

# Short-term and long-term outcomes of robotic, laparoscopic and open radical gastrectomy in gastric cancer: A single-center retrospective study

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## Research article

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# Abstract

**Background:** Few studies on the comparison among robotic, laparoscopic, and open gastrectomy had been reported in gastric cancer. The goal of this study was to evaluate the advantages of robotic-assisted gastrectomy (RAG) by comparing with laparoscopic-assisted gastrectomy (LAG) and open gastrectomy (OG).

**Methods:** 147 gastric cancer patients who underwent gastrectomy were enrolled and retrospectively analyzed between January 2017 and July 2019. Short-term outcomes such as operation time, intraoperative estimated blood loss (EBL), number of retrieved lymph nodes, postoperative recovery, learning curve, and long-term outcome such as overall survival (OS) was compared among RAG, LAG and OG groups.

**Results:** RAG group included 47 patients, 44 in the LAG, and 61 in the OG. Basic information such as gender, age, BMI, ASA degree were similar among three groups, and there were no statistically significances in pathological TNM staging, tumor resection extent, resection margin, methods of reconstruction ( $P \geq 0.05$ ). The cumulative sum (CUSUM) method showed that learning curve of RAG reached stability after 17 cases. For short-term outcomes, the RAG group had the shortest EBL ( $P = 0.033$ ), the shortest time to first flatus ( $P \leq 0.001$ ), shortest time to first intake liquid diet ( $P = 0.004$ ), shortest postoperative hospital stay ( $P = 0.023$ ) and the largest number of retrieved lymph nodes ( $P = 0.044$ ), the longest operation time ( $P \leq 0.001$ ), the most expensive treatment cost ( $P \leq 0.001$ ), however, there were no significant differences in postoperative drainage, postoperative white blood cell (WBC) count and early complications among three groups ( $P \geq 0.05$ ). In addition to long-term outcome, similar OS was observed in three groups.

**Conclusion:** Compared with LAG and OG, RAG has certain advantages in short-term outcomes and is a safe and reliable surgical method. But still need further prospective, multi-center research to confirm this.

## Introduction

Gastric cancer (GC) is a cancer with high mortality rate in the world, especially in China, although the incidence is decreasing year by year<sup>[1]</sup>. At present, the main treatment of gastric cancer is radical gastrectomy. At the end of the 20th century, laparoscopic-assisted gastrectomy (LAG) was introduced<sup>[2]</sup>. Compared with traditional open gastrectomy (OG), this type of surgery has a significant point in the terms of short-term and long-term oncologic outcomes<sup>[3-5]</sup>. However, laparoscopic-assisted surgery still has certain shortcomings, such as camera instability, limited range of operation, hand tremor, only two-dimensional imaging<sup>[6, 7]</sup>.

Advances in technology have taken robotic surgical systems to a new level<sup>[8]</sup>. Da Vinci robot has a three-dimensional surgical field of view, magnified ten times of clarity, multiple arm joint degrees of freedom<sup>[9]</sup>, these advantages are good complements to laparoscopic. In 2003, Hashizume et al. first reported robotic-

assisted gastrectomy(RAG)<sup>[10]</sup>. Since then, clinical research reports on RAG have emerged. So far, there have been a lot of studies comparing the clinical efficacy of RAG, LAG, and OG<sup>[11-14]</sup>. But the conclusions of these studies are slightly different. Studies have shown that RAG only presents certain advantages in the short-term results of gastric cancer. Moreover, Kim et al. show that RAG does not affect the incidence of complications after radical gastrectomy compared with LAG<sup>[15]</sup>. Therefore, there are still some controversies about the results of postoperative gastric cancer among RAG,LAG and OG, clinical research is still need to be held to verify the security and feasibility of RAG.

In our study, We use a variety of indicators to evaluate the strengths and weaknesses of RAG, LAG, and OG. Among them, Intraoperative blood loss, the number of retrieved lymph nodes, the days of first intestine flatus after surgery, the days of first ingested, the postoperative complication, and postoperative hospital stays et al. were used to measure short-term outcomes, overall survival(OS) rate after gastric cancer surgery was used to measure long-term outcomes. What's more, studies have argued that when the cases of surgical procedures reaches a certain amount, the operation time will tend to be stable<sup>[16]</sup>. This study also use the cumulative Summation (CUSUM) technique to analyze the learning curve of RAG.

## **Materials And Methods**

### **Patients**

This is a single-center retrospective study conducted by the Department of Oncology, the First Affiliated Hospital of Xi'an Jiaotong University, Shaanxi Province, China. From January 2017 to July 2019, the study had included 147 patients (42 in the RAG group, 44 in the LAG group, and 61 in the OG group). Same inclusion, exclusion criteria were used in the patients. The inclusion criteria as follows: (i) All patients were diagnosed as gastric cancer by pathological examination.(ii) All patients were performed by routine examinations such as gastroscopy, abdominal ultrasound and computer tomography. (iii) All patients met the requirements of anesthesia, no other major diseases that cause inoperability.(iv) All patients signed informed consent before surgery. After the patient was included, the most appropriate surgical method was chosen based on his or her comprehensive situation and doctor's preoperative assessment. The study was approved by the Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University(No.XJTU1AF2017LSL-3D010)

### **Surgical Approach**

In this study, there were a few differences in the specific modes of operation of the three procedures, and specific operational details are similar to other studies<sup>[17, 18]</sup>. During the operation, the extent of gastric resection, lymph node dissection and reconstruction after gastrectomy were also accomplished according to the Japanese gastric cancer treatment guidelines<sup>[19]</sup>.

### **Perioperative Data**

During the perioperative period, patient's baseline information had been collected, including the followings: age, sex, gender, body mass index (BMI). In addition, clinicopathologic characteristics such as American Society of Anesthesiologists physical status (ASA); pathological tumor node metastasis(pTNM) had also been collected. Among them, the standard of TNM staging was according to the rules of the American Joint Committee on Cancer<sup>[20]</sup>. Intraoperative estimated blood loss, total operation time, abdominal drainage, anal the time of first flatus, first intake liquid diet, complication morbidity and WBC count,etc. were recorded to evaluated short-term outcomes of the surgical procedure. All patients were discharged with no obvious discomfort, and their postoperative hospital stay were also recorded. Discharged patients were regular follow-up after gastrectomy.

## Cumulative Sum Analysis

The cumulative sum (CUSUM) method was used to evaluate the learning curve of RAG. The formula is [Due to technical limitations, this equation is only available as a download in the supplemental files section], where  $S_n$  was the accumulation of differences among each data  $x_i$  and the average of all data  $\mu$ . In this study,  $x_i$  represents the operation time of RAG patient, and  $n$  represents the total number of cases. Because there were no failure cases in the RAG, no risk-adjusted CUSUM(RA-CUSUM) was required<sup>[21]</sup>.

## Long-Term Outcome

Overall survival(OS) was defined as the time from the date of surgery completion to the date of death or the date of the last follow-up. Patients were followed up regularly after surgery and OS data were collected, which reflects the long-term outcome of patients. And the long-term outcomes after surgery were also used to assess the strengths and weaknesses of different surgical methods.

## Statistical Analysis

SPSS version 18.0(SPSS Inc., Chicago, IL, USA) was used to analyses statistical data. Continuous variables were expressed as mean±standard deviation(SD), the normal distribution data used the One-way ANOVA test, and the non-normally distributed data used the Kruskal-Wallis test. Categorical variables were expressed by the number of cases(%) and were analyzed by the Chi-squared test or Fisher's exact test. Kaplan-Meier survival curves were plotted for the OS, and the log-rank test was used to compare the differences among the three groups of surgery. All data were analyzed using a two-tailed test, and  $P$  value less than 0.05 was considered statistically significant.

## Results

### Baseline clinicopathologic characteristics of included patients

Total 42 patients of RAG, 44 patients of LAG, and 61 patients of OG were included (Table 1). No significant differences in the basic clinical information of the three groups were seen, such as gender, age and BMI ( $P > 0.05$ ). In the pre-operative ASA classification evaluation, 1–2 degree patients accounted for 71.4%, 79.5%, and 62.3%, respectively, but there was no difference in ASA classification among the three groups ( $P = 0.159$ ). In the operation, distal, proximal and total resection extent of the stomach were chosen according to the location of the tumor. However, there was no statistical difference among the RAG, LAG and OG groups in the choices of resection extent ( $P = 0.363$ ). Similarly, after resection of the stomach, there were similar in the ways of reconstruction ( $P = 0.283$ ), extend of lymph node dissection ( $P = 0.066$ ) and R0 resection ( $P = 0.239$ ) of three groups.

With respect to pathological parameters, the average tumor size and the differentiation degree of the OG group patients were statistically different from the LAG and RAG groups ( $P = 0.036, P = 0.040$ , respectively). In each group, patients with T4 were accounted for majority, but no significant difference was seen in the distribution of the pathological T classification in three groups ( $P = 0.055$ ). Similarly, there were no significant differences between the Pathological N classification ( $P = 0.623$ ) and the pathological stage ( $P = 0.329$ ) in the three groups.

## Surgical short-outcomes of included patients

Both RAG and LAG surgery were successful of all patients, without conversion to open surgery. As shown in Table 2, in the operation, the RAG group used the longest, while the OG group used the shortest time (RAG:  $300.50 \pm 46.17$  min, LAG:  $282.41 \pm 63.67$  min, OG:  $209.61 \pm 49.77$  min,  $P < 0.001$ ), For the estimated blood loss (EBL) among three groups, the RAG group had the least EBL (RAG:  $114.52 \pm 84.14$  mL, LAG:  $137.73 \pm 72.04$  mL, OG:  $153.61 \pm 67.41$  mL,  $P = 0.033$ ). Similarly, the RAG group was less than the other two groups in terms of time to first flatus (RAG:  $4.7 \pm 1.2$  d, LAG:  $5.4 \pm 1.1$  d, OG:  $5.5 \pm 0.9$  d,  $P < 0.001$ ), time to first intake liquid diet (RAG:  $5.5 \pm 1.2$  d, LAG:  $5.9 \pm 0.9$  d, OG:  $6.0 \pm 0.8$  d,  $P = 0.004$ ) and postoperative hospital stay (RAG:  $8.5 \pm 1.9$  d, LAG:  $9.2 \pm 2.5$  d, OG:  $9.8 \pm 2.0$  d,  $P < 0.023$ ).

Lymph node dissection is an important step after radical gastrectomy, in the three groups of surgery, the RAG group had the highest number of retrieved lymph nodes (RAG:  $26.8 \pm 7.7$ , LAG:  $25.9 \pm 8.4$ , OG:  $23.4 \pm 5.9$ ,  $P = 0.044$ ). Subsequently, the number of retrieved lymph nodes among RAG, LAG, OG groups in D1, D1+ and D2 dissection extend was compared. As shown in Figure 1, After grouping according to the dissection extend, there was similar in the number of retrieved lymph nodes among the three groups.

For postoperative patient drainage, such as abdominal drainage, gastric tube drainage, there were no statistically differences among the three groups ( $P = 0.499, P = 0.148$ , respectively). In addition, there was no significant difference in the complications among the three groups during hospitalization. What's more, as shown in Figure 2, Pre- and postoperative WBC count at postoperative day (POD) 1, 3 were recorded, no significant difference was seen in postoperative the WBC count among the groups ( $P >$

0.05).Furthermore, the RAG group had the most expensive treatment costs(RAG:124002.59±16636.45¥, LAG:102138.29±17492.23¥,OG:98077.55±17120.58¥,P=0.001.)

## Learning curves of RAG

The number of cases was taken as the abscissa, and the operation time as the ordinate, a line chart was established(Fig3), and as shown in Table3,the operation time of RAG was decreased with the extension of the number of cases( $R^2 = 0.1636$   $P = 0.0079$  ). However, the operation time of LAG and OG has no obvious relationship with the number of cases( $P = 0.8582$ , $P = 0.0758$ ). The CUSUM plot(Fig4)showed the cumulative time peaked when the number of surgical procedures accumulated to the 17th case, and 17 cases were the minimum surgical cases required to master the surgery across the learning curve. And the best fitting equation for the CUSUM learning curve is  $y = 0.04x^3 - 3.2527x^2 + 70.377x - 83.946$ ,the goodness of fit determination coefficient  $R^2 = 0.7617$ .

## Surgical long-outcomes of included patients

42 RAG, 44 LAG, and 61 OG patients were successfully followed up, and the median follow-up time was 426 days (13–970 days). In these patients, 5 patients died in the RAG group, 4 in the LAG group, and 12 in the OG group. Overall survival among three groups was comparable(Fig5),and there was no difference in survival among RAG,LAG and OG groups( $P = 0.4482$ ).

## Discussion

With the development of the Da Vinci robot system, minimally invasive treatment technology has once again risen to a new level<sup>[22]</sup>. However, the importance of RAG is still controversial in the clinic, there is not enough evidence to prove that RAG is superior to other radical gastrectomy. In this study, 147 patients with gastric cancer were included and divided into RAG,LAG and OG groups according to their own circumstances. A series of clinicopathologic characteristics and postoperative parameters were collected to compare the advantages and disadvantages of the three surgical methods.

We performed a statistical analysis of the patient's clinical data before surgery, and found that there were no statistically differences in gender, age, BMI and ASA degree among the three groups. This also means that the error in the surgical results caused by individual differences among patients can be ignored. Factors such as the location, size and pathological stage of the patient's tumor have a greater impact on the resection extent and reconstruction of the gastric cancer<sup>[23]</sup>. In our study, there was no significant difference in the distribution of the above parameters except for tumor size and differentiated degree among the three groups.

Subsequently, some short-term outcomes after surgery were analyzed. In this study, the RAG group had the longest operation time, followed by the LAG group, while the OG group had the shortest operation

time. Studies reported that the reason is RAG requires additional docking time<sup>[12, 24]</sup>. Another possible reason is that in this study, before RAG operation, the surgeon had completed hundreds of LAG and OG procedures and had more experience. Although the operation time is the longest in RAG group, the EBL is the least among the three groups. Because the Da Vinci surgical robot has more stable arms and joint freedom, which can help you operate freely in a special space, what's more, a 3-dimensional images can provide a broader and finer view. During the operation, especially during lymph node dissection, precise and free operation will bring less injury to the patient<sup>[25]</sup>. Studies have shown that intestinal function will restore faster due to less damage in RAG group<sup>[26]</sup>, as the same in our study, the time of first flatus and first intake liquid diet in RAG group were significantly lower than other groups. Finally, this method of less injury and quick recovery makes the hospital stay significantly shorter, which is consistent with the study of Kim et al<sup>[9]</sup>. In addition, postoperative abdominal drainage, gastric tube drainage among three groups were similar, the possible reason is the large data difference within the group. Postoperative stress response is very common, which is closely related to postoperative complication and WBC count can fully reflect the postoperative stress state of patients<sup>[11]</sup>. In this study, we recorded WBC count of baseline, PODs 1 and 3 in the groups, however, no significant difference of WBC count was found, which consistent with the occurrence of complication in three group. Furthermore, common early complications of radical gastrectomy, such as anastomotic leakage, anastomotic bleeding, pulmonary infection, delayed gastric emptying were recorded, which were similar in three groups. However, some research suggest that fewer complications were observed in RAG than LAG and OG<sup>[27]</sup>, the reason for the inconsistency may be the sample size in our study, and the complications can't reflect the advantages of RAG.

The number of retrieved lymph nodes have a strong relationship with the prognosis of patients in gastric cancer<sup>[28]</sup>. This study showed that the total number of lymph nodes in RAG group is more than in OG group. The extent of systematic lymphadenectomy is defined according to the resection extent and cTNM stages, and the extent is divided into D1, D1+, and D2<sup>[19]</sup>. We separately counted the number of retrieved lymph nodes of D1, D1+, and D2 categories. Although no statistically significance, we can see that the number of dissected lymph nodes in the RAG group is the highest in the three groups. Some studies have said that traditional method can't clean lymph nodes in some areas<sup>[29]</sup>, and RAG has some advantages in lymph node dissection because of its wide field of view, 3D vision and flexible endowrist.

Study have shown that surgeons with experience in skilled LAG will quickly overcome the learning curve of RAG<sup>[30]</sup>. However, there is still not enough large sample data for the study of the RAG learning curve. In this study, the CUSUM method was used to evaluate the learning curve of surgeon who already qualified for Da Vinci surgery, and operation time was used to as a measure. The result showed that the CUSUM value peaks in the 17th case, which means 17 cases were needed to be accumulated for proficiency in RAG surgery. This is lower than the number of cases proficient in LAG<sup>[31, 32]</sup>. With the popularity of Da Vinci surgical robots around the world, the simplicity and ease of learning of this technology has also become a huge advantage.

All three surgical methods can successfully complete radical gastrectomy, and there is no significant difference in the long-term outcome. During the follow-up period, more than one patient died in each group, but the cause of each death had not been collected, and, no data on progression-free survival(PFS) was collected. In addition, our research has the following limitations. First, this study is a single-center retrospective study, and the sample size is small, there will be some bias in data collection and analysis, therefore, more cautious conclusion should be taken in this study. Second, this study only analyzed the surgical learning curve of RAG, and did not compare it with LAG and OG groups. Third, We have not collected data on late complications of radical gastrectomy, making the comparison of complications more limited. Fourth, the follow-up time was short and the median follow-up date was only 426 days. Despite these shortcomings, our research is sufficient to demonstrate the advantages of RAG in radical gastrectomy. In the future, more large-scale, multicenter randomized controlled trials need be conducted to confirm our findings.

## Conclusion

RAG is a simple and feasible surgical method, which has certain advantages in radical gastrectomy, but more well-design, multi-center, large sample randomized controlled trials need to be designed to confirm this.

## List Of Abbreviations

Robotic-assisted gastrectomy—RAG

Laparoscopic-assisted gastrectomy—LAG

Open gastrectomy—OG

Estimated blood loss—EBL

White blood cells—WBC

American Society of Anesthesiologists physical status—ASA

pathological tumor node metastasis—pTNM

Overall survival—OS

Cumulative sum—CUSUM

Postoperative day—POD

## Declarations

# Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to the privacy of patients and the preservation of hospital medical records but are available from the corresponding author on reasonable request.

## Competing interests

The author(s) declared that there were no conflicts of interest with the research, authorship and publication of this article.

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## Author contributions

Weifan Zhang was responsible for the whole experiment design and paper writing; Xinhui Zhao, Hui Dang were contributed to the data collection and analysis, Xinhui Zhao [analyzed](#) the experimental data, Peng Xia was the main surgeon, Lei Meng and Zhao Liu were the assistants of all operations.

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## Tables

**TABLE 1 Baseline clinicopathologic characteristics of patients**

|                               | RAG n(%)<br>(n=42) | LAG n(%)<br>(n=44) | OG n(%)<br>(n=61) | Pvalue             |
|-------------------------------|--------------------|--------------------|-------------------|--------------------|
| Age(years)                    |                    |                    |                   | 0.074 <sup>a</sup> |
| ≥60                           | 21(50.0)           | 22(50.0)           | 42(68.9)          |                    |
| <60                           | 21(50.0)           | 22(50.0)           | 19(30.6)          |                    |
| Sex                           |                    |                    |                   | 0.082 <sup>a</sup> |
| Male                          | 31(73.8)           | 40(90.9)           | 46(75.4)          |                    |
| Female                        | 11(26.2)           | 4(9.1)             | 15(24.6)          |                    |
| BMI(kg/m <sup>2</sup> )       | 22.98±3.17         | 21.94±2.53         | 22.36±3.63        | 0.301 <sup>b</sup> |
| ASA                           |                    |                    |                   | 0.159 <sup>a</sup> |
| 1 or 2                        | 30(71.4)           | 35(79.5)           | 38(62.3)          |                    |
| 3 or 4                        | 12(28.6)           | 9(20.5)            | 23(37.7)          |                    |
| Tumor size(cm)                | 3.5±1.9            | 3.5±1.8            | 4.5±2.7           | 0.036 <sup>b</sup> |
| Lymph node dissection         |                    |                    |                   | 0.066 <sup>c</sup> |
| D1                            | 2(4.8)             | 4(9.1)             | 3(4.9)            |                    |
| D1+                           | 13(31.0)           | 9(20.5)            | 6(9.8)            |                    |
| D2                            | 27(64.2)           | 31(70.4)           | 52(85.3)          |                    |
| Pathological T classification |                    |                    |                   | 0.055 <sup>a</sup> |
| T1                            | 15(35.7)           | 13(29.5)           | 9(14.8)           |                    |
| T2                            | 4(9.5)             | 8(18.2)            | 6(9.8)            |                    |
| T3                            | 1(2.4)             | 5(11.4)            | 9(14.8)           |                    |
| T4                            | 22(52.4)           | 18(40.9)           | 37(60.7)          |                    |
| Pathological N classification |                    |                    |                   | 0.623 <sup>a</sup> |
| N0                            | 19(45.2)           | 19(43.2)           | 19(31.1)          |                    |
| N1                            | 9(21.4)            | 6(13.6)            | 16(26.2)          |                    |
| N2                            | 7(16.7)            | 10(22.7)           | 12(19.7)          |                    |
| N3                            | 7(16.7)            | 9(20.5)            | 14(23.0)          |                    |
| Stage                         |                    |                    |                   | 0.329 <sup>a</sup> |
| 1                             | 16(38.1)           | 17(38.6)           | 14(23.0)          |                    |
| 2                             | 5(11.9)            | 5(11.4)            | 6(9.8)            |                    |
| 3                             | 21(50.0)           | 22(50.0)           | 41(67.2)          |                    |
| Resection margin              |                    |                    |                   | 0.339 <sup>c</sup> |
| Negative                      | 42(100)            | 44(100)            | 59(96.7)          |                    |
| Positive                      | 0(0)               | 0(0)               | 2(3.3)            |                    |
| Differentiated degree         |                    |                    |                   | 0.040 <sup>a</sup> |
| Poorly                        | 19(45.2)           | 24(54.5)           | 16(26.2)          |                    |
| Moderately                    | 14(33.3)           | 15(34.1)           | 29(47.5)          |                    |
| Well                          | 9(21.4)            | 5(11.4)            | 16(26.2)          |                    |
| Resection extent              |                    |                    |                   | 0.363 <sup>a</sup> |
| Distal                        | 17(40.5)           | 22(50.0)           | 29(42.0)          |                    |
| Proximal                      | 12(28.6)           | 5(20.8)            | 8(33.3)           |                    |
| Total                         | 13(31.0)           | 17(31.5)           | 24(44.4)          |                    |
| Reconstruction                |                    |                    |                   | 0.391 <sup>c</sup> |
| Roux-en-Y esophagojejunostomy | 12(8.6)            | 17(38.6)           | 24(39.3)          |                    |
| Double tract method           | 5(11.9)            | 1(2.3)             | 1(1.6)            |                    |
| Billroth I gastroduodenostomy | 4(9.5)             | 8(18.2)            | 9(14.8)           |                    |
| Billroth II gastrojejunostomy | 13(31.0)           | 13(29.5)           | 20(32.8)          |                    |
| Esophagogastrostomy           | 8(19.0)            | 5(11.4)            | 7(11.5)           |                    |

Note: data are mean ± standard deviation or n (%) of patients

<sup>a</sup>Chi-squared test

<sup>b</sup>one-way ANOVA test

<sup>c</sup>Fisher's exact test

**TABLE 2 Short-term outcomes of patients**

|                                    | RAG n(%)<br>(n=42) | LAG n(%)<br>(n=44) | OG n(%)<br>(n=61) | P value             |
|------------------------------------|--------------------|--------------------|-------------------|---------------------|
| Operation time (min)               | 300.50±46.17       | 282.41±63.67       | 209.61±49.77      | 0.001 <sup>a</sup>  |
| Estimated blood loss (mL)          | 114.52±84.14       | 137.73±72.04       | 153.61±67.41      | 0.033 <sup>b</sup>  |
| First exhaust [days]               | 4.7±1.2            | 5.4±1.1            | 5.5±0.9           | 0.001 <sup>a</sup>  |
| First intake liquid diet (days)    | 5.5±1.2            | 5.9±0.9            | 6.0±0.8           | 0.004 <sup>a</sup>  |
| Abdominal drainage (mL)            | 315.33±158.80      | 328.41±206.15      | 382.05±423.46     | 0.499 <sup>b</sup>  |
| Gastric tube drainage (mL)         | 221.79±171.46      | 261.02±275.15      | 329.26±339.67     | 0.148 <sup>b</sup>  |
| Early complications                |                    |                    |                   | 0.999 <sup>c</sup>  |
| Anastomosis leakage                | 1(2.3)             | 2(4.5)             | 2(3.3)            |                     |
| Anastomotic bleeding               | 0(0)               | 0(0)               | 1(1.6)            |                     |
| Delayed gastric emptying           | 0(0)               | 1(2.3)             | 1(1.6)            |                     |
| Pulmonary infection                | 2(4.7)             | 1(2.3)             | 2(3.3)            |                     |
| Retrieved lymph nodes              | 26.8±7.7           | 25.9±8.4           | 23.4±5.9          | 0.044 <sup>b</sup>  |
| Postoperative hospital stay (days) | 8.5±1.9            | 9.2±2.5            | 9.8±2.0           | 0.023 <sup>b</sup>  |
| WBC Count (10 <sup>9</sup> /L)     |                    |                    |                   |                     |
| Baseline                           | 5.140±1.600        | 5.653±1.624        | 6.000±1.933       | 0.0532 <sup>b</sup> |
| POD1                               | 13.330±4.882       | 13.080±3.728       | 13.630±4.247      | 0.8083 <sup>b</sup> |
| POD3                               | 8.693±4.043        | 9.418±2.736        | 10.400±3.767      | 0.0571 <sup>b</sup> |
| Cost (¥)                           | 124002.59±16636.45 | 102138.29±17492.23 | 98077.55±17120.58 | 0.001 <sup>b</sup>  |

Note: data are mean ± standard deviation or n (%) of patients

<sup>a</sup>Kruskal-Wallis test

<sup>b</sup>One-way ANOVA test

<sup>c</sup>Fisher's exact test.

**TABLE 3 Best fitting equation of number of cases and operation time**

|              | Equation   | R square  | P value |
|--------------|--|-----------|---------|
| RAG          | Y = -1.522X+333.2  | 0.1636    | 0.0079  |
| LAG          | Y = 0.1374X+279.3  | 0.0007687 | 0.8582  |
| OG           | Y = 0.6423X+189.7  | 0.05248   | 0.0758  |
| CUSUM of RAG | Y = 0.04X <sup>3</sup> - 3.2527X <sup>2</sup> + 70.377X - 83.946 | 0.7617    | 0.0172  |

## Figures

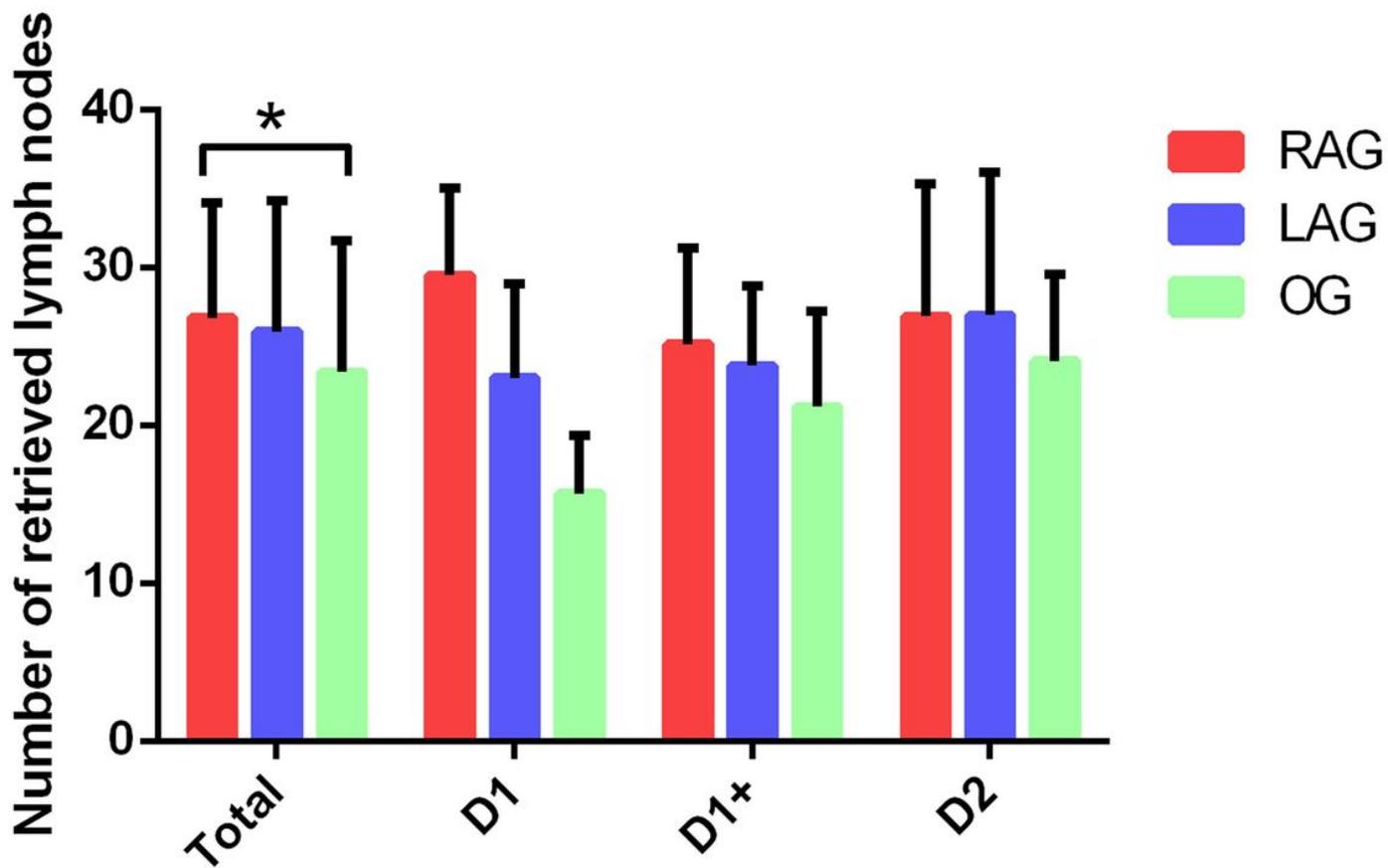


Figure 1

The number of retrieved lymph nodes of total, D1, D1+, and D2 categories \*means  $p < 0.05$

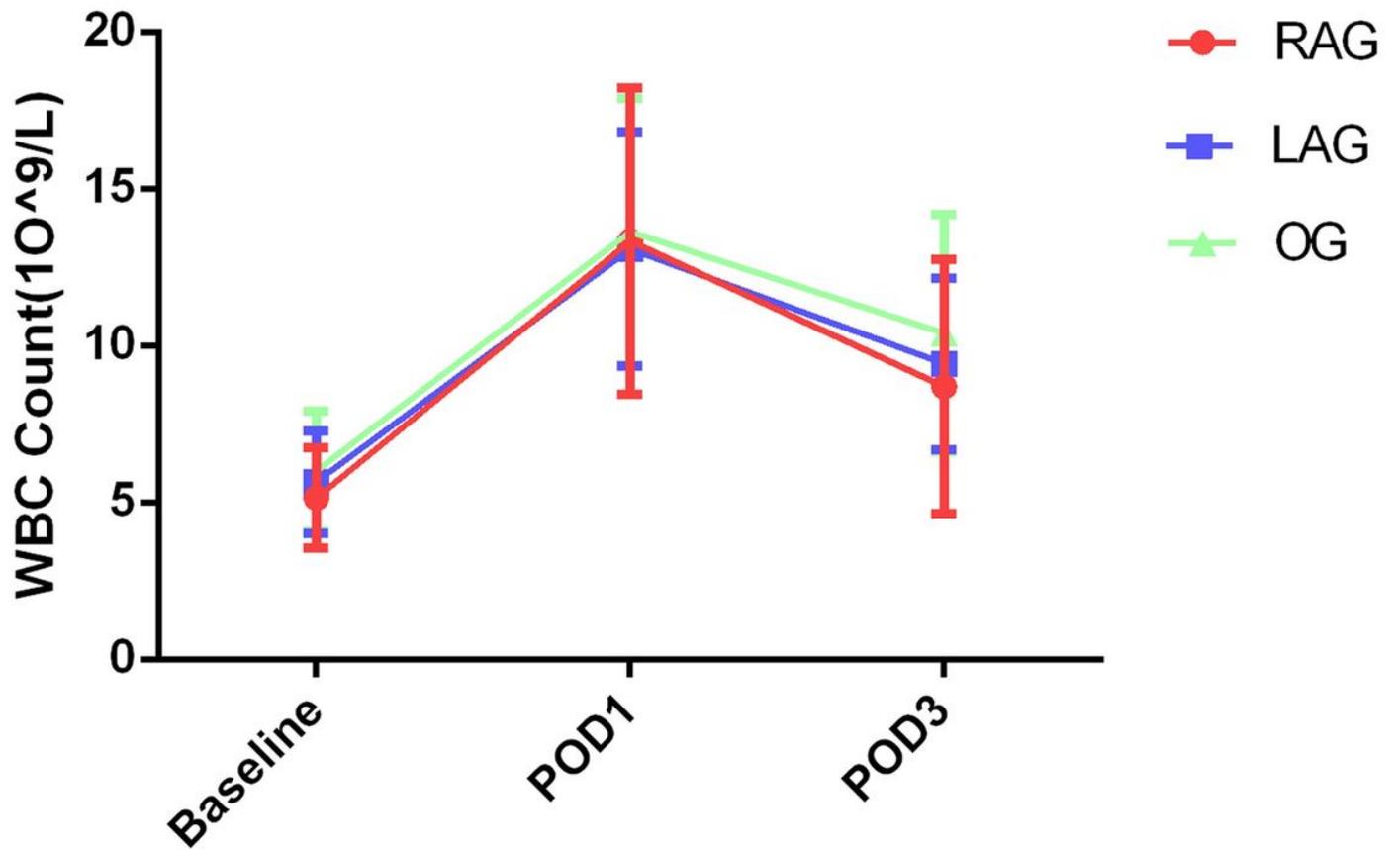


Figure 2

The WBC count of baseline and postoperative day(POD)1 and 3

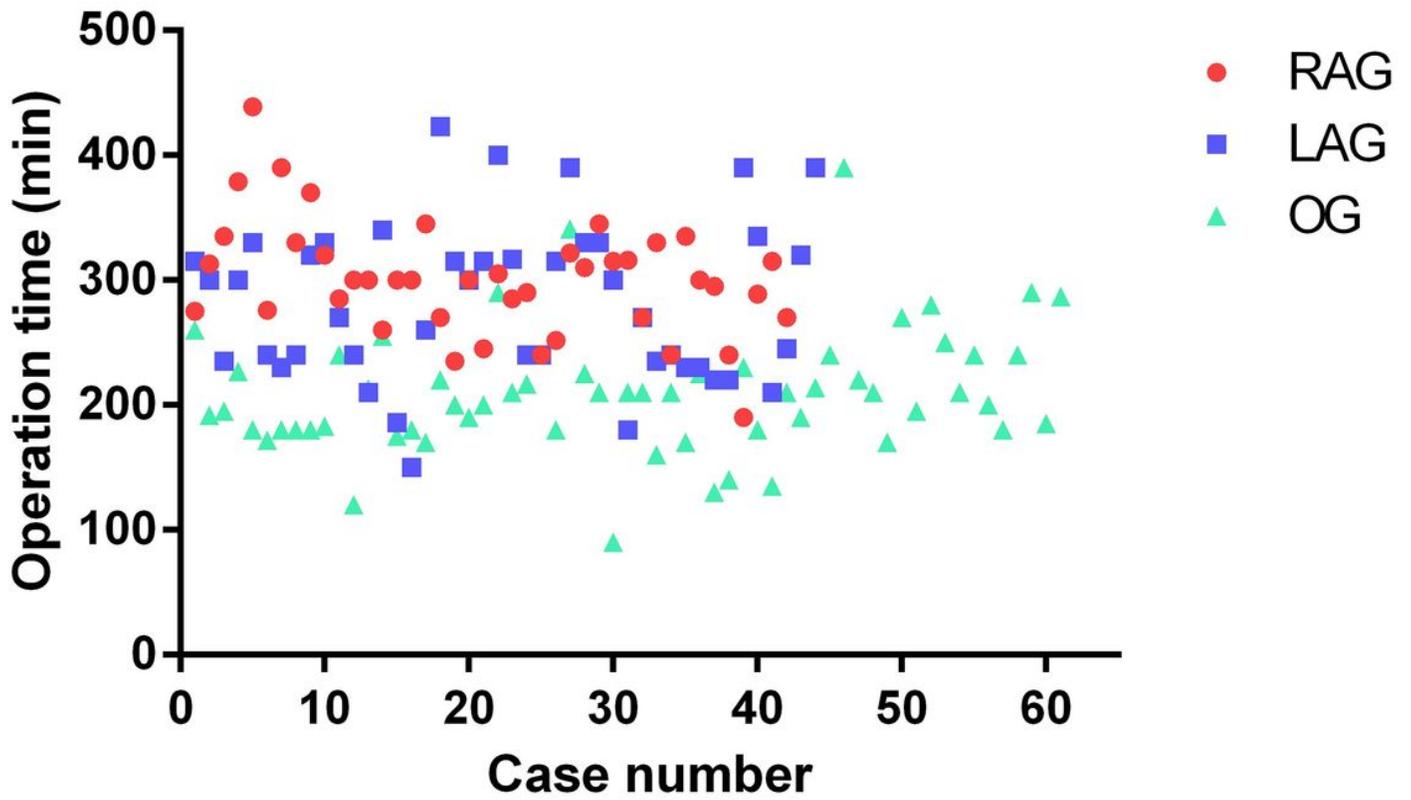


Figure 3

Operation time with number of cases in three groups

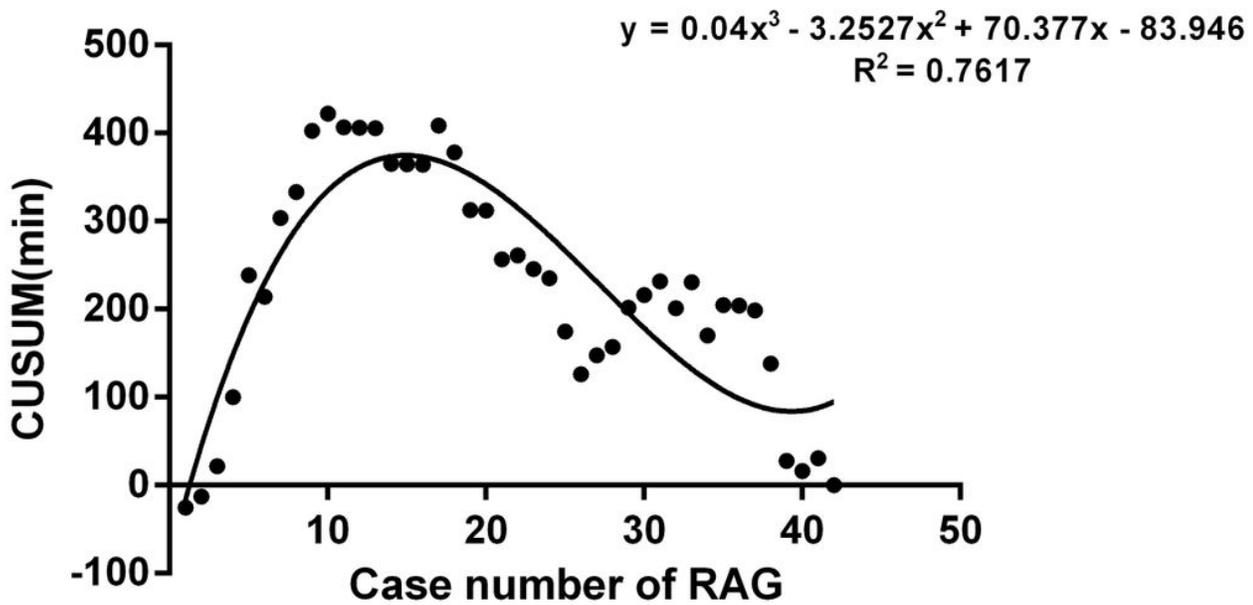


Figure 4

The CUSUM for the operation time of RAG group

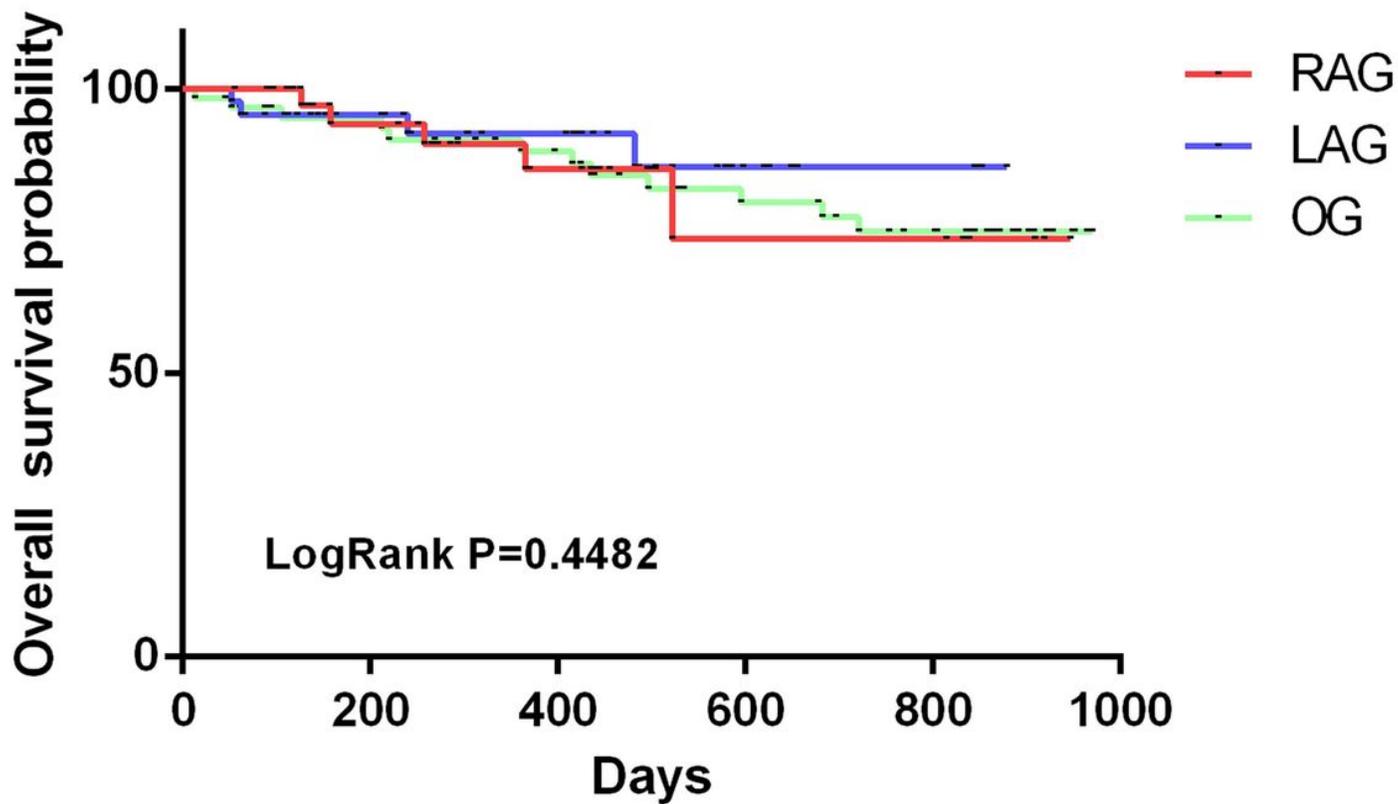


Figure 5

The overall survival of three groups

## Supplementary Files

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- [eq1.jpg](#)