Efficacy and safety of gasless single-port laparoscopic-assisted radical rectal cancer surgery: A single-center prospective observational study

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Abstract

Purpose

Gasless single-port laparoscopic-assisted surgery (GSLR) has more applications in gynecologic surgery, but its safety and efficacy still need to be explored in rectal cancer surgery.

Methods

Patients who underwent GSLR surgery and carbon dioxide pneumoperitoneum laparoscopic surgery (LR) from June 2017 to June 2022 were collected. General information data of the patients were collected along with the relevant central venous pressure (CVP), peak airway pressure (PIP), postoperative pain scores, T-cell subpopulations and postoperative complications.

Results

In this study, a total of 186 patients were enrolled, including 90 patients in the GSLR and 96 patients in the LR groups, and no significant differences were observed in the general data of the two groups. The results of the study showed that the CVP and PIP of the GSLR group were significantly lower than those of the LR group during and at the end of the operation ($P<0.05$). Also, the GSLR group had lower postoperative pain scores and smaller abdominal incisions than LR ($P<0.05$). Similarly, on postoperative day 7, CD3+, CD4+ and CD8+ cell levels resumed more rapidly in the GSLR group than in the LR group ($P<0.05$). Moreover, the incidence of postoperative lung infection was also lower in the GSLR group than in the LR group ($P<0.05$).

Conclusions

This study demonstrates that the GSLR procedure is a favorable safety and efficacy profile in rectal cancer and can be used as a new surgical treatment option for rectal cancer patients.

Introduction

About 30% of colorectal cancers (CRC) are rectal cancers (RC), of which RC ranks fourth among the leading causes of cancer-related deaths in China (1). Improving the quality of life of rectal cancer patients and reducing surgical trauma are among the directions in which minimally invasive surgery is striving to develop (2). Many studies have demonstrated that minimally invasive rectal cancer surgery has many advantages over traditional open surgery, such as less stress (3), fewer effect on urinary function and sexual function (4), faster recovery of gastrointestinal function (5). However, minimally invasive rectal cancer surgery with gas insufflation still has its limitations. Gas-infused minimally invasive surgical procedures require the use of carbon dioxide (CO2) gas to create an artificial pneumoperitoneum, which
has an impact on the patient's cardiorespiratory function, intra-abdominal organ perfusion, and immune system, as well as risks of subcutaneous and mediastinal emphysema, hypercapnia, and air embolism (6, 7). Hence, there is a need to find a minimally invasive rectal cancer surgery with reduced gas filling to reduce the risk of surgery for patients.

Gasless laparoscopic surgery shows the intra-abdominal surgical space by a suspension device. Complications related to pneumoperitoneum are removed and there is less impact on blood circulation (8, 9). Moreover, single-port laparoscopic surgery is performed through a small incision, which reduces the amount of analgesic medication and postoperative pain (10, 11). Previous studies have shown that the technique of gasless laparoscopic surgery combined with single-port laparoscopic surgery demonstrates faster postoperative recovery, fewer complications, and shorter hospital stays in appendectomy and gynecologic surgery (12, 13). However, there are no relevant studies combining gasless laparoscopic surgery with single-port laparoscopic surgery in rectal cancer in a clinical prospective study.

In this study, we attempted to use gasless single-port laparoscopic-assisted surgery (GSLR) in patients with rectal cancer and compared it with carbon dioxide pneumoperitoneal laparoscopic surgery (LR). The purpose of this study was to evaluate the efficacy and safety of gasless single-port laparoscopic-assisted radical rectal cancer surgery.

Materials and methods

Study design and participants

This study was conducted from June 2017 to June 2022 at the Second Affiliated Hospital of Chongqing Medical University. The inclusion criteria for this study were as follows: Patients rectal adenocarcinoma confirmed by pathology. No distant metastasis was found in preoperative imaging. Patients underwent gasless single-port laparoscopic-assisted surgery (GSLR) and carbon dioxide pneumoperitoneal laparoscopic surgery (LR). A total of 194 patients were randomly assigned.

The exclusion criteria for this study were as follows: patients who had history of abdominal surgery (n = 2). Patients who underwent emergency surgery for rectal cancer (n = 3). Patients converted to open surgery during minimally invasive rectal cancer surgery (n = 2). Patients who refused informed consent (n = 1). Finally, 186 patients were included in this study.

Since the preliminary preparation began in September 2017, this clinical research was registered on the official website of clinicaltrials.gov, Project No. NCT03318185, Project name: Efficacy and safety of gasless single-port laparoscopic-assisted radical resection for rectal carcinoma. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki (6th revision, 2008). Informed consents were written by all the patients.

Surgical Procedures
Gasless single-port laparoscopic-assisted surgery (GSLR): After general anesthesia, the patient was placed in the lying position. Using an open surgical approach, a 3.0 cm McBurney incision was made in the right lower abdomen. A wound retractor (Alexis® Wound Retractor, Applied Medical, Rancho Santa Margarita, California, USA) was used at the incision. The Kirschner wire was passed through the plane of the midpoint of the pubic symphysis and the navel and, if necessary, 3.0 cm below the navel. It was then attached to a traction chain and secured to a suspended laparoscopic swing arm. The abdominal wall is pulled up by adjusting the length of the retractor chain. The surgeon and assistant are on the right side of the patient. Both conventional surgical instruments and laparoscopic instruments are introduced through the abdominal wall through the McBurney incision. After mobilization and resection, the bowel and lesion were brought out of the abdominal cavity through this incision. The continuity of the bowel was re-established with a stapled anastomosis.

Carbon dioxide pneumoperitoneal laparoscopic surgery (LR): After general anesthesia, the patient was placed in the lithotomy position. Pneumoperitoneum was initiated through a supraumbilical incision with a 10-mm trocar needle. Intra-abdominal pressure was set at 12 mmHg. LR was then performed using a four-hole technique (one 12-mm trocar and three 5-mm trocars). After movement and resection, the pneumoperitoneum was deflated. Then, the bowel and lesion were brought out of the abdominal cavity through a small incision. Stapled anastomoses were used to re-establish the continuity of the bowel.

Assessment parameters

General information about the participants included gender, age, and body mass index (BMI). Surgery-related parameters included the participants' operative time, number of lymph node dissection, perioperative central venous pressure (CVP), peak airway pressure (PIP), time to anal voiding, and postoperative incisional pain score (postoperative pain scoring was done using a visual analog scale (VAS)). Meanwhile, changes in T-cell subpopulation indexes were detected by the patients' peripheral blood, which included the peripheral blood CD3+, CD4+, and CD8+ cell levels of the patients' preoperative, postoperative day 1, and postoperative day 7.

Statistics

Statistical analyses were performed using SPSS 17.0 software (SPSS, Chicago, IL, USA). Data are presented as the means ± standard deviation. Student t test or Mann–Whitney rank sum test was used to compare continuous variables between groups, while for discrete variables Chi-square or Fisher exact test was used. A P-value < 0.05 was considered significant.

Results

186 participants were included in this study and the flow chart of the study is shown in Fig. 1. In this study, there were 90 patients in the gasless single port laparoscopic assisted surgery (GSLR) group while 96 patients in the control Carbon dioxide pneumoperitoneal laparoscopic surgery (LR) group. As shown in
Table 1, there was no statistically significant difference between the two groups in terms of age, gender and BMI.

Table 1
General participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>GSLR group(n = 90)</th>
<th>LR group(n = 96)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages (years)</td>
<td>68.46 ± 3.756</td>
<td>66.63 ± 2.932</td>
<td>0.2798</td>
</tr>
<tr>
<td>Genders</td>
<td>male 48</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>female 42</td>
<td>40</td>
<td>0.5642</td>
</tr>
<tr>
<td>BMI(kg/m^2)</td>
<td>22.82 ± 0.6124</td>
<td>23.77 ± 0.4235</td>
<td>0.3174</td>
</tr>
</tbody>
</table>

GSLR: gasless single port laparoscopic assisted surgery. BMI: body mass index. LR: Carbon dioxide pneumoperitoneal laparoscopic surgery.

As shown in Fig. 2, GSLR can still expose the key anatomical structures of the pelvis without affecting the surgical operation. Meanwhile, as shown in Table 2, there were no significant differences between the GSLR and LR groups in terms of operative time, lymph node dissection, preoperative central venous pressure (CVP) and preoperative peak airway pressure (PIP). The results of this study showed that CVP and PIP in the GSLR group were significantly lower than those in the LR group during and 10 min after the procedure (Table 2).

Table 2
Parameters related to the perioperative period

<table>
<thead>
<tr>
<th></th>
<th>GSLR group(n = 90)</th>
<th>LR group(n = 96)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery time (min)</td>
<td>139.8 ± 3.677</td>
<td>125.8 ± 2.217</td>
<td>0.2132</td>
</tr>
<tr>
<td>Number of lymph node dissection</td>
<td>13.59 ± 0.2926</td>
<td>14.23 ± 0.326</td>
<td>0.1431</td>
</tr>
<tr>
<td>Central venous pressure (CVP)(cmH2O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to the start of surgery</td>
<td>10.63 ± 0.1503</td>
<td>10.28 ± 0.1288</td>
<td>0.0758</td>
</tr>
<tr>
<td>During the surgery</td>
<td>15.62 ± 0.1537</td>
<td>18.29 ± 0.1381</td>
<td><strong>0.0079</strong></td>
</tr>
<tr>
<td>After the surgery</td>
<td>12.63 ± 0.1503</td>
<td>14.28 ± 0.1297</td>
<td><strong>0.0221</strong></td>
</tr>
<tr>
<td>Peak airway pressure (PIP) (cmH2O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to the start of surgery</td>
<td>15.37 ± 0.1912</td>
<td>14.8 ± 0.164</td>
<td>0.2256</td>
</tr>
<tr>
<td>During the surgery</td>
<td>19.37 ± 0.1932</td>
<td>21.75 ± 0.1649</td>
<td><strong>0.0067</strong></td>
</tr>
<tr>
<td>After the surgery</td>
<td>17.36 ± 0.1885</td>
<td>18.81 ± 0.1671</td>
<td><strong>0.0356</strong></td>
</tr>
</tbody>
</table>
GSLR: gasless single port laparoscopic assisted surgery. LR: Carbon dioxide pneumoperitoneal laparoscopic surgery.

In this study, the results showed that the pain scores of the patients in the GSLR group were significantly lower than those of the LR group from postoperative day 1 to postoperative day 4, and the postoperative anal defecation time of the patients in the GSLR group was earlier than that of the patients in the LR group (Table 3). As shown in Fig. 3, patients in the GSLR group also had significantly smaller surgical incision scars than those in the LR group ($P<0.05$).

![Table 3](image)

<table>
<thead>
<tr>
<th>Duration of anal defecation (hours)</th>
<th>GSLR group(n = 90)</th>
<th>LR group(n = 96)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>The day of surgery</td>
<td>2.35 ± 0.243</td>
<td>2.54 ± 0.253</td>
<td>0.3124</td>
</tr>
<tr>
<td>Postoperative day 1</td>
<td>3.56 ± 0.342</td>
<td>4.64 ± 0.274</td>
<td>0.0321</td>
</tr>
<tr>
<td>Postoperative day 2</td>
<td>3.66 ± 0.245</td>
<td>4.92 ± 0.315</td>
<td>0.0278</td>
</tr>
<tr>
<td>Postoperative day 3</td>
<td>2.24 ± 0.235</td>
<td>3.34 ± 0.312</td>
<td>0.0198</td>
</tr>
<tr>
<td>Postoperative day 4</td>
<td>1.43 ± 0.087</td>
<td>2.25 ± 0.177</td>
<td>0.0368</td>
</tr>
<tr>
<td>Postoperative day 5</td>
<td>1.36 ± 0.121</td>
<td>1.43 ± 0.153</td>
<td>0.6843</td>
</tr>
</tbody>
</table>

GSLR: gasless single port laparoscopic assisted surgery. LR: Carbon dioxide pneumoperitoneal laparoscopic surgery.

As shown in Table 4, on postoperative day 1, the levels of CD3+, CD4 + and CD8 + cells were significantly lower in both groups compared with preoperative levels ($P<0.05$). Meanwhile, the reduction of lymphocyte subpopulations in patients in the GSLR group was relatively less compared with that in the LR group, and the difference between the two groups was statistically significant ($P<0.05$, Table 4). Moreover, on postoperative day 7, the reduced immune cell subpopulations began to rebound, and the cell counts in the GSLR group rebounded rapidly, and the difference between the two groups was also statistically significant (Table 4). The results of this study showed that the rate of pulmonary infection in patients in the GLSR group was significantly lower than that in the LR group (Table 5).
Table 4
Parameters of lymphocyte subset subgroups

<table>
<thead>
<tr>
<th></th>
<th>GSLR group(n = 90)</th>
<th>LR group(n = 96)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CD3+ (n/µL)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>912.6 ± 55.29</td>
<td>1032.2 ± 72.32</td>
<td></td>
</tr>
<tr>
<td>Postoperative 1</td>
<td>736.4 ± 62.42</td>
<td>712.6 ± 57.44</td>
<td>0.0366</td>
</tr>
<tr>
<td>Postoperative 7</td>
<td>896.4 ± 64.32</td>
<td>787.0 ± 52.43</td>
<td>0.0198</td>
</tr>
<tr>
<td><strong>CD4^+ (n/µL)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>492.8 ± 32.76</td>
<td>526.6 ± 46.47</td>
<td></td>
</tr>
<tr>
<td>Postoperative 1</td>
<td>386.4 ± 29.72</td>
<td>227.9 ± 37.48</td>
<td>0.0323</td>
</tr>
<tr>
<td>Postoperative 7</td>
<td>456.6 ± 37.56</td>
<td>468.4 ± 35.39</td>
<td>0.0478</td>
</tr>
<tr>
<td><strong>CD8^+ (n/µL)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>334.6 ± 25.77</td>
<td>347.5 ± 38.92</td>
<td></td>
</tr>
<tr>
<td>Postoperative 1</td>
<td>271.2 ± 31.47</td>
<td>236.0 ± 25.37</td>
<td>0.0378</td>
</tr>
<tr>
<td>Postoperative 7</td>
<td>314.6 ± 32.23</td>
<td>260.2 ± 27.43</td>
<td>0.0436</td>
</tr>
</tbody>
</table>

GSLR: gasless single port laparoscopic assisted surgery. LR: Carbon dioxide pneumoperitoneal laparoscopic surgery.

Table 5
Postoperative complications in two groups.

<table>
<thead>
<tr>
<th></th>
<th>GSLR group(n = 90)</th>
<th>LR group(n = 96)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incision infection</td>
<td>5(5.56%)</td>
<td>6(6.25%)</td>
<td>0.6453</td>
</tr>
<tr>
<td>Lung infection</td>
<td>8(8.89%)</td>
<td>12(12.50%)</td>
<td>0.0265</td>
</tr>
<tr>
<td>Anastomotic leakage</td>
<td>5(5.56%)</td>
<td>5(5.21%)</td>
<td>0.5865</td>
</tr>
<tr>
<td>Difficulty urinating</td>
<td>10(11.11%)</td>
<td>11(11.46%)</td>
<td>0.6837</td>
</tr>
</tbody>
</table>

GSLR: gasless single port laparoscopic assisted surgery. LR: Carbon dioxide pneumoperitoneal laparoscopic surgery.

Discussion

The aim of this study was to explore the use of gasless single-port laparoscopic-assisted surgery (GSLR) in rectal cancer surgery in a prospective study in 186 patients. The results of this study showed that the GSLR procedure does not affect the exposure of important anatomical locations during surgery and does
not interfere with the surgical procedure. Moreover, GSLR has less effect on cardiopulmonary function during surgery and faster recovery of wound pain and gastrointestinal function in the postoperative period. During the postoperative recovery, our results showed that the GSLR procedure had less impact on the patient's immune cells and lung infections.

Clinical treatment of rectal cancer continues to rely on surgery, chemotherapy, radiotherapy, and typically signal-targeted therapy (14). In many countries, laparoscopic surgery has become one of the optional treatments for rectal cancer (15). Previous studies have shown that the survival benefit of laparoscopic surgery is encouraging and supports the routine use of laparoscopic surgery in adult patients with rectal cancer in the current era of minimally invasive surgery (16). Carbon dioxide pneumoperitoneum is the classic method of surgical field exposure in laparoscopic surgery (17), which is usually safe and effective but has some disadvantages. First, elevated abdominal pressure increases cardiac preload and afterload, thereby decreasing cardiac function (18–20). Second, respiratory function may be impaired due to elevated intrathoracic and airway pressures (21). In addition, pneumoperitoneum may lead to hypercapnia, internal environment disorders, and even life-threatening complications such as gas embolism and renal dysfunction (22–24). Therefore, it is necessary to find a new minimally invasive surgical procedure to improve the adverse effects of pneumoperitoneum in conventional laparoscopic rectal cancer surgery.

The GSLR procedure is an excellent solution to the effects of pneumoperitoneum on patients. Previous studies have shown that the GSLR procedure is a safe, effective and minimally invasive treatment in gynecologic surgery, with associated savings in medical costs (25). Intriguingly, studies have shown that even pregnant women can tolerate various GSLR surgeries, avoiding hypercapnia and elevated intra-abdominal pressure due to gas insufflation (26). However, the GSLR surgery has not been explored in the context of radical resection for rectal cancer.

In our study, a total of 186 patients underwent minimally invasive radical resection of rectal cancer, of whom 90 underwent GSLR. Our results show that the GSLR does not affect the exposure of the surgical field, and it is able to visualize the critical anatomical areas well, facilitating the surgical procedure. In our study, there was no significant difference between patients in the GSLR and LR groups in terms of parameters such as age, sex, and BMI. As shown in Table 2, our results demonstrated that CVP and PIP were lower in the GSLR group at 1 h from the start of surgery and at 10 min from the end of surgery than in the LR surgical group. This indicates that the GSLR surgery had less impact on the cardiopulmonary function of the patients than the LR group. We also found that patients in the GSLR group recovered earlier from postoperative anal defecation and had less postoperative pain than those in the LR group. In Fig. 2, we also found that the surgical scar was smaller in the GSLR group. Moreover, the results of this study showed that the effect of GSLR on CD3+, CD4+, CD8 + cells of the patients was also less on postoperative day 1 and postoperative day 7 (Table 4). As shown in Table 5, in terms of postoperative complications, the results of the present study also showed that there were fewer complications of lung infection in the GSLR group compared with the LR procedure.
This study also has some limitations. First, the number of people included in this study is small, and a large sample is needed to confirm the results. Second, the results of this study are only for the Chinese population, and further research is needed for other ethnic groups. Third, the results of this study are only applicable to radical resection for rectal cancer, and further research is needed for other types of surgery.

In conclusion, the GSLR procedure in radical rectal resection does not interfere with the surgeon's operation and is effective in exposing key anatomical sites during surgery, while having less impact on the patient's cardiopulmonary function during surgical anesthesia. In the postoperative recovery process, the GSLR surgery also restored the patient's postoperative gastrointestinal function and T-cell subpopulations earlier compared with the LR surgery. Therefore, the GSLR surgery offers a new surgical treatment option for suitable rectal cancer patients.

**Declarations**

**Data Availability Statement**

The original contributions generated for the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

**Ethics approval**

The studies involving human participants were reviewed and approved by the Ethical Committee of the Second Affiliated Hospital of Chongqing Medical University. Written informed consent was obtained from the patient for publication of this case report.

**Author Contributions**

Hang Liu and Haitao Gu participated in the data collection of patients and wrote a manuscript. Peng Zhu, Tong Li and Yaxu Wang participated in the patient's treatment. Daihua Zhu and Yang Li made contributions to the manuscript review. Jijian Wang and Jianbo Zhang were the project leaders and wrote the final manuscript. All authors have read and approved the final manuscript.

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**Conflict of Interest**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Acknowledgements**
We would like to thank Dr. Huaying Xiong for the revisions of language and grammar.

References


**Figures**

**Figure 1**

Flow-chart.
Figure 2

The process of gasless single port laparoscopic assisted surgery (GSLR). (a) Ma McBurney incision in the right lower abdomen, (b) extracorporeal suspension system and laparoscopic access, (c) intra-abdominal manipulation of the space, (d) dissection of the inferior mesenteric vasculature, (e) dissection of the retrorectal space, and (f) dissection of the collateral rectal ligament.

Figure 3

Surgical scarring in postoperative patients. GSLR: gasless single port laparoscopic assisted surgery. LR Carbon dioxide pneumoperitoneal laparoscopic surgery.