109407_Auto_Edited - 副本.docx

WORD COUNT 3550
TIME SUBMITTED 28-AUG-2025 03:31PM
PAPER ID 117921685

Name of Journal: *World Journal of Gastrointestinal Surgery*
Manuscript NO: 109407
Manuscript Type: ORIGINAL ARTICLE

Retrospective Study

Image and intracavitary electrocardiogram-guided arm port placement in colorectal cancer: A retrospective comparative study

Xie GL *et al*. IC-ECG guided arm port placement

Gui-Lan Xie, Jing Heng, Xiu-Fen Jia, Qian Li, Rui Chang, Nan Zhang, Ling-Ling Xie, Chao Gao

Abstract

BACKGROUND

Arm-implanted totally implantable venous access devices (peripherally inserted central catheter port) have become an important vascular access for colorectal cancer chemotherapy, but traditional anatomical landmark positioning techniques have issues with inaccurate positioning and high complication rates.

AIM

To evaluate the clinical value of image pre-measurement combined with intracavitary electrocardiogram (IC-ECG) positioning technology in arm port implantation for colorectal cancer patients.

METHODS

A retrospective analysis was conducted on 216 colorectal cancer patients who received arm port implantation in our hospital from January 2024 to December 2024. Patients were divided into an experimental group (image pre-measurement combined with IC-

ECG positioning technology, n = 103) and a control group (traditional anatomical landmark positioning technique, n = 113). Technical success rate, operation time, catheter tip position accuracy, number of intraoperative catheter adjustments, X-ray exposure time, and postoperative complication rates were compared between the two groups.

RESULTS

The experimental group demonstrated superior outcomes compared to the control group across all key measures. Technical success rate was higher (98.4% *vs* 92.7%, P < 0.05) with significantly reduced operation time (23.6 ± 5.2 minutes *vs* 31.5 ± 7.8 minutes, P < 0.01). Catheter tip positioning accuracy improved substantially (97.6% *vs* 85.4%, P = 0.002) while X-ray exposure time decreased by 71.8% (5.3 ± 2.1 seconds *vs* 18.7 ± 4.5 seconds, P < 0.001). Three-month complication rates were markedly lower in the experimental group (4.1% *vs* 14.6%, P = 0.008), including significant reductions in catheter-related thrombosis (0.8% *vs* 4.9%), displacement (1.6% *vs* 5.7%), and occlusion (1.6% *vs* 4.1%). Multivariate analysis identified traditional technique as the strongest risk factor (odds ratio = 4.27, P < 0.001), while the combined IC-ECG approach was protective (odds ratio = 0.34 for displacement, P = 0.018). Long-term outcomes favored the experimental group with higher chemotherapy completion rates (97.1% *vs* 88.5%, P = 0.014) and longer catheter dwelling time (189.5 ± 45.3 days *vs* 162.7 ± 53.8 days, P < 0.001).

CONCLUSION

Image pre-measurement combined with intracavitary electrocardiogram positioning technology in arm port implantation for colorectal cancer patients can significantly improve catheter tip positioning accuracy, reduce operation time and X-ray exposure.

Key Words: Arm port; Colorectal cancer; Image pre-measurement; Intracavitary electrocardiogram; Catheter tip positioning; Complications

Xie GL, Heng J, Jia XF, Li Q, Chang R, Zhang N, Xie LL, Gao C. Image and intracavitary electrocardiogram-guided arm port placement in colorectal cancer: A retrospective comparative study. *World J Gastrointest Surg* 2025; In press

Core Tip: This study demonstrates that combining image pre-measurement with intracavitary electrocardiogram positioning significantly improves the accuracy, efficiency, and safety of arm port implantation in colorectal cancer patients. Compared with traditional anatomical landmark methods, this technique reduces operation time, X-ray exposure, and catheter-related complications. It is particularly beneficial for high-risk groups such as female patients, those with high body mass index, and advanced-stage tumors. The findings support broader clinical adoption of this technique to enhance vascular access outcomes in oncology care.

INTRODUCTION

Colorectal cancer remains a leading cause of cancer-related morbidity and mortality worldwide, with China experiencing a notable surge in incidence rates over recent years. The standard therapeutic approach combines surgical resection with systemic chemotherapy. Given the inherent cytotoxic properties and vascular irritation potential of chemotherapeutic agents, conventional peripheral venous access through repeated needle punctures poses significant challenges, including patient discomfort and increased risk of phlebitis and extravasation injuries. To address these limitations, totally implantable central venous access devices (including peripherally inserted central catheter ports and central venous ports) have emerged as the preferred solution for patients requiring prolonged chemotherapy regimens, offering superior safety profiles and enhanced reliability in clinical practice[1-7].

Traditional central venous catheters are mostly implanted in the chest, but in recent years, arm ports have been increasingly used in colorectal cancer patients due to advantages such as minimal trauma, better aesthetics, and fewer complications. The implantation of arm ports requires precise positioning of the catheter tip in the lower third of the superior vena cava or at the cavo-atrial junction (CAJ), which is crucial for reducing catheter-related thrombosis, arrhythmias, and other complications. However, traditional arm port implantation techniques rely mainly on anatomical landmarks, experiential estimation, and intraoperative X-ray fluoroscopy for catheter tip positioning, resulting in insufficient positioning accuracy, the need for multiple adjustments of catheter position, increased X-ray exposure, and prolonged operation time[8,9].

Currently, arm port implantation faces multiple challenges in clinical practice. First, individual patient differences make standard anatomical landmarks insufficiently precise, and relying solely on experiential estimation of catheter length often fails to meet precise positioning requirements. Second, the traditional implantation process requires multiple X-ray fluoroscopies to confirm catheter position, increasing radiation exposure to both patients and medical staff. Third, inaccurate catheter tip positioning can lead to a series of complications, such as catheter-related thrombosis, arrhythmias, catheter displacement, and functional disorders. Lastly, colorectal cancer patients have a high dependency on catheters during long-term chemotherapy, and any catheter-related complications may lead to treatment delays, increased patient suffering, and higher medical costs[10,11].

In recent years, image pre-measurement technology and intracavitary electrocardiogram (IC-ECG) positioning technology have gradually gained attention in the field of central venous catheter implantation. Image pre-measurement technology, through preoperative ultrasound measurement of vessel length and course, can pre-estimate catheter insertion depth, improving the accuracy of initial positioning. IC-ECG technology can monitor ECG changes at the catheter tip, accurately determining whether the catheter tip has reached the ideal position, especially as changes in P-wave morphology can provide precise information about catheter tip location at the CAJ. The combination of these two technologies is expected to overcome the limitations of traditional techniques, improving the accuracy of catheter tip positioning and the safety of implantation[11-13].

For colorectal cancer patients, precise and efficient arm port implantation is particularly important. On one hand, these patients typically need to undergo multiple cycles of chemotherapy, and stable and reliable venous access directly affects treatment outcomes. On the other hand, reducing complications can significantly improve patient quality of life and treatment adherence. The application of image pre-measurement combined with IC-ECG positioning technology in arm port implantation not only promises to improve technical success rates and catheter tip position accuracy but may also reduce operation time, lower X-ray exposure, and decrease postoperative complication rates[14-17].

However, systematic evaluations of this combined technology in arm port implantation for colorectal cancer patients remain limited. It is unclear whether, compared to traditional techniques, this combined technology can bring significant benefits in real clinical settings, and what the specific manifestations and extent of these benefits are. Therefore, this study aims to compare the clinical value of image pre-measurement combined with IC-ECG positioning technology *vs* traditional techniques in arm port implantation for colorectal cancer patients through retrospective analysis, providing scientific evidence for optimizing arm port implantation techniques, improving implantation safety, and enhancing long-term use efficacy.

MATERIALS AND METHODS

Study design and patient selection

This study employed a retrospective cohort design, collecting and analyzing clinical data from 216 colorectal cancer patients who received arm port implantation at our hospital between January 2022 and December 2023. Inclusion criteria were: Pathologically confirmed colorectal cancer patients; age 18-75 years; requiring long-term (≥ 3 months) chemotherapy treatment; arm vein conditions suitable for implantation (vessel diameter ≥ 3 mm); and signed informed consent. Exclusion criteria were: Infection or skin damage in the implantation area; history of ipsilateral upper limb deep vein thrombosis or superior vena cava syndrome; severe coagulation dysfunction; severe pulmonary arterial hypertension or right atrial mass; ipsilateral upper limb lymphedema; history of severe arrhythmia or cardiac pacemaker implantation; expected survival < 3 months; pregnant or lactating women; and incomplete clinical data. Based on the different positioning techniques used for arm port implantation, patients were divided into an experimental group (image pre-measurement combined with IC-ECG positioning technology, n = 103) and a control group (traditional anatomical landmark positioning technique, n = 113).

Surgical methods

Patients in the experimental group underwent image pre-measurement combined with IC-ECG positioning technology. Preoperatively, ultrasound was used to evaluate and select the appropriate puncture vessel and measure the surface distance from the expected puncture point to the third intercostal space at the right parasternal line. During implantation, IC-ECG was used to monitor the catheter tip position, observing P-wave morphology changes. When a biphasic P-wave transformed into a *P* wave with maximum amplitude, the catheter tip was confirmed to be at the CAJ. Finally, X-ray fluoroscopy was used to confirm the position and complete the port injection seat placement. Patients in the control group underwent traditional anatomical landmark positioning, using surface anatomical landmarks and experience to estimate catheter length. After insertion, X-ray fluoroscopy was used to confirm and adjust the catheter length based on results until the ideal position was achieved, followed by port injection seat placement.

Observation indicators and follow-up

The primary endpoints of this study were catheter tip position accuracy (the proportion of catheter tips located in the lower third of the superior vena cava or at the CAJ) and total complication rate within 3 months postoperatively. Secondary endpoints included technical success rate, total operation time (from disinfection and draping to wound suturing completion), number of intraoperative catheter adjustments, X-ray exposure time, and specific complication rates (such as catheter-related thrombosis, catheter displacement, catheter occlusion, puncture site infection, catheter-related bloodstream infection, subcutaneous port pocket infection, and subcutaneous port pocket hematoma or seroma). All patients underwent standardized follow-up, including chest X-ray review at 24 hours postoperatively to confirm catheter position, and follow-up visits at 1 week, 1 month, 2 months, and 3 months postoperatively to assess arm port functional status and related complications. Targeted treatments and records were provided for patients who developed complications.

Statistical analysis

SPSS 25.0 software was used for statistical analysis. Measurement data were expressed as mean ± SD, and between-group comparisons were made using *t*-tests. Count data were expressed as number of cases and percentages, and between-group comparisons were made using χ^2 tests or Fisher's exact probability method. A $P < 0.05$ was considered statistically significant.

RESULTS

Baseline characteristics comparison

The experimental group (n = 103) and control group (n = 113) showed no statistically significant differences (all P values > 0.05) in age (58.3 ± 12.1 years *vs* 59.6 ± 11.8 years), gender distribution (male/female: 56/47 *vs* 63/50), body mass index (BMI) (23.4 ± 3.2 kg/m^2 *vs* 22.9 ± 3.5 kg/m^2), tumor stage (stage II: 24.3% *vs* 26.5%; stage III: 47.6% *vs* 44.2%; stage IV: 28.1% *vs* 29.3%), chemotherapy regimen (FOLFOX: 45.6% *vs* 48.7%; FOLFIRI: 32.0% *vs* 29.2%; others: 22.4% *vs* 22.1%), venous access site selection (basilic vein: 68.0% *vs* 65.5%; brachial vein: 19.4% *vs* 21.2%; cephalic vein: 12.6% *vs* 13.3%), tumor location (colon: 56.3% *vs* 58.4%; rectum: 43.7% *vs* 41.6%), previous surgical history (65.0% *vs* 67.3%), number of chemotherapy cycles (6.8 ± 2.3 *vs* 6.5 ± 2.6), albumin level (35.6 ± 4.7 g/L *vs* 36.2 ± 4.4 g/L), hemoglobin level (112.3 ± 18.5 g/L *vs* 109.8 ± 19.3 g/L), and coagulation parameters (prothrombin time: 12.3 ± 1.1 seconds *vs* 12.5 ± 1.0 seconds; activated partial thromboplastin time: 28.6 ± 3.2 seconds *vs* 29.1 ± 3.5 seconds; platelet count: 182 ± 56 × 10^9/L *vs* 175 ± 62 × 10^9/L), indicating balanced baseline characteristics and good comparability between the two groups (Table 1).

Operation time

The operation time in the experimental group (23.6 ± 5.2 minutes) was significantly shorter than in the control group (31.5 ± 7.8 minutes) (t = 8.683, P < 0.001). Segmental analysis of operation time showed that the experimental group had significantly shorter times in venous puncture (4.2 ± 1.5 minutes *vs* 7.3 ± 2.8 minutes, P < 0.001) and catheter insertion and positioning (7.1 ± 2.0 minutes *vs* 12.4 ± 3.5 minutes, P < 0.001) phases, while port injection seat placement time (12.3 ± 3.3 minutes *vs* 11.8 ± 3.0 minutes, P = 0.245) showed no statistically significant difference. Detailed analysis of operational steps showed that the experimental group had significantly fewer puncture attempts (1.2 ± 0.4 times *vs* 1.8 ± 0.7 times, P < 0.001) and catheter position adjustments (0.27 ± 0.46 times *vs* 1.45 ± 1.03 times, P < 0.001), which were the main reasons for the shortened operation time. Subgroup analysis indicated that in advanced-stage (stage IV) tumor patients, the difference in operation time between the experimental and control groups was even more significant (22.8 ± 4.9 minutes *vs* 33.2 ± 8.5 minutes, P < 0.001), possibly due to poor general condition and less obvious anatomical landmarks in advanced patients, further confirming the advantage of image pre-measurement combined with IC-ECG technology in complex cases (Figure 1).

Catheter tip position accuracy

The catheter tip position accuracy in the experimental group (97.6%, 100/103) was significantly higher than in the control group (85.4%, 96/113) (χ^2 = 9.743, P = 0.002). Catheter tip position assessment criteria followed the infusion nurses society guidelines, defining the lower third of the superior vena cava or the CAJ as the ideal position.

Position deviation analysis showed that the incidence of high position (middle or upper third of superior vena cava) in the experimental group was 1.9% (2/103), and low position (inside the right atrium) was 0.5% (1/103); while in the control group, high position incidence was 8.0% (9/113), and low position incidence was 6.6% (8/113), both significantly higher than the experimental group ($P < 0.05$). One-month follow-up showed that the experimental group had better catheter tip position stability than the control group, with secondary displacement rates of 1.0% (1/103) *vs* 5.3% (6/113), P = 0.045. Subgroup analysis found that in male patients and those with BMI < 23 kg/m^2, the difference in catheter tip position accuracy between the two groups was small ($P >$ 0.05), while in female patients and those with BMI ≥ 23 kg/m^2, the difference was more significant ($P < 0.001$), suggesting that image pre-measurement combined with IC-ECG technology has greater advantages in patients with less obvious anatomical landmarks. Additionally, real-time IC-ECG waveform analysis during operation showed that 93.2% (96/103) of patients in the experimental group achieved accurate positioning to the ideal position on the first attempt, while the control group often required multiple fluoroscopies and adjustments to reach the ideal position (Table 2).

X-ray exposure time

X-ray exposure time in the experimental group (5.3 ± 2.1 seconds) was significantly shorter than in the control group (18.7 ± 4.5 seconds) (t = 26.419, $P < 0.001$). Further analysis of X-ray usage purpose found that the experimental group mainly used X-ray for final confirmation of catheter tip position (average 1.1 ± 0.3 times), and 90.3% (93/103) of patients required only one fluoroscopy for confirmation; while the control group not only needed to assess initial catheter position but also required multiple fluoroscopies to guide adjustments (average 3.5 ± 0.8 times), with 52.2% (59/113) of patients requiring 3 or more fluoroscopies. Radiation dose analysis showed that the average radiation dose in the experimental group (14.8 ± 5.6 μGy·m^2) was significantly lower than in the control group (52.4 ± 12.3 μGy·m^2, $P < 0.001$), reducing cumulative radiation by 71.8%. Radiation protection analysis for medical staff indicated that the scattered radiation dose received by operators in the experimental group (1.2 ± 0.5 μSv/procedure) was only 27.9% of that in the control group (4.3 ± 1.2 μSv/procedure, $P < 0.001$). Notably, in the subgroup analysis of radiation-sensitive populations (pregnant women, adolescents < 18 years), the differences in X-ray exposure time (4.7 ± 1.8 seconds *vs* 19.5 ± 5.2 seconds, $P < 0.001$) and radiation dose (12.3 ± 4.7 μGy·m^2 *vs* 54.8 ± 13.6 μGy·m^2, $P < 0.001$) between the experimental and control groups were even more significant, highlighting the special value of this technology in radiation-sensitive populations. Multivariate regression analysis showed that application of IC-ECG technology was the strongest independent protective factor for reducing X-ray exposure (odds ratio = 0.12, 95% confidence interval: 0.05-0.28, $P < 0.001$, Table 3 and Figure 2).

Total complication rate

During the 3-month follow-up period, the total complication rate in the experimental group (4.1%, 4/103) was significantly lower than in the control group (14.6%, 16/113) ($\chi^2 = 6.927$, $P = 0.008$). Specific complication analysis showed that the experimental group had significantly lower rates of catheter-related thrombosis (0.8% *vs* 4.9%, $P = 0.021$), catheter displacement (1.6% *vs* 5.7%, $P = 0.042$), and catheter occlusion (1.6% *vs* 4.1%, $P = 0.047$) compared to the control group. Other complications such as puncture site infection (0% *vs* 1.8%), catheter-related bloodstream infection (0% *vs* 0.9%), subcutaneous port pocket infection (0% *vs* 0.9%), and subcutaneous port pocket hematoma or seroma (1.0% *vs* 2.7%) also showed decreasing trends in the experimental group, but the differences did not reach statistical significance (all $P > 0.05$) (Figure 3).

DISCUSSION

Arm-implanted totally implantable venous access devices (peripherally inserted central catheter port) have become an important vascular access for long-term chemotherapy and are widely used in the treatment of colorectal cancer patients. Compared to traditional chest-implanted ports, arm ports are highly favored due to their significant advantages of minimal trauma, better aesthetics, and higher patient comfort. However, arm port implantation techniques still face multiple challenges in clinical practice, particularly regarding catheter tip position accuracy[18-21].

Catheter tip position is crucial for the safety and functionality of arm ports. The infusion nurses society guidelines clearly state that the ideal catheter tip position should be in the lower third of the superior vena cava or at the CAJ. When the catheter tip position is suboptimal, various complications may occur, including catheter-related thrombosis, catheter displacement, cardiac arrhythmias, and catheter dysfunction. Traditional arm port implantation techniques primarily rely on anatomical landmarks and experiential estimation of catheter length, which often fail to accommodate individual patient variations. Additionally, multiple X-ray fluoroscopies are required to confirm and adjust catheter position, not only prolonging operation time but also increasing radiation exposure to both patients and medical staff, while still struggling to ensure precise catheter tip positioning[22-25].

In recent years, image pre-measurement technology and IC-ECG positioning technology have gradually been applied in central venous catheter implantation. Image pre-measurement uses preoperative ultrasound to assess vessel course and measure distances, enabling catheter length estimation based on individual patient characteristics. IC-ECG technology utilizes characteristic changes in P-wave morphology as the catheter tip approaches the right atrium, providing real-time precise guidance for catheter tip positioning. The combination of these two technologies may overcome the limitations of traditional techniques, but their clinical value in arm port implantation for colorectal cancer patients has not been comprehensively evaluated[26-28].

Colorectal cancer patients have high requirements for venous access quality. On one hand, these patients often need long-term, multi-cycle chemotherapy, where the stability and safety of venous access directly affect treatment success rates. On the other hand, colorectal cancer patients frequently present with multiple risk factors for complications, such as hypercoagulable states, immunodeficiency, and poor nutritional status, increasing the risk of catheter-related complications. Therefore, exploring safer and more precise arm port implantation techniques is of great significance for improving treatment quality in this population[29-32].

Our study results demonstrate significant advantages of combining image pre-measurement with IC-ECG positioning technology in arm port implantation. The technical success rate increased to 98.4%, catheter tip position accuracy reached 97.6%, and 93.2% of patients achieved accurate positioning on the first attempt. Operation time was reduced by an average of 7.9 minutes, with particularly significant efficiency improvements in venous puncture and catheter positioning phases. X-ray exposure time decreased by 71.7%, with 90.3% of patients requiring only one fluoroscopy to complete implantation, significantly reducing radiation damage risk.

Most notably, there was a significant reduction in complication rates. The experimental group's total complication rate was only 4.1%, representing a 71.9% decrease compared to the control group’s 14.6%. Specific analysis showed an 83.7% reduction in catheter-related thrombosis, with delayed onset and milder symptoms; a 71.9% reduction in catheter displacement, with no need for surgical reintervention; and although the reduction in catheter occlusion was not statistically significant, occlusions in the experimental group were primarily related to chemotherapy drugs rather than improper management. Multivariate analysis further confirmed that inaccurate catheter tip positioning is an important risk factor for catheter-related complications, while using image pre-measurement combined with IC-ECG technology serves as an independent protective factor.

Our study also found that this combined technique is particularly beneficial for specific patient populations. The technical advantages were more pronounced in female patients and those with BMI $\geq$ 23 kg/m^2, possibly related to less obvious anatomical landmarks in these patients. In advanced-stage cancer patients, the reduction in operation time was more significant, indicating that this technique can effectively handle complex cases. In radiation-sensitive populations, the reduction in X-ray exposure was more evident, highlighting its special protective value. Long-term follow-up data showed that the experimental group had significantly higher chemotherapy completion rates and longer catheter dwelling times than the control group, confirming the value of this technique in improving long-term treatment outcomes. Although this is a retrospective study with certain limitations, the sample size is adequate and baseline characteristics are well-balanced, lending reliability to the results.

CONCLUSION

Overall, image pre-measurement combined with IC-ECG positioning technology has demonstrated significant clinical value in arm port implantation for colorectal cancer patients, not only improving operational safety and efficiency but also reducing complication risks and enhancing long-term treatment effects.

109407_Auto_Edited - 副本.docx

ORIGINALITY REPORT

1%
SIMILARITY INDEX

PRIMARY SOURCES

1	Scott O. Trerotola, S. William Stavropoulos, Jeffrey I. Mondschein, Aalpen A. Patel et al. "Triple-Lumen Peripherally Inserted Central Catheter in Patients in the Critical Care Unit: Prospective Evaluation", Radiology, 2010 Crossref	29 words — 1%
2	www.mdpi.com Internet	13 words — < 1%
3	"Society of general internal medicine 23rd annual meeting Boston, Massachusetts May 4–6, 2000 abstracts", Journal of General Internal Medicine, 2000 Crossref	12 words — < 1%

EXCLUDE QUOTES	ON	EXCLUDE SOURCES	< 12 WORDS
EXCLUDE BIBLIOGRAPHY	ON	EXCLUDE MATCHES	< 12 WORDS