 and 8 patients had postoperative pneumonitis ($P=0.785$), 1 and 0 patient suffered anastomotic

leakage ($P=1.000$), 2 and 4 patients suffered anastomotic stenosis ($P=0.392$), 5 and 3 had postoperative arrhythmia ($P=0.454$), 0 and 1 patient suffered bleeding ($P=1.000$), 4 and 3 patients suffered gastric conduit palsy ($P=0.692$), 0 and 2 patients suffered gastric conduit tearing ($P=0.494$), 6 and 8 patients suffered recurrent laryngeal nerve palsy ($P=0.556$), 1 and 1 patient suffered chylothorax ($P=1.000$), 3 and 2 patients had 30-day re-admission ($P=0.643$) and none had 90-day mortality, respectively. After comparing their DFS and OS, no statistical difference had been demonstrated within these two groups (Fig. 3A and B; $P=0.5114$ and 0.7875 , respectively).

Table III. Perioperative surgical outcome (n=80).

Parameters	CDHA, n (n=40)	MOMA, n (n=40)	χ^2	P-value
Resection margin			1.099	0.294
R0	37	39		
R1	3	1		
Blood transfusion			0.065	0.799
Yes	11	10		
No	29	30		
Pneumonitis			0.075	0.785
Yes	9	8		
No	31	32		
Anastomotic leakage ^a			/	>0.999
Yes	1	0		
No	39	40		
Anastomotic stenosis			0.734	0.392
Yes	2	4		
No	38	36		
Arrhythmia			0.561	0.454
Yes	5	3		
No	35	37		
Bleeding ^a			/	>0.999
Yes	0	1		
No	40	39		
GC palsy			0.157	0.692
Yes	4	3		
No	36	37		
GC tearing ^a			/	0.494
Yes	0	2		
No	40	38		
RLN palsy			0.346	0.556
Yes	6	8		
No	34	32		
Chylothorax ^a			/	>0.999
Yes	1	1		
No	39	39		
30-day re-admission			0.215	0.643
Yes	3	2		
No	37	38		
90-day mortality	0	0	/	NA

^aUsing Fisher's exact test. CDHA, conventionally double-layer hand-sewn anastomosis; MOMA, modified One-piece mechanical anastomosis; RLN, recurrent laryngeal nerve; GC, gastric conduit; NA, not available.

Discussion

Esophagectomy remains the gold standard in the treatment of esophageal cancer with curative intent. However, this operation is complicated and associated with high morbidity and mortality (26-29). Anastomosis-related complications especially anasomotic leakage is one of the most lethal comorbidities, usually resulting in pyothorax, mediastinitis, tracheal

fistula, arterial fistula or septicemia, and ending up with multiple organ failure eventually. In order to achieve satisfactory esophagogastric anastomosis, much effort had been tried either to optimize the anasomotic procedure (18,19,30-37), to better off the blood flow at the anastomotic site on the grafted conduits (11,38,39), or to manage prophylactic measurements to ensure the confinement of inflammation and facilitate the healing in case of leakage (20,21).

In the present study we evaluated the utility of MOMA and compared it with CDHA in cervical esophagogastric anastomosis after sub-total esophagectomy in TE-SCC patients. Major modifications of MOMA lie in gastric conduit preparation and anastomotic maneuver, without fully transecting the lesser curvature while preserving it for no longer than 3 cm at the conjuncional part and pulling the conduit up to the neck to fulfill a circular end-to-end stapled anastomosis, quite different from conventional way by transecting the gastroesophageal junction with the continuation of extracorporeal gastropasty by fully cutting off the lesser curvature of stomach (40,41). As could be expected and eventually testified in our study that this modification would firstly simplify the procedure of gastric conduit preparation and esophagogastric anastomosis by avoiding the action of transecting lower esophagus and making pulling-up stitches at the apex of gastric conduit, and secondly decrease the amount of hemorrhage although it would probably be due only to the shorter duration of the operation, especially hand-sewn cervical anastomosis (40-43).

Major clinical findings in our study indicated that in comparison to CDHA, time consumption in total operation and anastomosis in MOMA group was statistically shortened, and therefore estimated blood loss was reduced accordingly. However, anastomosis-related complications like anastomotic leakage and stricture bore no difference within these two maneuvers. Recently, Li *et al* (19) reported a T-shaped linear-stapled cervical esophagogastric anastomosis in a sample size of 32 patients, demonstrating a time consumption in anastomosis at 17.6 min, which was much longer than ours. Furthermore, their anastomotic method was similar with the triangulating anastomosis, which was reported to have higher rate of leakage at the site of staple overlapping (17).

Besides the beneficiary aspects mentioned above, analyses demonstrated no different incidence of postoperative complications like pneumonitis, arrhythmia, bleeding, gastric conduit palsy, RLN palsy, chylothorax, 30-day re-admission and mortality (all $P > 0.05$) in both groups. However, it should be noticed that there were 2 patients suffering from the gastric conduit tearing at the endpoint on the lesser curvature because of the inadequate cutting. As a result, the gastric conduits had to be returned to the abdomen to get the torn part fixed, re-cut and pulled up to the neck again. So, we had to address the importance that in the MOMA procedure the remnant part of the gastroesophageal junction left should not be longer than 3 cm lest the conduit gets torn in process of being pulled up into the neck. In addition, before the gastric conduit was about to be pulled up, adequate muscle relaxant should be administered and transient respiratory cessation could be used to ensure the safety of pulling-up action. As most causes of anastomotic leakage were likely due to gastric conduit compression and congestion of the gastric conduit stump caused by the sternoclavicular joint of the thoracic inlet, therefore, when the width of the thoracic inlet was less than three fingerbreadths, the left sternoclavicular joint was resected and the thoracic inlet was dilated to ensure the adequate space for the passover of the gastric conduit. After taking these factors into account, our early experience confirmed the feasibility and safety of this procedure.

Some limitation of this study should be noted. With a retrospective study at a sample-size of 40 in each group, although the results supported the feasibility of MOMA maneuver, further study is necessary to validate the efficacy and safety of this procedure. In addition, in order to facilitate proving the feasibility, open procedure was used in both groups to compare MOMA and CDHA, however, with the global acceptance of minimally invasive procedure and traditional mechanical anastomosis (TMA) (44), further study would be designated to compare MOMA and TMA, and even the effectiveness of MOMA in both minimally invasive settings.

In conclusion, MOMA suggests a feasible, effective and reproducible alternative in McKeown esophagogastric resection for the treatment of TE-SCC, providing significantly shorter operation and anastomosis time, and less estimated intraoperative blood loss as well.

Acknowledgements

The authors would like to thank Professor Junqiang Chen and Professor Jiancheng Li from the Department of Radiotherapeutic Oncology (Fujian Cancer Hospital, Fuzhou, China) for their kind help in the process of the study and paper writing.

Funding

This work was supported by the Science and Technology Program of Fujian Province, China (grant no. 2018Y2003; to KZ and XC).

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

KZ and XC conceived and designed the study. KZ provided administrative support. KZ, JZ, XC, YD, SL, YC and GW provided study materials or patients. JZ, XC, YD, SL and YC collected and assembled the data. KZ, JZ, XC, YD, SL, YC and GW analyzed and interpreted the data. KZ and XC were responsible for confirming the authenticity of the raw data and the paper itself. All authors wrote the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study protocol was approved by the Human Ethics Review Committee of Fujian Cancer Hospital and Fujian Medical University Cancer Hospital (Fuzhou, China), and written informed consent was obtained from each patient.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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