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# Camera inversion and pelvic rectal dissection time in laparoscopic sphincter-preserving surgery for mid-to-low rectal cancer A single-center retrospective cohort study with historical controls

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# Camera inversion and pelvic rectal dissection time in laparoscopic sphincter-preserving surgery for mid-to-low rectal cancer

## A single-center retrospective cohort study with historical controls

**Running title:** Camera inversion and pelvic rectal dissection time

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## Abstract

**Background:** We examined the association between camera inversion and pelvic rectal dissection time during laparoscopic sphincter-preserving surgery for mid-to-low rectal cancer.

**Methods:** This single-center retrospective cohort study used historical controls. The eligibility window was January 2021 through January 2026. Camera inversion was introduced in July 2023. We measured pelvic rectal dissection time from surgical videos and compared groups using multivariable linear regression. Perioperative and 30-day postoperative outcomes were compared in the full cohort.

**Results:** Of 138 patients (55 conventional and 83 camera inversion), 115 had evaluable videos (47 conventional and 68 camera inversion). Mean pelvic rectal dissection time was 69.28 ± 5.40 min with camera inversion and 86.51 ± 9.44 min with conventional viewing. The adjusted mean difference (conventional minus camera inversion) was 17.45 min (95% confidence interval [CI], 13.99–20.90). The respective proportions with any 30-day complication were 15/83 (18.1%) and 12/55 (21.8%). Clavien–Dindo grade III or higher complications occurred in 5/83 (6.0%) and 0/55 (0.0%), respectively. Two patients in the camera inversion group died within 30 days.

**Conclusions:** Among patients with evaluable surgical videos, camera inversion was associated with shorter pelvic rectal dissection time.

**Keywords:** Rectal cancer, Laparoscopy, Camera inversion, Sphincter-preserving surgery, Pelvic rectal dissection time

## Background

In sphincter-preserving surgery for mid-to-low rectal cancer, distal rectal dissection in the deep pelvis must preserve the pelvic autonomic nerves and achieve adequate resection margins [1-3]. As dissection approaches the pelvic floor, the bony pelvis, the curvature of the distal rectum, and adjacent structures such as the prostate, seminal vesicles, and posterior vaginal wall limit visualization and instrument movement [4, 5]. Maintaining a clear view of the intended dissection plane is important at this stage [6].

Three-dimensional (3D) laparoscopy provides stereoscopic depth cues. Studies have examined how camera orientation and monitor position affect laparoscopic performance and have compared 2D and 3D systems [7-10]. Camera inversion entails rotating a 30° laparoscope 180° about its long axis and switching the display to reverse mode to provide an additional view during distal rectal dissection and low anastomosis. A previous study with historical controls reported shorter total operative time with this technique [11]. Total operative time also includes vascular control, specimen extraction, reconstruction, and diverting stoma formation.

Using the same 3D laparoscopic system in both groups, we measured pelvic rectal dissection time from surgical videos using defined start and end landmarks. We examined its association with camera inversion and explored perioperative outcomes.

## Methods

### Study design and participants

We conducted a single-center retrospective cohort study with historical controls using a compiled dataset of patients who underwent surgery for mid-to-low rectal cancer in the Department of Gastrointestinal Surgery at Henan Provincial People's Hospital. The eligibility window was January 2021 through January 2026. Camera inversion

was introduced in July 2023 and was used in all subsequent eligible laparoscopic sphincter-preserving procedures for mid-to-low rectal cancer. The conventional group comprised patients treated from January 2021 through June 2023, and the camera inversion group comprised those treated from July 2023 through January 2026. We obtained clinical data from electronic medical records and hospital archives and measured pelvic rectal dissection time from surgical videos. The number of eligible records in the dataset determined the sample size. The patients in this cohort were distinct from those in our studies of early proximal rectal transection with camera inversion, transanal assistance, and intersphincteric resection with rectal eversion. We followed the STROBE reporting guidance [12].

The Ethics Committee of Henan Provincial People's Hospital approved the study (approval no. 2522312026). All patients provided written informed consent for the use of their clinical data in research.

**Eligibility criteria**

Patients were eligible if they were at least 18 years old, had rectal adenocarcinoma confirmed by endoscopic biopsy, had a tumor that straddled or lay below the peritoneal reflection on preoperative magnetic resonance imaging (MRI), underwent elective laparoscopic sphincter-preserving resection with curative intent, and had a documented camera technique. The relationship to the peritoneal reflection was determined using the lower tumor edge. MRI was used for preoperative local staging [13].

Exclusion criteria were distant metastases or local recurrence, previous surgery likely to alter pelvic anatomy (such as prostate, gynecologic, or other pelvic surgery), and prior pelvic radiotherapy for another condition. We also excluded patients who underwent multivisceral resection for invasion of adjacent organs, abdominoperineal

resection, palliative or emergency surgery, or conversion to open surgery. Patients were excluded if missing clinical, operative, or pathological information precluded determination of eligibility or group assignment.

For patients with no residual primary tumor in the resection specimen, we used the preoperative biopsy to confirm the diagnosis. Patients who underwent curative resection of a synchronous colonic lesion during the same operation remained eligible, and the additional procedure was recorded. Patients without evaluable videos remained in the clinical cohort and were excluded only from the primary outcome analysis.

**Surgical procedures**

*Standard operative technique*

Patients were placed in the lithotomy position under general anesthesia. The team used a standard five-port approach with an umbilical camera port and working ports in the lower abdomen and paraumbilical region, and a rigid 30° 3D laparoscopic system (KARL STORZ, Germany). The same team performed all operations, with the same lead surgeon, who had 20 years of experience in laparoscopic rectal cancer surgery. After abdominal exploration, the inferior mesenteric artery was ligated low with preservation of the left colic artery. The team divided the relevant branches, dissected regional lymph nodes, and mobilized the sigmoid colon and mesorectum. Following total mesorectal excision (TME) principles [14], dissection began at the sacral promontory and proceeded distally along the plane between the mesorectum and pelvic wall. Posterior, anterior, and lateral dissection were performed in sequence, with care to preserve the pelvic autonomic nerves.

Tumor location and the required distal margin determined the extent of distal dissection and resection. When intersphincteric resection (ISR)[15] was unnecessary,

the rectum was divided at the planned level after distal mobilization. For ISR, the dissection continued into the intersphincteric plane, followed by resection of the corresponding portion of the internal anal sphincter. Operative records were used to classify procedures as TME alone or TME with ISR. Early proximal rectal transection or rectal eversion was used in selected cases.

After rectal transection and specimen removal, a colorectal or coloanal anastomosis was constructed according to the operative approach and assessed for integrity. The decision to create a diverting stoma was based on anastomotic height, perfusion, and tension [16]. For standard intracorporeal anastomosis, the circular stapler was inserted transanally, and anastomotic integrity was assessed with an intraoperative air leak test.

*Camera orientation and the three-step inversion technique*

The conventional group used the same 30° 3D laparoscopic system. Camera position and angle were adjusted as needed without rotating the camera 180° or switching to reverse display. The camera inversion group followed a fixed three-step sequence, using inversion during posterior distal rectal dissection, anterior and lateral distal rectal dissection, and low anastomosis.

At each step, the 30° laparoscope was rotated 180° about its long axis to turn the bevel from downward to upward, and the image was simultaneously switched to reverse display. The camera was returned to its conventional orientation at the end of each step. The timing interval for the primary outcome covered the first two steps and ended before the third, which was performed during low anastomosis.

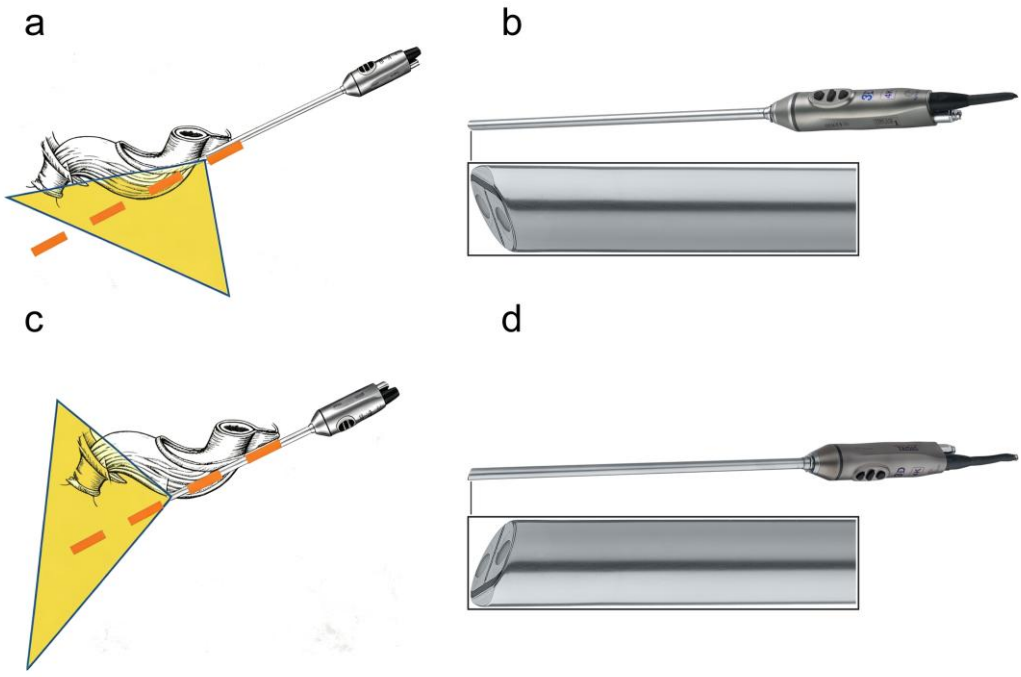



**Fig. 1.** Camera inversion technique. Panels a and b show the conventional orientation. Panels c and d show the orientation after the camera was rotated 180°.

**First inversion during posterior distal rectal dissection.** As posterior dissection approached the pelvic floor, the laparoscope was inverted (**Fig. 1**) and repositioned to show the posterior wall of the distal rectum and the levator ani plane. With traction, dissection continued distally along the established plane. For ISR, posterior dissection continued through the planned extent of the intersphincteric plane.

**Second inversion during anterior and lateral distal rectal dissection.** The laparoscope was inverted again during anterior dissection to show the plane between the anterior rectal wall and the seminal vesicles, prostate, or posterior vaginal wall. The camera and traction were adjusted as dissection progressed. The anterior and lateral planes were joined to the posterior plane. For ISR, intersphincteric dissection continued to the planned level of rectal transection.

**Third inversion during low anastomosis.** After rectal transection, specimen removal, and preparation for anastomosis, the laparoscope was inverted to expose the rectal or anal canal stump (**Fig. 2**). Under laparoscopic visualization, the circular

stapler was inserted transanally, its center shaft was advanced through the stump and connected to the anvil, and the stapler was fired. Anastomotic integrity was then assessed with a transanal air leak test.

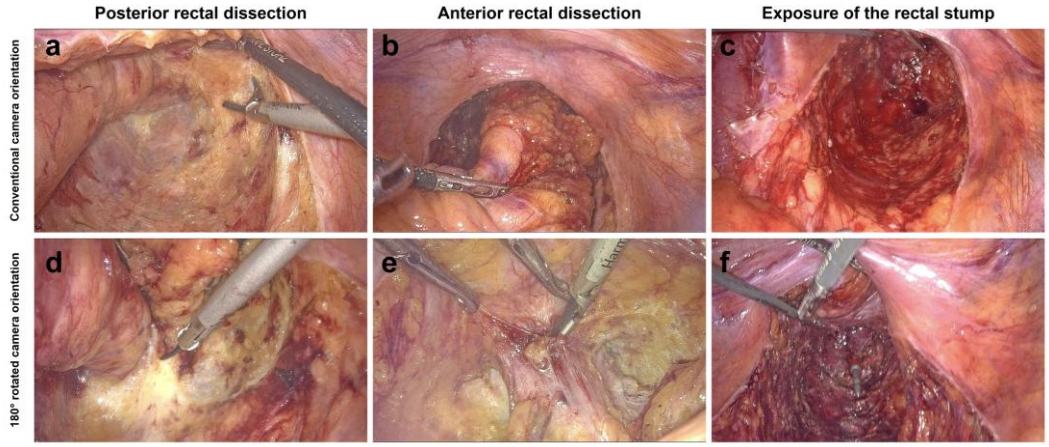



**Fig. 2.** Operative views in conventional and inverted camera orientations. Panels a–c show conventional views, and panels d–f show views after 180° camera inversion. Panels a and d show posterior rectal dissection, b and e show anterior rectal dissection, and c and f show exposure of the rectal stump.

## Outcomes

*Primary outcome*

The primary outcome was pelvic rectal dissection time measured from surgical videos. Timing began with the first incision initiating dissection at the level of the sacral promontory and ended after pelvic dissection was complete, immediately before the stapler was fired to transect the rectum. Timing was continuous and included camera adjustments, instrument exchanges, traction adjustments, and hemostasis.

*Secondary outcomes*

**Operative outcomes.** These included total operative time, intraoperative blood loss, and diverting stoma formation. Total operative time was measured from skin incision to wound closure. Blood loss was obtained from anesthesia records.

**Pathological outcomes.** These included maximum tumor diameter, pathological T and N categories, distal margin distance, distal and circumferential margin status, and lymph node yield. The original p and yp prefixes were retained, and results were pooled by T and N category.

**Postoperative recovery and hospital charges.** Time to first flatus, time to urinary catheter removal, and postoperative length of stay were measured from the day of surgery. Total hospital charges covered the full admission. Comparisons used the original amounts in Chinese yuan (CNY). **Table 3** reports charges in units of CNY 10,000.

**Thirty-day postoperative outcomes.** We ascertained outcomes from hospital records and verified event dates. We recorded anastomotic leak (based on clinical and imaging findings)[17], anastomotic bleeding, intra-abdominal or pelvic infection, urinary retention, bowel obstruction, other complications [18], reoperation, readmission, and all-cause mortality. Complications were graded using the Clavien–Dindo classification [19]. We recorded the highest grade for each patient and classified grades III and above as major. Death due to a postoperative complication was classified as grade V. The overall complication count included patients with at least one complication, and individual events were recorded separately. Other complications included catheter-related infection, bacteremia, impaired wound healing, delirium, acute kidney injury, multiple organ failure, and postoperative fever without an identified source. Fever associated with an infection was counted under the corresponding infection category.

## Surgical video assessment

Prior work has used surgical videos to identify operative steps in transanal total mesorectal excision [20]. In this study, a surgeon with 5 years of experience in

laparoscopic rectal cancer surgery who had not participated in the procedures identified the start and end landmarks on the video timeline. A second surgeon with comparable experience reviewed the timestamps. The two surgeons resolved disagreements by reviewing the recording together. The same timing definition was used for both groups, and camera inversion was visible to the reviewers.

Videos were evaluable if they covered the full dissection interval and both landmarks were identifiable. Patients without evaluable videos remained in the clinical cohort. The primary outcome analysis was restricted to observed times from evaluable videos.

**Statistical analysis**

Analyses were performed in R version 4.6.1. Age, body mass index (BMI), and pelvic rectal dissection time were summarized as means and standard deviations and compared using Welch's t test. Other continuous variables were summarized as medians (25th and 75th percentiles), with percentiles calculated by linear interpolation, and compared using the Mann–Whitney U test with a normal approximation, correction for ties, and continuity correction. Categorical variables were summarized as counts and percentages and compared using Fisher's exact test, extended to larger contingency tables when appropriate. All tests were two-sided with a significance threshold of $P < 0.05$.

The main post hoc multivariable regression model for dissection time included study group, age, sex, BMI, and tumor distance from the anal verge. The sensitivity model added ISR and maximum pathological tumor diameter. Exploratory models added neoadjuvant chemotherapy to each of these models. We also performed leave-one-out analyses. Regression models used ordinary least squares with HC3 heteroskedasticity-consistent standard errors. We calculated 95% confidence intervals (CIs) and P values using the t distribution with residual degrees of freedom. Mean differences were

calculated as conventional minus camera inversion, and unadjusted risk differences for overall and major 30-day complications as camera inversion minus conventional. We used the Newcombe method to calculate 95% CIs for risk differences. Secondary outcome analyses were exploratory, with no adjustment for multiple comparisons.

## Results

### Study population and clinical characteristics

The compiled dataset contained 140 records. One patient underwent surgery before the eligibility window and one lacked documented group assignment. The final clinical cohort comprised 138 patients (55 conventional and 83 camera inversion) who underwent surgery between January 2021 and December 2025 (**Fig. 3**).

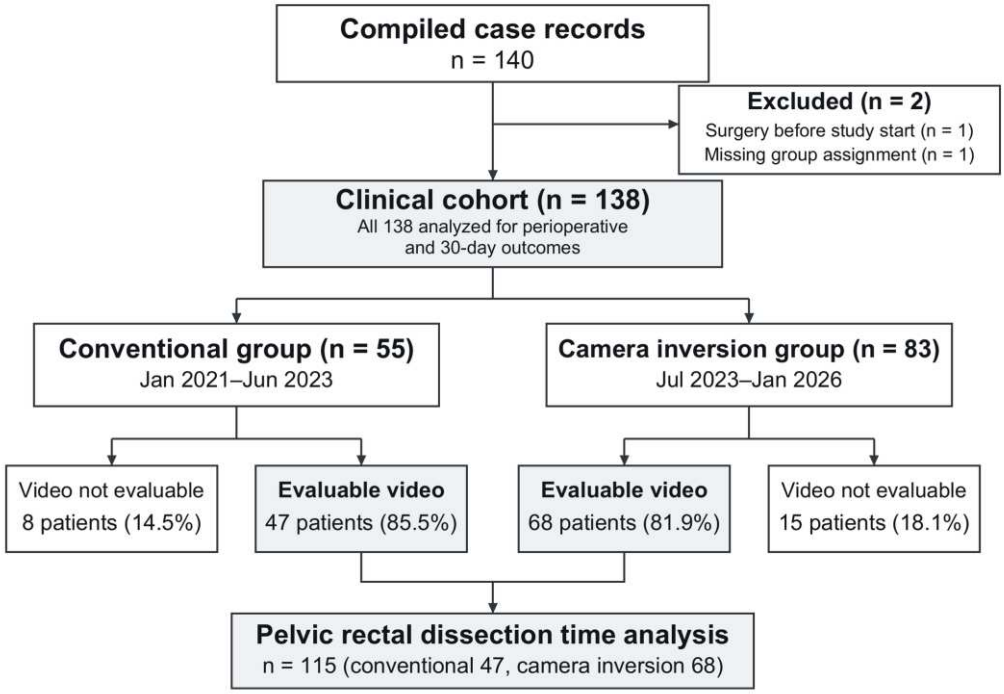



**Fig. 3.** Patient inclusion and video analysis.

Dates indicate the eligibility window for each group. The 23 patients without evaluable videos remained in the clinical cohort.

The camera inversion group had tumors closer to the anal verge, a higher proportion of TME with ISR, and smaller maximum tumor diameters on pathological examination (**Table 1**).

Videos were evaluable for 115 patients (83.3%), including 47 in the conventional group and 68 in the camera inversion group. In both groups, patients with evaluable videos were younger on average and more often underwent TME with ISR. In the conventional group, 17 of 47 patients with evaluable videos and none of the eight without evaluable videos underwent TME with ISR (Table S1 in Additional file 1). Eight videos in the conventional group were unevaluable because of incompatible formats or overwritten files (n = 7) or because records could not be retrieved from dispersed archives (n = 1). In the camera inversion group, 15 videos could not be retrieved because of dispersed archives (n = 5) or separate storage and access restrictions (n = 10).

**Table 1. Patient characteristics by study group**

| Characteristic | Conventional (n = 55) | Camera inversion (n = 83) | *P* value |
|---|---|---|---|
| Age (years) | 64.04 ± 11.44 | 64.72 ± 9.56 | 0.714 |
| Male sex | 38 (69.1) | 49 (59.0) | 0.281 |
| BMI (kg/m²) | 24.33 ± 3.11 | 24.81 ± 3.10 | 0.376 |
| Tumor distance from anal verge (cm) | 5 (4, 5) | 4 (3, 5.25) | 0.012 |
| **ASA physical status** | | | 0.695 |
| I | 1 (1.8) | 3 (3.6) | |
| II | 46 (83.6) | 65 (78.3) | |
| III | 8 (14.5) | 15 (18.1) | |
| **Clinical T category** | | | 0.130 |
| T1–2 | 15 (27.3) | 13 (15.7) | |
| T3–4 | 40 (72.7) | 70 (84.3) | |
| **Clinical N category** | | | 0.456 |
| N0 | 35 (63.6) | 59 (71.1) | |
| N-positive | 20 (36.4) | 24 (28.9) | |
| Neoadjuvant chemotherapy | 23 (41.8) | 39 (47.0) | 0.602 |
| TME with ISR | 17 (30.9) | 48 (57.8) | 0.003 |
| Maximum pathological tumor diameter (cm) | 3.5 (3, 4.9) | 3 (2.8, 4) | 0.021 |

Values are means ± standard deviations, medians (25th and 75th percentiles), or counts (%). BMI, body mass index. ASA, American Society of Anesthesiologists physical status. TME, total mesorectal excision. ISR, intersphincteric resection. Operative procedure and pathological tumor size are shown to describe case mix.

## Pelvic rectal dissection time

Mean pelvic rectal dissection time was 69.28 ± 5.40 min in the camera inversion group and 86.51 ± 9.44 min in the conventional group. The adjusted mean difference was 17.45 min (95% CI, 13.99–20.90, $P < 0.001$). **Table 2** shows the unadjusted and sensitivity analyses. **Fig. 4** shows the distribution of dissection times by group. Table S3 in Additional file 1 presents the exploratory analyses and model diagnostics.

**Table 2. Between-group comparison of pelvic rectal dissection time (n = 115)**

| Analysis | Mean difference (min) | 95% CI (min) | *P* value |
|---|---|---|---|
| Unadjusted comparison | 17.23 | 14.19–20.27 | <0.001 |
| Primary adjusted model | 17.45 | 13.99–20.90 | <0.001 |
| Sensitivity model | 18.02 | 14.44–21.61 | <0.001 |

Mean differences are expressed as conventional minus camera inversion. Positive values indicate shorter times in the camera inversion group.

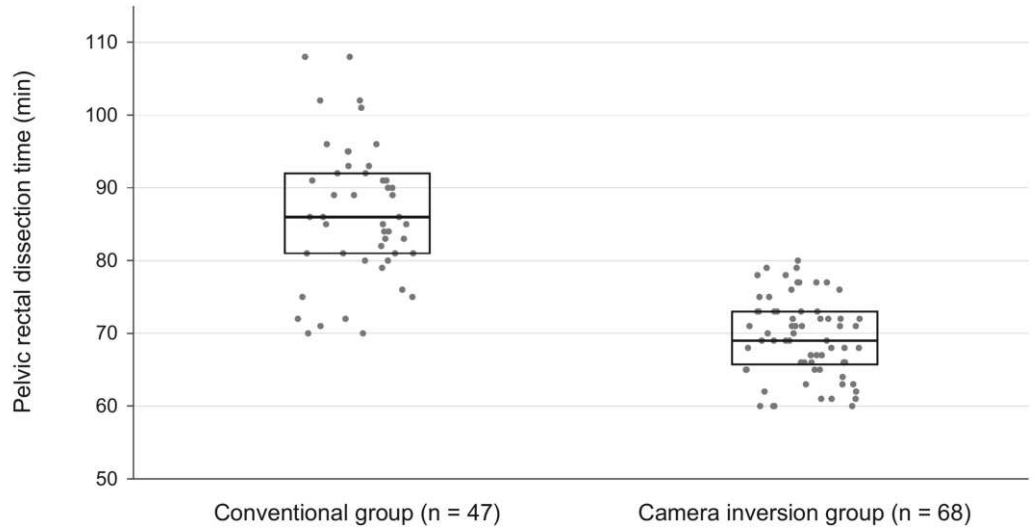



**Fig. 4.** Distribution of pelvic rectal dissection time by group. Each point represents one patient. Points are offset horizontally to show overlapping values. Boxes span the 25th to 75th percentiles, and horizontal lines indicate the medians.

## Other operative and pathological outcomes

Median total operative time was 146 min in the camera inversion group and 155 min in the conventional group ($P = 0.021$). Circumferential and distal resection margins were negative in both groups. **Table 3** and Table S2 in Additional file 1 show the remaining operative and pathological outcomes.

## Postoperative recovery and 30-day outcomes

Median total hospital charges were CNY 65,600 in the camera inversion group and CNY 79,600 in the conventional group ($P < 0.001$). Table 3 shows the other recovery outcomes.

Within 30 days, 15/83 patients (18.1%) in the camera inversion group and 12/55 (21.8%) in the conventional group had a complication (risk difference, −3.75 percentage points, 95% CI, −18.02 to 9.35). Major complications occurred in 5/83 (6.0%) and 0/55 (0.0%), respectively (risk difference, 6.02 percentage points, 95% CI, −1.35 to 13.34). **Table 3** reports reoperations, readmissions, and deaths.

Of the five major complications in the camera inversion group, three were grade IIIb and involved reoperation with stoma formation for anastomotic leak. The other two were grade V. One patient died after an anastomotic leak complicated by severe intra-abdominal infection and sepsis. The other developed multiple organ failure and died after self-discharge. Both deaths occurred within 30 days of surgery.

**Table 3. Perioperative and 30-day postoperative outcomes by study group**

| Outcome | Conventional (n = 55) | Camera inversion (n = 83) | *P* value |
|---|---|---|---|
| Total operative time (min) | 155 (130, 180) | 146 (118.5, 165) | 0.021 |
| Intraoperative blood loss (mL) | 50 (50, 50) | 50 (50, 50) | 0.988 |
| Diverting stoma | 11 (20.0) | 24 (28.9) | 0.318 |
| Distal margin distance (cm) | 2 (1, 2) | 2 (1, 2) | 0.847 |
| Lymph nodes retrieved | 16 (13, 19) | 16 (13, 20) | 0.491 |
| Time to first flatus (days) | 5 (3, 6) | 6 (3, 6) | 0.199 |

| Outcome | Conventional (n = 55) | Camera inversion (n = 83) | *P* value |
|---|---|---|---|
| Time to urinary catheter removal (days) | 2 (1, 3) | 1 (1, 2) | 0.126 |
| Postoperative length of stay (days) | 11 (9, 12.5) | 11 (9, 12) | 0.610 |
| Total hospital charges (CNY × 10,000) | 7.96 (7.32, 8.57) | 6.56 (5.74, 7.34) | <0.001 |
| **Any 30-day complication** | 12 (21.8) | 15 (18.1) | 0.663 |
| Anastomotic leak | 2 (3.6) | 4 (4.8) | 1.000 |
| Anastomotic bleeding | 3 (5.5) | 1 (1.2) | 0.301 |
| Intra-abdominal or pelvic infection | 1 (1.8) | 4 (4.8) | 0.648 |
| Urinary retention | 2 (3.6) | 1 (1.2) | 0.563 |
| Bowel obstruction | 0 (0.0) | 2 (2.4) | 0.517 |
| Other complications | 4 (7.3) | 5 (6.0) | 1.000 |
| **Clavien–Dindo grade ≥III** | 0 (0.0) | 5 (6.0) | 0.157 |
| 30-day reoperation | 0 (0.0) | 3 (3.6) | 0.276 |
| 30-day readmission | 0 (0.0) | 3 (3.6) | 0.276 |
| 30-day mortality | 0 (0.0) | 2 (2.4) | 0.517 |

Values are medians (25th and 75th percentiles) or counts (%). Hospital charges were compared using the original amounts in CNY. There were three grade I and nine grade II Clavien–Dindo complications in the conventional group, and one grade I and nine grade II complications in the camera inversion group.

## Discussion

Among 115 patients with evaluable videos, pelvic rectal dissection time was shorter in the camera inversion group. The groups differed by 17.45 min after adjustment for age, sex, BMI, and tumor distance from the anal verge. The direction of the association was similar after additional adjustment for ISR and maximum pathological tumor diameter. In the full cohort, median total operative time was shorter and median hospital charges were lower in the camera inversion group. Hou et al. reported shorter total operative time and postoperative stay with camera inversion in a study with historical controls [11]. We observed a difference in total operative time in the same direction, with a median postoperative stay of 11 days in each group. In a randomized comparison of 2D and 3D laparoscopic TME, Curtis et al. found similar total operative times [9]. By using the same 3D system in both

groups and timing pelvic dissection from video, we examined the operative phase during which the first two inversions were used.

The curvature of the distal rectum and the bony confines of the pelvis restrict camera and instrument movement [4, 6]. Camera and display orientation can also affect how the operative view aligns with instrument movement [7, 8]. Rotating the 30° laparoscope and reversing the displayed image provides an additional view of the posterior distal rectal wall, the levator ani plane, and the anterior rectal plane. This view may reduce the need for repeated camera or traction adjustments while identifying the dissection plane. The measured interval covered the first two inversions, and the third was used during low anastomosis. In selected sphincter-preserving operations for very low rectal cancer, camera inversion can be combined with early proximal rectal transection or transanal pull-through and rectal eversion.

The difference in dissection time should be interpreted alongside resection quality and postoperative outcomes. Both groups had negative circumferential and distal margins and similar lymph node yields. TME specimen completeness, another measure of resection quality used in a previous trial [21], was unavailable in the pathology data. Major complications occurred in five patients in the camera inversion group and none in the conventional group (risk difference, 6.02 percentage points, 95% CI, −1.35 to 13.34).

Camera technique and study period coincided. Changes in team experience or perioperative practice may therefore have contributed to the observed differences. Tumor location, ISR use, and pathological tumor size also differed between groups. Hospital charges may have varied with changes in care and reimbursement.

Age and ISR use differed according to video evaluability, so the primary result applies to the patients with evaluable recordings. Reviewers could identify the operative

group from the video, and differences in operative sequence could affect how they identified the end landmark. Thirty-day outcomes came from hospital records, which may have missed events managed elsewhere.

Studies with contemporaneous controls could standardize video timing and postoperative outcome ascertainment, and include bowel function measures [22] and longer oncologic follow-up [23] to assess the clinical relevance of the observed difference in dissection time.

## Conclusions

Among patients with evaluable videos of laparoscopic sphincter-preserving surgery for mid-to-low rectal cancer, camera inversion was associated with shorter pelvic rectal dissection time.

## List of abbreviations

2D, two-dimensional. 3D, three-dimensional. ASA, American Society of Anesthesiologists. BMI, body mass index. CD, Clavien–Dindo. CI, confidence interval. CNY, Chinese yuan. ISR, intersphincteric resection. MRI, magnetic resonance imaging. STROBE, Strengthening the Reporting of Observational Studies in Epidemiology. TME, total mesorectal excision.

## Declarations

### Ethics approval and consent to participate

The Ethics Committee of Henan Provincial People's Hospital approved the study (approval no. 2522312026). The study was conducted in accordance with the Declaration of Helsinki. All patients provided written informed consent for the use of their clinical data in research.

## Consent for publication

Written informed consent was obtained for publication of the operative images.

## Availability of data and materials

De-identified data supporting the findings are available from the corresponding author upon reasonable request and with institutional ethics committee approval. Public access is restricted to protect patient privacy.

## Competing interests

The authors declare no competing interests related to this manuscript or to KARL STORZ, and no other relevant financial or nonfinancial interests. All authors confirm this declaration.


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This study received no funding.


## Authors' contributions

CZ contributed to study design and reviewed and revised the manuscript. HL contributed to study design, prepared the figures, and reviewed and revised the manuscript. XW and XY drafted the manuscript. ML and QF collected the data. LY and GL performed the statistical analysis. All authors contributed to data analysis and manuscript drafting and revision, approved the final version, and agreed to be accountable for all aspects of the work.


## Acknowledgements

Not applicable.


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## Additional file

**Additional file 1 (DOCX).** Supplementary Tables S1–S3. Cohort characteristics by video availability, pathological stage, and dissection-time analyses.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- TableS1.docx
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