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Comparison of Single-Port Robotic Breast Conserving Surgery and Conventional Open Pattern for Early Breast Cancer

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Abstract

Background: Breast-conserving surgery is one of standard surgical modalities for early-stage breast cancer. Conventional breast-conserving surgery (C-BCS) is typically conducted by two incisions, and the incision on the breast surface compromises aesthetic outcome. This study introduces a single-incision robotic breast-conserving surgery (SIR-BCS) performed and compares the differences in surgical effectiveness and aesthetic outcomes between SIR-BCS and C-BCS.

Method: 56 patients with early-stage breast cancer were enrolled in this study, of whom 23 underwent SIR-BCS and 33 underwent C-BCS. The clinical-pathological characteristics were evenly distributed between the two cohorts. Aesthetic outcomes were evaluated using the BREAST-Q scale.

Results: The mean incision length was remarkably shorter for SIR-BCS than for C-BCS (3.48±0.77 cm vs 4.67±1.61 cm). The patients in SIR-BCS cohort remains higher satisfaction of breasts than patients in C-BCS cohort (81.20±19.20 vs 71.24±13.59) and higher score of psychological well-being (72.95±21.38 vs 60.55±23.37). While duration of operation and drainage duration of SIR-BCS were consistent with C-BCS.

Conclusion: Single-incision robotic breast conserving surgery is a feasible option for early breast cancer treatment and offers better aesthetic outcome, compared with conventional open approach.

Keywords: Robotic Surgery; Single-Incision; Breast-Conserving Surgery; Breast Cancer

Abbreviations: C-BCS: Conventional Breast-Conserving Surgery; SIR-BCS: Single-Incision Robotic Breast-Conserving Surgery; BCS: Breast-conserving surgery; SLNB: Sentinel Lymph Node Biopsy; ALND: Axillary Lymph Node Dissection; DCIS: Ductal Carcinoma in Situ; PROs: Patient-Reported Outcomes; MRI: Magnetic Resonance Imaging

Introduction

Breast cancer is the most commonly diagnosed malignant disease among women all over the world [1,2], ranking the second nationwide [3], and one of the leading causes of cancer-related death. The incidence rate of breast cancer increases continuously worldwide with a trend of younger age at diagnosis. Due to multidimensional progress in comprehensive treatment of breast cancer, including those with systemic therapy, survival outcomes of early breast cancer patients have been significantly prolonged. There emerges patients' demand for aesthetic outcome and psychological recovery. Breast-conserving surgery (BCS) for breast cancer has been widely verified for its safety [4]. BCS could be performed by conventional open approach, endoscopic approach or robotic approach. Conventional breast conserving surgery (C-BCS) is frequently performed by creating two incisions for local extend lumpectomy and axillary lymph node grading respectively [5]. These incisions may cause lowered satisfaction with their visible cosmetic outcome and self-perceived body image, and potentially higher risk of radiotherapy related adverse events. In the past decade, single-incision endoscopic breast-conserving surgery has partially addressed the issue of breast scars [6-9]. Since the da Vinci robotic surgery system may offer further magnifying the surgical field and enable stable operations, we designed single-incision robotic breast conserving surgery (SIR-BCS) technique. According to our experience, single-incision robotic breast-conserving surgery provides substantial oncological safety and improved aesthetic outcomes compared with conventional pattern. The present retrospective cohort study involving 56 early breast cancer patients treated at Beijing Chao-Yang Hospital aimed to compare cosmetic and clinical outcomes of SIR-BCS and C-BCS.

Materials and Methods

Patients

Patients who had undergone surgical treatment for stage I or II invasive breast cancer between January 2025 and December 2025 are enrolled. Inclusion criteria are as follow: tumor constrained to the mammary gland (as confirmed by magnetic resonance imaging [MRI]); lesion diameter ≤ 3 cm; adequate glandular volume; Eastern Cooperative Oncology Group grade 0-2; normal liver, kidney, and bone marrow function. Patients were excluded if they met any of the following criteria: severe cardiopulmonary comorbidities, myocardial infarction, or cerebrovascular disease; any condition precluding general anesthesia or surgical treatment; history of second malignant disease within the past 5 years; pregnancy or lactation; persistently positive pathological margins; and risk of failure of postoperative radiological therapy. The patient cohort included 23 breast cancer patients who underwent R-BCS and 33 patients who underwent C-BCS.

Preoperative preparation

All surgical procedures were conducted by one single surgeon (Dr. Zihan Wang).

Patients were placed in a supine position with the ipsilateral arm abducted. After anesthesia, methylene blue injection was used to mark the area extending 1 cm beyond the palpated edge of the tumor. Then methylene blue was injected continuously surrounding the lesion to set visible mark of the gland that would be excised during the upcoming procedure. The pigment dots were injected 1cm outer from palpation edge of the tumor. As for those patients with unpalpable tumor, wire-localization was conducted in advance. To avoid the formation of an excessively wide stained band of methylene blue in the surgical field, which might interfere with the surgeon's judgment of the target resection range, the injection volume at each point should be as small as possible. Meanwhile, intradermal injection of methylene blue could be performed around the areola synchronously for sentinel lymph node tracing.

Axillary lymph node grading

Axillary lymph node grading was conducted under direct vision through a 3-4-cm single-port incision parallel to the wrinkles in the axilla. The decision of sentinel lymph node biopsy was made according to preoperative evaluation. When axillary dissection was necessary, we would extend the incision to approximately 6cm. Sentinel lymph node status was confirmed by intraoperative frozen-section pathological examination.

SIR-BCS procedure

First, prepare 0.2% epinephrine saline by dissolving 1.0 ml of epinephrine into 500 ml of normal saline. Use an L-shaped needle (Figure 1a) to inject epinephrine saline into the superficial layer of the superficial fascia. To minimize bleeding to the greatest degree, these strips formed by the injected epinephrine saline should be as close to adjacent strips as possible or slightly overlap with them. Then a scalpel with curved hilt, a patent transformation product credit to Dr. Wang Zihan, as applied to transect the Cooper's ligament (Figure 1b). The ideal outcome of this step is to keep small granular fat on the skin flap side while large granular fat on the specimen side. The dissection range in the superficial layer of the gland should be slightly larger than the planned resection range to facilitate the subsequent approximation and suture of the glandular stumps.

Given that Xi and Si system are more widely equipped, our team uses a single-port laparoscopic insufflation kit to connect robotic instruments, aiming at converting multi-port robotic surgery system into single-port robotic surgery system. We inserted a disposable single-port laparoscopic set (Victor Medical Device Co., Ltd.) that offered 3×10 mm and 1×5 mm channels for optical and endoscopic instruments through the axillary incision, and insufflated CO_2 to establish a surgical operating space with a flow rate of 40L/min and a pressure of 10 mmHg (Figure 1c). A da Vinci 30° three-dimensional electronic endoscope (da Vinci Endoscope plus with Camera, 8mm, 30 degree) was installed through the topmost channel. The left robotic arm was connected to robotic Maryland bipolar forceps, the right one was connected to a robotic permanent cautery hook (Figure 1d). Then we drove the surgical robot (da Vinci Xi Surgical System, Intuitive Surgical, Inc.) into the working space, the superficial glandular operating plane.

Under robotic visualization, we could easily recognize the target resection range referring to methylene blue staining (Figure 1e). Then we used the robotic permanent cautery hook to execute cylindrical vertical resection of tumor lesion itself and approximately 1 cm of the surrounding gland, down to the retromammary space (Figure 1f). Finally, the specific part of pectoralis major fascia posterior to the tumor lesion was removed along with the specimen (Figure 1g).

Intraoperative cryosection margin evaluation was performed. If there were detectable residual malignant cells, then additional extend resection and cryosection evaluation would be performed again. If the cryosection pathology reported positive more than twice, a mastectomy procedure would be performed immediately.

After confirming negative margins, we inserted a clip applier through the right robotic arm. Titanium clips were set along the edge of residual gland tissue to facilitate postoperative chest-wall irradiation planning (Figure 1h). Afterwards, we replaced the instrument on the right robotic arm with a needle holder (MEGA SUTURECUT) and stitched the residual cavity of mammary gland with a running suture with absorbable 3-0 barbed thread (Figure 1i). The surgical field was irrigated with sterilized distilled water

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and normal saline subsequently. One drainage tube was placed. The sole incision was sutured with a 4-0 absorbable barbed thread at intradermal level (Figure 1j). All 15 patients who underwent SIR-BCS accomplished postoperative radiotherapy (Figure 1).

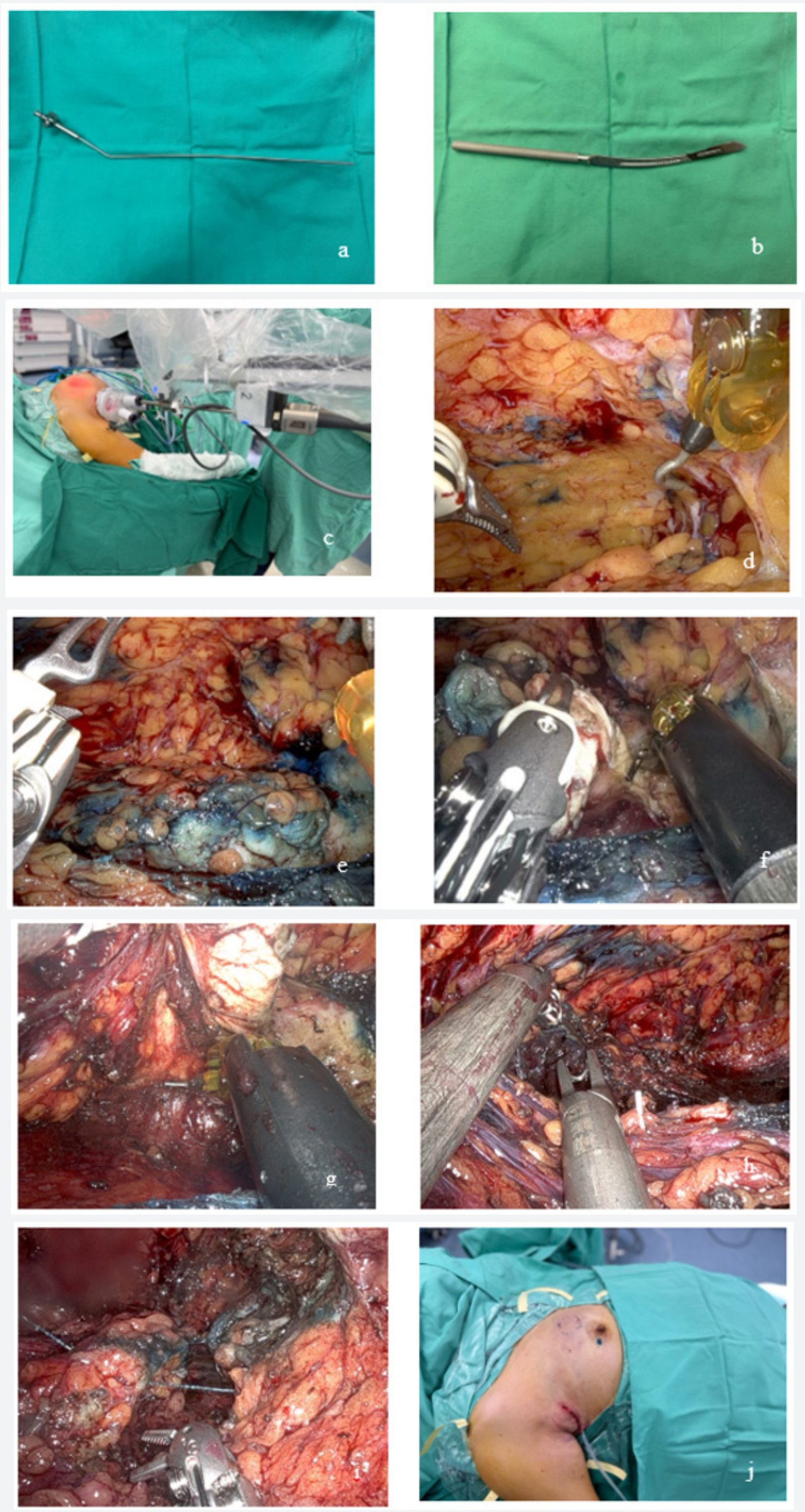

Figure1: Intraoperative scenes of single-incision breast-conserving surgery.

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C-BCS procedure

Firstly, the dissection region was also marked by methylene blue similarly. Methylene blue was injected continuously surrounding the lesion, 1cm outer from palpation edge of the tumor. Axillary lymph node grading was performed via an axillary incision under direct vision. Another incision was made on the skin over the tumor surface. The tumor itself and glandular tissue surrounding the lesion within 1 cm range was excised. Likewise, the resection should include the backside pectoralis major fascia of the target lesion. Cryosection examination was applied to evaluate margin status in the surgical process. If pathological examination revealed residual tumor cells, we would implement further extend resection and repeat intraoperative cryosection examination. If the cryosection pathology reported positive more than twice, a mastectomy procedure would be performed immediately. Similarly, titanium clips were placed in the residual cavity for radiotherapy prompt. Finally, both surgical fields on the breast and within axillary area were irrigated and the two of incisions were stitched with barbed threads after one drainage tube was placed properly. The drainage tube can be removed when its daily drainage volume less than 30 ml 3 days in a row.

Cosmetic outcomes evaluation

The cosmetic outcomes were evaluated by the BREAST-Q scale one month after the operation. The BREAST-Q scale is a series of questionnaire measuring patients' postoperative quality of life on multiple dimensions ranging from satisfaction of breasts, satisfaction of chest-wall, sexual well-being, psychological well-being to adverse events of irradiation and other concerns. The BREAST-Q scale is recognized internationally as the most objective and comprehensive tool of patient reported outcome among breast cancer patients.

Statistical analysis

Measuring data was presented as mean value ± standard deviation. Discrepancy of patient age, duration time of operation, incision length, BREAST-Q scores and drainage duration time between the two cohorts were detected with independent-samples t test (normal distribution). Enumeration data was displayed as absolute value or percentage. The Fisher exact test was involved to detect intragroup differences of menopausal status, cryosection results, rate of neoadjuvant therapy, rate of repetition of surgical procedure due to positive pathology findings, hormonal status and HER2 status. The difference of baseline factors was determined on the basis of the chi-square test. SPSS 26.0 (IBM Corp., Armonk, NY, USA) was applied for all statistical analysis. The threshold of statistically significance was identified as $p < 0.05$.

Results

All 23 patients in the single-incision robotic breast conserving surgery (SIR-BCS) cohort and 33 patients in the conventional breast conserving surgery (C-CBS) cohort successfully completed the surgery. None of the patients in SIR-BCS cohort transferred to open approach. Clinical-pathological factors between the two of the groups were well-balanced. No complications related to robotic arms or were insufflation observed, such as subcutaneous emphysema. In the SIR-BCS cohort, 18 patients underwent sentinel lymph node biopsy (SLNB), and 5 underwent further axillary lymph node sampling according to preoperative evaluation or intraoperative cryosection examination. In the C-BCS cohort, 21 patients underwent SLNB, 10 underwent axillary lymph node dissection (ALND), and 2 patient was initially diagnosed with ductal carcinoma in situ (DCIS) and had accomplished biopsy via lumpectomy, thus this specific patient was allowed to omit axillary grading. Mean value of incision length was shorter in SIR-BCS cohort than it in C-BCS cohort (3.48±0.77 vs 4.67±1.61, $p<0.001$). Every of the 56 patients enrolled accepted cryosection examination during the operation. The mean operative time was longer in the SIR-BCS group than it in the C-BCS group (145.22 ± 36.55 vs 126.67 ± 46.95 minutes, $p=0.1028$).

All 23 patients in the SIR-BCS cohort and 33 patients in the C-BCS cohort achieved negative surgical margins on cryosection analysis and postoperative pathological examination. Therefore, there is no need for additional resection to reassure radical excision. We used BREAST-Q questionnaire to assess patients' satisfaction with breast appearance, satisfaction with chest wall status, psychosocial well-being, and sexual well-being. Patients in the SIR-BCS cohort reported higher postoperative breast satisfaction and higher chest-wall satisfaction scores compared to those in the C-BCS group. Regarding psychosocial well-being and sexual well-being, the patient-reported outcomes (PROs) were similar between the SIR-BCS group and the C-BCS group (Table 1-3).

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Table 1: Clinical-pathological data of patients enrolled.

Variable		SIR-BCS N=23	C-BCS N=33	p value
Age(years)	Mean	47.65±10.40	50.15±10.28	0.3769
Menstrual status, n(%)	Range Premenopausal Postmenopausal	28.0-71.0 17(73.91%) 6(26.09%)	33.0-74.0 21(63.64%) 12(36.36%)	0.5628
Neoadjuvant therapy, n(%) T stage	0 1	8(34.78%) 5(21.74%) 14(60.87%)	11(33.33%) 6(18.18%) 21(63.64%)	1.0000 0.9471
N stage	2 0 1	4(17.39%) 16(69.57%) 7(30.44%)	6(18.18%) 19(57.58%) 12(36.36%)	0.463
ER, n(%)	2 Positive Negative	0(0%) 17(73.91%) 6(26.09%)	2(6.06%) 26(78.79%) 7(21.21%)	0.7528
PR, n(%) HER2, n(%)	Positive Negative Positive	16(69.57%) 7(30.43%) 8(34.78%)	22(66.67%) 11(33.33%) 7(21.21%)	1.0000 0.3594
SLNB or ALND,n(%)	Negative SLNB only ALND	15(65.22%) 18(78.26%) 5(21.74%)	26(78.79%) 21(63.64%) 10(30.30%)	0.4087
	Non	0(0%)	2(6.06%)	

Table 2: Perioperative parameters of SIR-BCS cohort and C-BCS cohort.

Variable		SIR-BCS N=15	C-BCS N=21	p value
Operation time (min)	mean range	145.22±36.55 90-235	126.67±46.95 85-265	0.1028
Margin status of cryosection examination, n (%)	positive negative	0(0%) 23(100%)	0(0%) 33(100%)	1
Margin status of postoperative pathology report, n (%)	positive negative	0(0%) 23(100%)	0(0%) 33(100%)	1
Incision length (cm)	mean range	3.48±0.77 3-6	4.67±1.61 3-8	0.0006
Drainage duration (days)	mean range	7.35±5.60 2-11	8.36±4.15 3-15	0.4665

Table 3: BREAST-Q scale scores.

Viable	SIR-BCS N=23	C-BCS N=33	p value
Satisfaction with Breasts	81.20±13.98	71.24±13.59	0.0109
Physical Well-being chest	72.95±21.38	60.55±23.37	0.0452
Psychosocial Well-being	74.80±16.53	78.79±19.12	0.4088
Sextual Well-being	60.15±25.53	56.91±27.83	0.6546

Discussion

Breast-conserving surgery as a standard pattern for early breast cancer treatment has developed vigorously over the past few decades. The increase in the breast-conserving rate can be attributed to the promotion of breast disease screening, advancements in early diagnosis, appropriate application of neoadjuvant therapy, the involvement of Multidisciplinary Team (MDT) consultations, and the development of oncoplastic surgery techniques [4]. In western countries, breast-conserving rate has

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gradually exceeded 50%, especially in university hospitals, which could thrive more than 80%. NHS of the UK even advocated in the GIRFT (Getting It Right First Time) [10] manual that breast-conserving surgery should be performed on all patients for whom it is 'oncologically safe and aesthetically feasible'.

Historically, breast-conserving surgery usually requires two incisions, casting negative impact on aesthetic outcome and lowering patients' satisfaction of the breasts. With the development of endoscopic technology, single-port endoscopic breast-conserving surgery was also initially proven its feasibility and safety. This technology allows doctors to accomplish extend local resection and axillary grading through one single incision. Endoscopic breast conserving surgery omits surgical scars on the breast surface, thus improves the appearance of chest wall, patient's psychosocial well-being, and even reduces adverse reactions to radiotherapy.

Robotic surgery system has gradually been applied in breast cancer surgery since 2010s [11-14]. Compared with conventional open approach, robotic surgery system provides a 'crystal-like' visual field magnified up to 10 times. Robotic surgical instruments offered higher flexibility than those endoscopic instruments because of a noticeable wide rotating range up to 540°. Furthermore, the Da Vinci system installed software that could identify and filter off the surgeon's hand tremors to avoid unnecessary intraoperative risks. Its naked-eye 3D effect helps doctors lacking endoscopic experience overcome the challenges of a 2D surgical field, which may accelerate the surgeons' learning curve [15,16]. Its working space complies with human ergonomic features, helping surgeons to dedicate to surgical procedure. However, from the point of surgical treatment for breast cancer, robotic surgery is mainly involved in nipple-sparing mastectomy (NSM) and NSM followed by immediate reconstruction [17-21], robotic breast conserving surgery was not commonly recognized before. Patients enrolled in this study underwent intraoperative cryosection pathological examination of the surgical margins, with a positive margin rate of 0% and a corresponding reoperation rate of 0%. Such a low positive margin rate can be seen as consequence of our generous marking method. Before the operation began, the surgeon and assistant marked the palpable margin of the tumor on the body surface, and injected methylene blue to emphasize the area 1 cm outwards from the palpated margin as the dissection region. The palpated margin of a certain lesion often outranges the ultrasound detected margin, and we go one step further to design the dissection region as 1 cm outward from the palpated margin. Therefore, the dissection region we planned could be notably larger than the tumor lesion, guaranteeing for negative surgical margins.

Currently, the perioperative parameters of robotic breast-conserving surgery, such as operation duration and time to drain tube removal, are similar to those of C-BCS breast-conserving surgery, indicating that robotic surgery is a feasible method for breast-conserving surgery. The duration time in SIR-BCS cohort was approximately 20 minutes longer than it in C-BCS cohort, though numerically not statistically. Longer operative time is attributable to settlement of robotic arms and robotic instruments. Both docking time and console time are deemed to decrease significantly when the team, including surgeons, assistants and nurses, comes to a later phase of the learning curve [22]. Moreover, in the foreseeable future, the popularization of robotic surgery is expected to further reduce the operation duration of robotic breast-conserving surgery, achieving better damage control.

From the standpoint of technical feasibility, robotic surgery is more suitable for operations in narrower spaces, which is the reason why robotic surgery has developed rapidly in urology and gynecology industry. Compared with nipple-sparing mastectomy, breast-conserving surgery is much more space-constrained, making it better suited for the robotic surgical system. Additionally, the most challenging steps in single-port endoscopic breast-conserving surgery are intracorporeal suturing of the residual cavity. The 540° range of motion of the tips of robotic surgical instruments such as needle holders, combined with the assistance of naked-eye 3D visualization, has greatly simplified intracorporeal suturing motions. This study found that the incision length of single-port robotic breast-conserving surgery is shorter than that of traditional open breast-conserving surgery. This is because C-BCS involving oncoplastic surgery (OPS) technique demanded a longer incision for skin flap management, while SIR-BCS required only one axillary incision.

Currently, the robotic surgical systems used in most hospitals were multi-port systems such as the Da Vinci Xi or Si, which were difficult to execute single-incision operations. Our team attempted to connect the axillary incision and robotic instruments with a glove (Figure 1c), but we soon found that a glove could hardly retain its position. Since Dr. Wang Zihan is the surgeon who performed single-incision endoscopic in insufflation breast-conserving surgery, we used a single-port cannula for endoscopic surgery to connect the incision and robotic instruments (Figure 1d). We successfully achieved the goal of completing single-port robotic breast-conserving surgery with a multi-port robotic surgical system, further shortening the total incision length and improving the stability of instrument operation.

Patients' quality of life and aesthetic outcomes should be taken into account during decision-making process for breast cancer treatment. As a scarless surgical approach, robotic breast-conserving surgery could be a promising approach for early breast cancer patients. To evaluate breast appearance and patients' quality of life after robotic breast-conserving surgery, this study used the Chinese version of the BREAST-Q questionnaire to assess satisfaction of the breasts, physical well-being of chest, psychosocial well-being, and sexual well-being. The BREAST-Q scale is a well-recognized Patient-Reported Outcome Measure (PROM) [23]. Results of the one-month postoperative follow-up showed that patients who underwent SIR-BCS maintained

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higher breast satisfaction and higher chest-wall satisfaction scores than those who underwent C-BCS. The Satisfaction of Breasts was significantly higher in SIR-BCS cohort than it in C-CBS cohort, meanwhile patients' psychosocial well-being status was numerically better than C-BCS. Their sexual well-being score was consistent with those in C-BCS cohort. This may be attributed to the elimination of incisions on the breast surface by SIR-BCS. The generally low scores for chest wall satisfaction may be related to the early timing of follow-up.

Conclusion

This study introduces a novel single-port robotic breast-conserving surgery approach, which accomplishes breast lesion resection and axillary lymph node staging through one single axillary incision. Compared with conventional open approach breast-conserving surgery, single-port robotic breast-conserving surgery features a shorter incision, higher breast satisfaction, higher chest-wall satisfaction. Because of the relatively small scale and short follow-up time, the survival data remain immature, we had designed prospective study to illustrate the safety and aesthetic outcomes of SIR-BCS. Single-port robotic breast-conserving surgery is a feasible surgical option for the treatment of early breast cancer.

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