EJMO

DOI: 10.14744/ejmo.2024.51646
EJMO 2024;8(1):32–39

Research Article

Preliminary Surgery Experience for Preventing Heat Steam-Induced Skin Damage During in Robot-Assisted Breast Reconstruction Surgery

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Abstract

Objectives: The clinical objective of this study was to compare surgical outcomes and postoperative skin complications in patients with breasts without cooling and breasts with intraoperative cooling.

Methods: A retrospective study was conducetd for the patients who received RNSMIBR between September 2022 and August 2023 were examined. Surgical outcomes and postoperative skin complications were analyzed.

Results: A total of 57 R-NSMIBR procedures were analyzed by segregating the patient population into two groups, (group 1) 29 patients without cooling and (group 2) 28 patients with intraoperative cooling respectively. The proportion of postoperative skin complications was higher in the no-cooling group when compared to the intraoperative cooling group. Other clinical factors were not differed significantly between the two groups. Regarding surgical outcomes, skin complications in the no-cooling group resulted in implant loss. There was no significant difference in the rate of complications but statistically significant differences were observed in skin complications (erythematous flaps and vesication), infections, and loss of implant ($P<0.05$) between the two groups.

Conclusion: Significant difference was observed in surgical outcomes or postoperative complications between the patient groups such as breast without cooling and breast with intraoperative cooling. Intraoperative cooling of the breast is necessary due to the limited space in which the breast is operated and the heat steam generated by the robotic instruments can cause skin damage.

Keywords: Breast reconstruction, heat steam, implant, robotic surgery, skin damage

Cite This Article: *Chen K, Zhang J, Beeraka NM, Lu P. Preliminary Surgery Experience for Preventing Heat Steam-Induced Skin Damage During in Robot-Assisted Breast Reconstruction Surgery. EJMO 2024;8(1):32–39.*

Breast cancer (BC) stands as one of the significant cancers affecting the health of women globally. The absence of targeted therapeutic options with minimal adverse effects exacerbates the challenge. Recent epidemiological studies have highlighted the alarming scenario in sub-Saharan African countries specifically, Na-

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Submitted Date: December 07, 2023 **Revision Date:** January 15, 2024 **Accepted Date:** January 21, 2024 **Available Online Date:** March 06, 2024

mibia, Nigeria, South Africa, Uganda, and Zambia, where breast cancer patients face mortality rates ranging from 28% to 37%, primarily attributed to the severity of metastatic breast cancer.[1, 2] Other than Africa, the incidence of breast cancer contributes significantly to higher mortality rates among women in various regions, including India, China, Europe, the Middle East, Australia, USA, and UK.[3, 4] To cure metastatic breast cancer, multiple chemotherapy regimens, and surgical interventions like mastectomy are commonly employed. These regimens aim to target tumor cell proliferation within the tumor microenvironment, indicating a significant strategy for managing this challenging disease. However, the complications related to conventional surgery are accompanied by lymphedema, fat necrosis, wound infection, limited range of motion, and arm paralysis. Quality of the life among the women received radical mastectomy is affected due to the poor esthetic outcomes. The da Vinci Xi Surgical Robotic System is a state-of-the art robotic surgical system with high definition, stereoscopic and microscopically magnified views. Robotic arm of this surgical robotic system rotates 360 degrees and typically performs delicate surgical operations in the confined space of the surgical area.[5, 6] There is a higher incidence of flap infection and necrosis complications, which can lead to implant loss due to the incisions occurred by the breast reconstruction surgery. NSMIBR has been substantiated, establishing it as a recognized and acceptable surgical approach.[7, 8] With recent advances in technology, robotic nipple-sparing mastectomy and immediate breast reconstruction (RNSMIBR) has proven efficacy in fostering better psychosocial outcomes and aesthetic outcomes when compared to traditional mastectomy.[9]

Unlike the natural space of the body in the abdominal cavity, the breast has a very limited operating space. During robotic-based surgical mastectomy, a large amount of heat energy is generated and CO_2 propagation through the pneumoperitoneum fills the entire breast space, which can confer heat steam-induced damage to the breast skin, subsequently resulting in skin complications and affect the overall aesthetic outcomes in females.[10, 11] The current study compares relevant clinical data and attempts to address this issue using the simplest method of cooling to provide preliminary experience aiming to offer initial insights for the enhanced development of the RNSMIBR procedure.

Methods

Patient Selection

In this study, we conducted a comprehensive evaluation of the medical records pertinent to the patients who underwent RNSMIBR with gel implant surgery. This study was carried out at a single institution between September 2022 and August 2023. All the therapeutic interventions adhered to the National Comprehensive Cancer Network (NCCN) guidelines for breast cancer and were determined through a collaborative decision-making process involving experienced breast surgeons and patients. The surgical procedures were executed with the aid of da Vinci Xi™ robotic-assisted surgical system (Intuitive Surgical Corp., Sunnyvale, CA, USA) along with the usage of the robot concomitantly with the AirSeal® system to maintain stable pneumoperitoneum air pressure. All the patients received anatomical gel implants (Mentor Worldwide LLC, USA).

Data were recorded and evaluated with the aid of Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Informed consent was obtained for each patient before participating in the study; the research was conducted with the complete approval of the Institutional Review Board of the First Affiliated Hospital of Zhengzhou University Ethics Committee (Serial number: 2023-KY-0841).

As part of the data analysis, we segregated the patient population into two groups such as (1) 29 patients without intraoperative cooling interventions and (2) 28 patients with cooling interventions. For each patient, we recorded body temperature and subsequently recorded pathological characteristics and skin complications, which were retrospectively analyzed after surgery.

Surgical Technique

The patient underwent a robot-assisted NSMIBR procedure by the administration of general anesthesia. Primarily, a 5 cm incision was selected at the confluence of the midaxillary line and the upper edge of the breast, along with a 0.5 cm incision parallel to the nipple in the midaxillary line and a 0.5 cm incision between the midaxillary line and the lower edge of the breast. An electrosurgical scalpel was used to release the flap through axillary incision into the nipple-areola complex and outer lower quadrant, thereby creating a lumen for manipulation by the robotic arm. The robotic arm was subsequently attached, and three robotic arms connected to grasping forceps, lenses, and electro-dissection scissors respectively (Fig. 1A, B). Air pressure was established and maintained at 12 mmHg (1 mm of Hg = 0.133 kPa) throughout the procedure. Using the robotic arm, the breast is sequentially dissected along the subcutaneous fat layer of the breast at the superior, lateral, inferior, nipple-areola complex, and medial borders. Subsequently, drains were placed, whereas the silicone gel implants were inserted, and simultaneously the incisions were closed.

Estimated Heat Production

Both grasping forceps (bipolar) and electro-dissection scissors (monopolar) to perform surgical procedures were used (Fig. 2). In the da Vinci Xi™ robot-assisted surgical system, the modes were defined as, forceps (bipolar) on: BIPOLAR CUT and BIPOLAR SOFT COAG with AUTO STOP; electro-dissection scissors (Monopolar) on: AUTO CUT and SWIFT COAG; Set all gears to level 4 while surgical procedure (Fig. 3). Statistical data was analyzed according to da Vinci Xi™ robot system parameters and we can roughly estimate the amount of heat generated per second while the usage of instrument use based on energy conversion (Fig. 4) (Table 1).

Energy conversion formula:

$$(Effective\ voltage)X=\frac{(High-frequency\ peak\ voltage)}{(crest\ factor)}$$

$$Heat\ energy=\frac{(Effective\ voltage)x^2}{(Rated\ load\ resistance)}\times time\ (h)$$

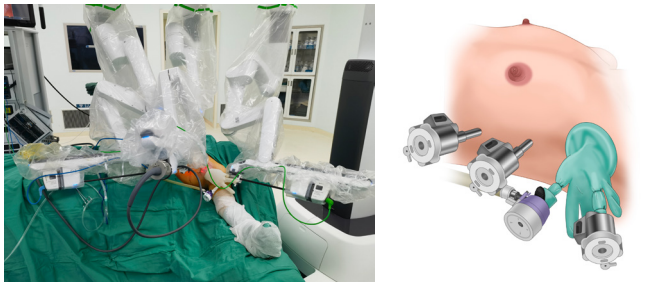

Figure 1. Schematic depiction of the da Vinci Xi™ robot-assisted system with a three-hole approach.

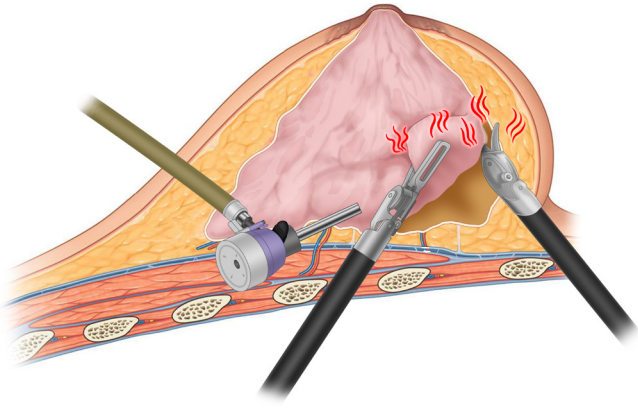

Figure 2. The mammary glands were removed using grasping forceps and electro-dissection scissors at the time of da Vinci Xi™ robot-assisted surgery.

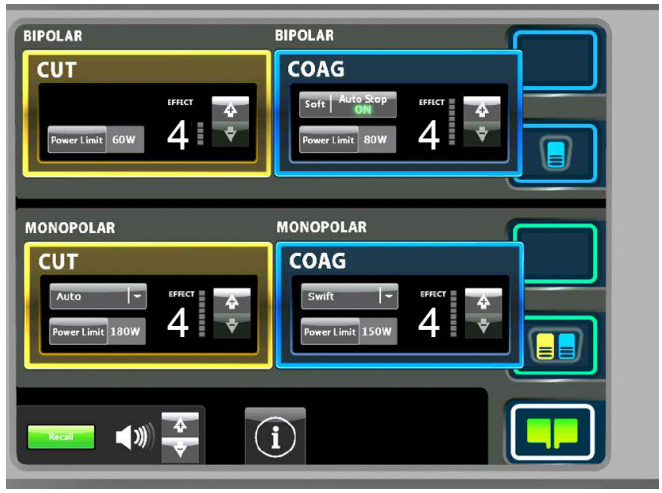

Figure 3. Parameters that were set up using The da Vinci Xi™ robot-assisted surgical system at the time of surgical intervention.

Cooling Technology

The heat generated by the robotic device during the surgery fills the entire breast space due to the effect of CO_2 inflation; a large amount of heat is accumulated in a short period, just like a "sauna room" (Fig. 5). This heat raises the temperature of the entire breast space rapidly and affects the skin temperature of the breast. The breast operating space is typically minimal to induce a cooling effect across the robot operating space. We used the most "simple and effective" way to cool the skin on the surface of the breast. The gauze was soaked inside the ice water and placed over the breast skin, and the procedure was repeated over time. A thermometer was used to monitor the temperature of the skin on the breast surface (Fig. 6).

Statistical Analysis

Mann-Whitney test was used to analyze the variables related to the patient groups. Comparisons of categorical variables were assessed by Fisher's exact test. Remainig statistical analyses were executged with the aid of SPSS (IBM Software, IBM, Armonk, NY, USA). P-values < 0.05 were considered statistically significant.

Results

Among the 57 patients who underwent RNSMIBR, skin-cooling technology was used in 28 patients. All RNSMIBR surgeries were executed by two experienced surgeons and all the patients received unilateral breast reconstruction. Median age of all patients was 40.3 years (27-56 years). There were no statistically significant differences between the two groups. Five patients in the non-cooling group underwent axillary lymph node dissection (ALND) whereas six patients in the cooling group underwent

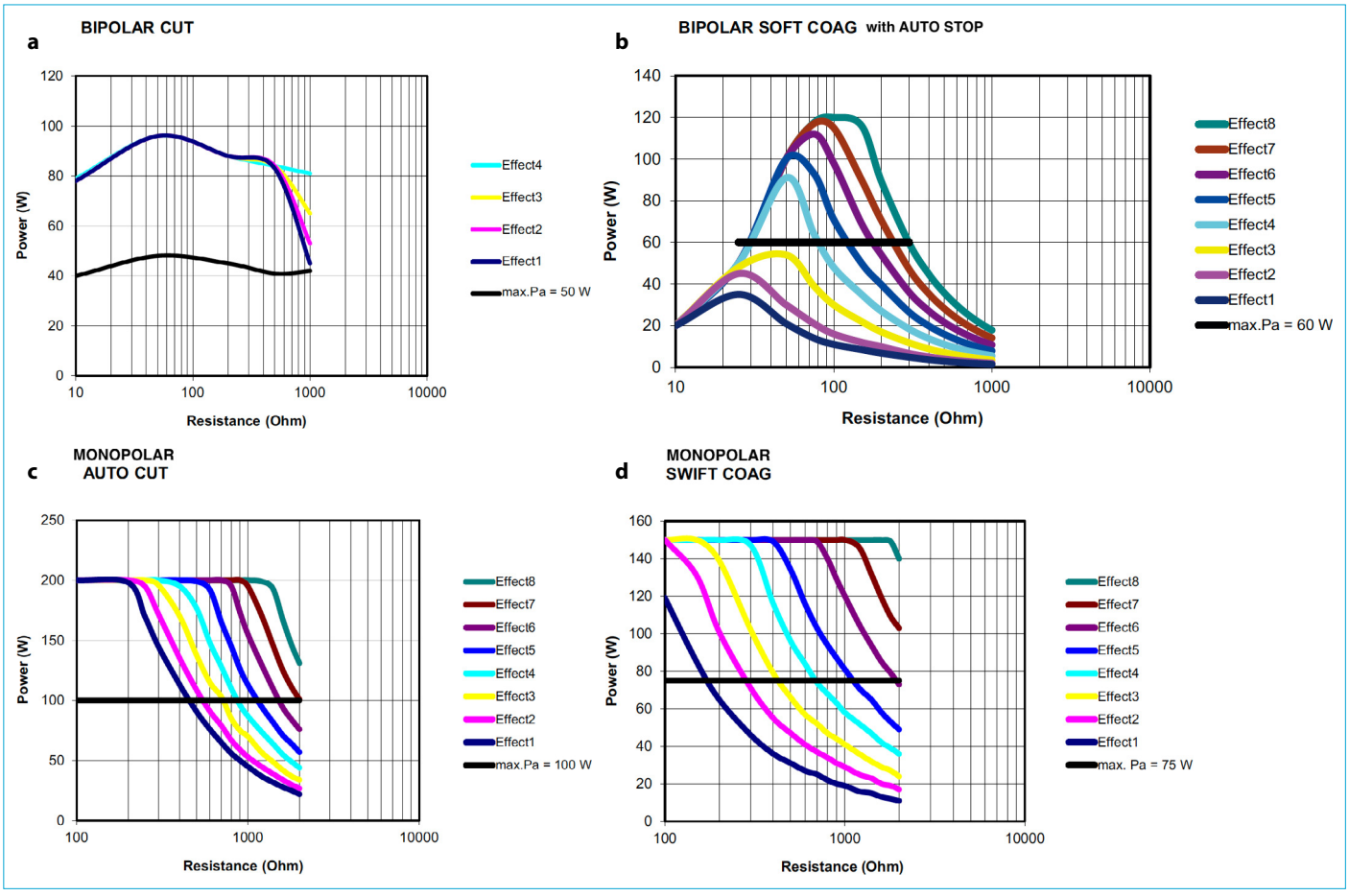

Figure 4. Technical Parameters implicated during the surgery and they were bipolar cut **(a)**; bipolar soft coag with auto stop **(b)**; monopolar auto cut **(c)**; monopolar swift coag **(d)**.

Table 1. Technical parameters of the da Vinci Xi™ robot system

Standard Model	Bipolar		Monopolar	
	Bipolar Cut	Bipolar Soft Coag with Auto Stop	Auto Cut	Swift Coag
Crest factor	1.4 (R_L = 500 Ohm/h)	1.4 (R_L = 500 Ohm/h)	1.4 (R_L = 500 Ohm/h)	5.2 (R_L = 500 Ohm/h)
High-frequency peak voltage (4th block)				
RL = ∞ [Vp]	490	110	430	1210
Rated load resistance	50 Ohm	75 Ohm	500 Ohm	500 Ohm
Heat energy (J)/h				

ALND. The clinicopathological characteristics of the patients were given in Table 2.

The mean time spent on surgery using robot-assisted removal of breast glands was 76.4 minutes for the non-cooling group whereas 74.8 minutes for the cooling group. Electronic thermometer was used to measure the skin surface temperature of the breasts, and a mean temperature of 33.4°C and 25.7°C were observed for the non-cooling group and the cooling group respectively (Table 3). Complications of erythematous flaps and vesication were observed among four patients in the non-cooling group. In one patient, a skin blister ruptured and became infected, causing the implant to be exposed, which consequently led to the most serious consequence and loss of the implant. However, there was no skin damage or other complications were reported postoperatively in the cooling group (Fig. 7).

Figure 5. A large amount of heat accumulated within a short period in the small vicinity of the breast during da Vinci Xi™ robot-assisted surgery.

Discussion

Park KU et al. (2020) described R-NSM as a significant strategy used to preserve the residual breast tissue than conventional open surgery.[12] Robot-assisted surgery can mitigate the natural tremors occurring in human hands at the time of surgery by increasing stability and coordination during surgical intervention.[13] The surgeon can execute the whole surgical intervention in a seated position without fatigue throughout the entire prolonged procedure. A plethora of previous reports elucidated that the gas-filled strategy for R-NSMIBR with gel implant is a significant method to confer safety to mitigate oncogenicity.[14-16] R-NSMIBR is implicated to attain effective esthetic outcomes and to improve favorable surgical outcomes in female diagnosed for early breast cancer.[17-20] In our study, the inflatable technology has been widely used. The advantages of this strategy are that this technique can appropriately extend the operating space, and the dome shape of the breast can be maintained by filling with CO_2 without destroying the associated anatomical structures.[10] Chen K et al. described the advantages of using the inflatable technique for R-NSMIBR.[21] However, the resulting high temperatures during breast surgery can also damage the skin due to the accumulation of smoke and heat generated by the instruments in the confined breast space.

Previous reports elucidated the impact of standard and heated-humidified carbon dioxde on core body temperature variations, particularly with regard to operation durations. A study assessing short-term gynecological laparoscopy described that the heated-humidified CO_2 insufflation did not demonstrate a significant benefit in preventing hypothermia.[22-25] Another study by Klugenberg et al.[24] observed that the patient group with heated-humidified CO_2 duringsurgery attained a higher core temperature (37.07 °C vs. 36.85 °C).[26] A recent study by Gunusen I et al described the effects of standard and heated-humidified CO_2 during laparoscopy surgery on both hemodynamic as well as respiratory parameters in healthy patients.[26] This report concluded the incidence of higher core body temperature and

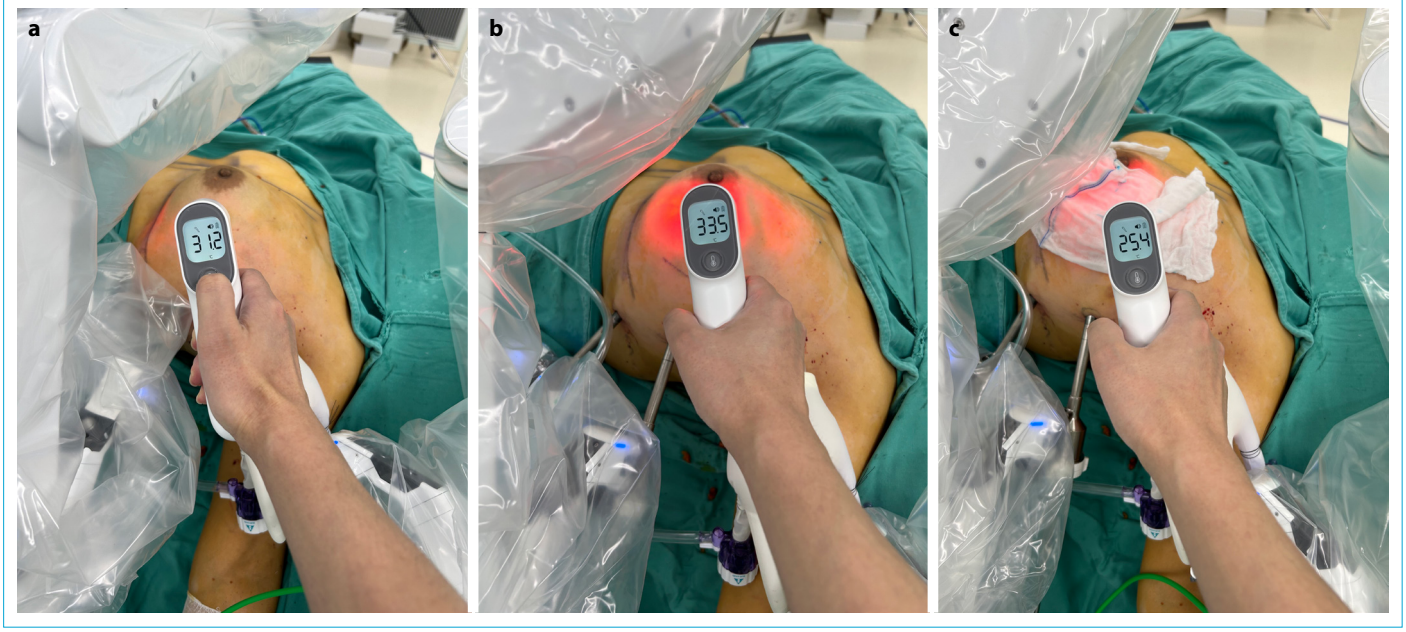

Figure 6. (a) Skin temperature begins to rise at the beginning of the da Vinci Xi™ robot-assisted surgical intervention. **(b)** Skin temperature rises significantly during the procedure. **(c)**, Skin temperature is observed after the cooling is performed.

Table 2. Patient characteristics pertinent to non-cooling group and cooling group in this study

	Non-cooling (Mean)	Cooling (Mean)	p
Age (median), years	41.4	39.1	0.055
	Non-cooling N (%)	**Cooling N (%)**	
Lymph node			
SLNB	24 (82.7)	22 (78.6)	0.062
ALND	5 (17.3)	6 (21.4)	0.068
Histology			
IDC	21 (72.4)	21 (75.0)	0.074
DCIS	8 (27.6)	7 (25.0)	0.084
Chemotherapy			
Adjuvant chemotherapy	22 (75.9)	19 (67.8)	0.069
Neoadjuvant chemotherapy (Neochemo)	7 (24.1)	9 (32.2)	0.075

IDC: Invasive ductal carcinoma; DCIS: Ductal carcinoma in situ; SLNB: Sentinel lymph node biopsy; ALND: Axillary lymph node dissection.

Table 3. Postoperative skin complications related to the heat steam induced damage in the patients segregated into non-cooling group and cooling group in this study

	Non-cooling (Mean)	Cooling (Mean)	p
Mastectomy (Median), minutes	76.4	74.8	0.527
Breast Surface Temperature (Median), ºC	33.4	25.7	0.034
	Non-cooling N (%)	**Cooling N (%)**	
Skin complications			
Erythematous flaps and vesication	4(13.8)	0	0.028
Other complications			
Infections	1(3.4)	0	0.046
Loss of implant	1(3.4)	0	0.046

inflammation in the heated-humidified CO_2 group.[26] This kind of hyperthermia is confirmed by our results, where the hot vapor raises the temperature during robotic breast surgery. In this study, the breast has a narrow space, unlike the abdominal cavity. In a confined and narrow space, a large amount of smoke and heat steam generated by the manipulation of the robotic arm, under the influence of the CO_2 inflation technique, collects heat steam in large quantities in a short period. The heat is generated through the body's skin surface, which consequently raises the temperature of the skin confined to the breast surface, thus generating postoperative skin complications. Although we used the AirSeal® system to keep the air pressure stable during surgery, it could not solve the problem of heat generation in the minor vicinity of the breast undergoing robotic surgery.[27] However, according to our study, AirSeal® system allowed the surgeon to visualize the operative field vividly, which consequently mitigated the overall surgery duration, whereas the increased efficiency of this robotic-based surgical procedure indirectly mitigated overall heat generation.[28] To minimize the skin complications on the breast body surface caused by hot steam, we have used the most "simple and effective" method to cool the skin on the breast surface. The results show that this method is safe and effective and very simple and practical.

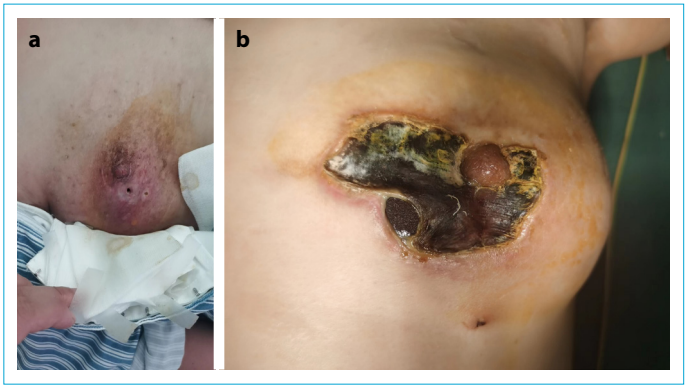

Figure 7. (a) Erythematous flaps and vesication were observed during the da Vinci Xi™ robot-assisted surgery. **(b)** Skin blisters rupture and become infected subsequently causing the implant to become exposed.

There are several limitations to this study. The differences that exist among individual patients and the different surgical approaches, such as SLNB and ALND, make it difficult to accurately compare surgical times between the two groups. In addition, we were only able to measure breast body surface temperature using a thermometer and were unable to accurately measure the temperature within the confined space of the breast. Since this study is our initial experience and focuses only on short-term postoperative outcomes, longer follow-up studies are needed on a large sample size.

Conclusion

Intraoperative cooling of the breast is necessary because of the confined space in which the breast is operated and the heat steam generated by the robotic instruments can cause skin damage. Future studies are warranted to explore the mitigation strategies for postoperative skin complications in mastectomy patients to enhance the overall quality of life and esthetic outcomes.

Disclosures

Ethics Committee Approval: This work has been approved by the institutional ethical committee of the First affiliated hospital of Zhengzhou University, Henan. This study protocol was reviewed and approved by [the institutional ethical committee of the First affiliated hospital of Zhengzhou University], approval number [2023-KY-0841]. All the work related to this retrospective study was by the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Acknowledgments: The authors thank the technical staff of the Department of Breast Surgery, The First affiliated with Zhengzhou University for their support.

Authorship Contributions: Concept – K.C., PW.L.; Design – K.C., N.M.B.; Supervision – J.Z.; Materials – K.C., PW.L.; Data collection &/or processing – K.C., N.M.B.; Analysis and/or interpretation – K.C., N.M.B.; Literature search – J.Z., N.M.B.; Writing – K.C., N.M.B.; Critical review – J.Z.

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