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ORIGINAL RESEARCH

A Brand-New Drainage Fluid Predictor, ICAM-1 for Implant Loss After the Immediate Reconstruction of Breast

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Background: Nearly 40% of breast cancer patients are ineligible for breast-conserving surgery. Immediate implant-based breast reconstruction is a preferred option for these patients. The most severe complication of this procedure is implant loss. Currently, there are no cytokines available to predict implant failure. To identify a drainage biomarker predicting implant loss and evaluate whether dexamethasone irrigation in high-risk cases is associated with reduced implant failure, we designed this study.

Methods: A retrospective cohort study was conducted between December 2022 and March 2024, patients undergoing mastectomy with immediate implant-based reconstruction were recruited. We applied protein microarray to analyze cytokines in the drainage fluid from the implant pocket to identify cytokines associated with implant failure.

Results: We initially selected 3 patients with implant failure and 3 with successful implant outcomes as the cohort for protein microarray analysis. Drainage fluid samples were collected and analyzed at 3 time points: 24 hours postoperatively, at drainage removal and at the onset of implant failure. This analysis identified intercellular adhesion molecule-1 (ICAM-1) as a candidate marker that meets the criteria for predicting implant failure. Subsequently, we validated ICAM-1's predictive potential in a separate cohort of breast cancer patients who underwent immediate implant-based breast reconstruction between December 2022 and March 2024. Our results demonstrated that ICAM-1 levels in drainage fluid at the time of drainage removal effectively predicted implant failure following immediate breast reconstruction for breast cancer. Additionally, a retrospective analysis revealed that intracavitary irrigation with dexamethasone significantly reduced ICAM-1 level in the drainage fluid and reversed impending implant failure.

Conclusion: The data confirmed the potential of ICAM-1 as a predictive factor for breast implant failure. Intracavitary irrigation with dexamethasone was effective to prevent implant loss.

Keywords: immediate breast reconstruction, implant loss, predictive factor, ICAM-1

Introduction

Breast cancer has become the second most common malignant tumor in humans, predominantly affecting women.[1,2] The incidence of breast cancer continues to rise globally and in China, posing a significant threat to women's health.[1,2] Breast cancer treatment modalities were evolving rapidly, contributing to an approximate 10% improvement in 5-year overall survival over the past decade.[3] Surgery continues to be the definitive intervention for curing breast cancer. Although the utilization of breast-conserving surgery (BCS) in China had increased by 20%. However, 40–50% of patients still required the mastectomy.[4] For these patients, breast reconstruction is an essential consideration. Compared with autologous reconstruction, implant-based reconstruction is procedurally simpler associated with lower failure rates and favorable aesthetic outcomes, thereby gaining widespread acceptance among breast surgeons.[5] Furthermore, immediate reconstruction offers the advantages

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over delayed reconstruction—including superior cosmetic results, expedited recovery and reduced complications—referring to it as the preferred approach in breast reconstruction.

Immediate implant-based breast reconstruction has emerged as the preferred surgical option for breast cancer patients undergoing mastectomy. Nevertheless, this technique is accompanied by several complications, including infection, skin necrosis, implant exposure, and notably, implant loss—the complication that significantly affects both patients and clinicians.[6,7] Mounting studies have identified factors such as obesity, smoking, diabetes, and the use of oversized implants as independent risk factors for implant failure.[8–10] However, these factors did not entirely elucidate the underlying causes of prosthesis failures, and the early predictive indicators remained unreported. Then, our research group aimed to investigate the drainage fluid of breast cancer patients with immediate implants reconstruction to identify cytokines that might serve as the early indicators of implant failure, ultimately facilitating timely interventions to prevent implant loss.

Materials and Methods

Ethics Approval and Consent to Participate

The procedures of this study were approved by the ethics committee of the second affiliated hospital of Xi'an Jiaotong University (2025LL100). The clinical experiments were performed upon receiving written consent from each subject.

Patients

We retrospectively analyzed all patients with early-stage breast cancer in the comprehensive breast care center of the second affiliated hospital of Xi'an Jiaotong University and Genertec Universal Xi'an Beihuan Hospital. Between December 2022 and March 2024, 232 patients with early-stage breast cancer underwent the mastectomy with immediate implant reconstruction in the comprehensive breast care center of the second affiliated hospital of Xi-an Jiaotong University and the general surgery department of Genertec Universal Xi-an Beihuan Hospital. We collected the drainage samples in 106 patients. All patients signed the operation consents. Besides, all surgeons and assistants had completed more than 300 traditional operations of breast cancer. The therapeutic strategies of patients with breast cancer were drawn up according to the National Comprehensive Cancer Network (NCCN) guideline for breast cancer (https://www.nccn.org/). During treatment, antibiotics were necessary as drainage culture was positive.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were made up according to the guideline of breast cancer reconstruction of China.[11] Inclusion criteria: 1. Female; 2. Invasive breast cancer or breast carcinoma in situ; 3. Contraindications or refusion of breast-conserving surgeries; 4. Thickness of subcutaneous tissue was acceptable, sub-areolar biopsy confirmed as tumor-free and negative; 5. Signed consent form; 6. Clinicopathological data was available; 7. Breast ptosis grade 1–2.[12] Radiation therapy was recommended according to the guidelines. During surgery, Tiloop mesh was routinely applied for immediate implant reconstruction.

Exclusion criteria: 1. Metastatic breast cancer; 2. No accomplishment of R0 resection, skin invasion or satellite nodules; 3. Severe underlying diseases or severe cardiopulmonary dysfunction leading to the inability to tolerate general anesthesia; 4. Clinicopathological data were missed or unavailable; 5. Breast ptosis grade 3.[12]

Indications for Drainage Tube Removal and Collection of Drainage Fluid

Following routine placement of drainage tubes after breast cancer surgery, removal was considered when the 24-hour drainage volume consistently remained less than 20 mL for two consecutive days. Cytokine chip analysis was conducted on the drainage fluid. Samples were routinely collected prior to tube removal and at the time of prosthesis exposure or displacement. In selected patients, an additional sample was obtained 24 hours postoperatively. Approximately 1–2 mL of drainage fluid was collected and stored at −80°C. When implant exposure or loss occurred, routine bacterial cultures were obtained.

Standards for Intracavitary Irrigation of Prostheses

In clinical practice, selected patients undergo prosthetic cavity irrigation. Indications for the procedure include turbid drainage fluid, localized erythema and swelling, and drainage persisting for more than 14 days. The procedure involves instilling 20–30 mL of normal saline combined with 5 mg of dexamethasone through the drainage tube, allowing the mixture to remain for 2 hours, applying negative pressure thereafter, and repeating the process twice weekly until the criteria for drainage tube removal are met.

Indications for Intracavitary Irrigation of Prostheses

The indications for intraluminal irrigation are as follows: (1) retention of the drainage tube for more than 14 days; (2) locoregional skin redness and swelling without ulceration; (3) drainage fluid remaining turbid for two consecutive days.

The Definition of Implant Failure

The skin overlying the prosthesis exhibited erythema, swelling, and ulceration, subsequently leading to prosthesis exposure. The ulcerated skin failed to heal spontaneously, and interventions have proven ineffective in achieving wound healing or preserving the prosthesis.

Quanti-Body Human Cytokine Examination and Quantitative Analysis

Each array needs 100 μL of total sample volume. To avoid matrix effects, we recommend using a minimum of 2× dilution for serum, plasma, cell culture media, or other body fluids, or 500 μg/mL-1 mg/mL (after a 5-fold to 10-fold dilution to minimize the effects of any detergent(s)) total protein for cell and tissue lysates. Please be aware, more sample volume is required for combination arrays. For example, the minimum sample volume for a 10-array kit is 500 μL, or 500 μg cell lysate. Upon receipt, all components should be stored at −20°C. The kit will retain activity for up to 6 months. Once thawed, the glass slide, standard mix, antibody cocktail and dye-conjugated Streptavidin should be kept at −20°C. All other components may be stored at 4°C. The entire kit should be used within 6 months of purchase.

Take out the glass slide from the box, and let it equilibrate to room temperature inside the sealed plastic bag for 20–30 minutes. Remove slide from the plastic bag, peel off the cover film, and let it air dry for another 1–2 hours. There is only one vial of standard provided in the two-slide kit, which is enough for making two standard curves. Reconstitute the lyophilized standard within one hour of usage. If you must use the standard for two different days, store only the Std1 dilution at −80°C. Reconstitute the Cytokine Standard Mix (lyophilized) by adding 500 μL Sample Diluent to the tube. For best recovery, always quick-spin vial prior to opening. Dissolve the powder thoroughly by a gentle mix. Labeled the tube as Std1. Label 6 clean microcentrifuge tubes as Std2 to Std7. Add 200 μL Sample Diluent to each of the tubes. Pipette 100 μL Std1 into tube Std2 and mix gently. Perform 5 more serial dilutions by adding 100 μL Std2 to tube Std3 and so on. Add 100 μL Sample Diluent to another tube labeled as CNTRL. Do not add standard cytokines or samples to the CNTRL tube, which will be used as negative control. For best results, include a set of standards in each slide. Add 100 μL Sample Diluent into each well and incubate at room temperature for 30 minutes to block slides. Decant buffer from each well. Add 100 μL standard cytokines or samples to each well. Incubate arrays at room temperature for 1–2 hour. Decant the samples from each well, and wash 5 times (5 min each) with 150 μL of 1× Wash Buffer I at room temperature with gentle rocking. Completely remove wash buffer in each wash step. Dilute 20× Wash Buffer I with H2O. Put the glass slide with frame into a box with 1× Wash Buffer I (cover the whole glass slide and frame with Wash Buffer I), and wash at room temperature with gentle rocking for 20 min. Decant the 1x Wash Buffer I from each well, wash 2 times (5 min each) with 150 μL of 1× Wash Buffer II at room temperature with gentle rocking. Completely remove wash buffer in each wash step. Dilute 20× Wash Buffer II with H_2O. Reconstitute the detection antibody by adding 1.4 mL of Sample Diluent to the tube. Spin briefly. Add 80 μL of the detection antibody cocktail to each well. Incubate at room temperature for 1–2 hour. After briefly spinning down, add 1.4 mL of Sample Diluent to Cy3 equivalent dye-conjugated streptavidin tube. Mix gently. Add 80 μL of Cy3 equivalent dye-conjugated streptavidin to each well. Cover the device with aluminum foil to avoid exposure to light or incubate in dark room. Incubate at room temperature for 1 hour. Decant the samples from each well, and wash 5 times (5 mins each) with 150 μL of 1× Wash Buffer I at room temperature with

gentle rocking. Completely remove wash buffer in each wash step. Disassemble the device by pushing clips outward from the slide side. Carefully remove the slide from the gasket. Place the slide in the Slide Washer/Dryer (a 4-slide holder/centrifuge tube), add enough 1× Wash Buffer I (about 30 mL) to cover the whole slide, and then gently shake at room temperature for 15 minutes. Decant Wash Buffer I. Wash with 1× Wash Buffer II (about 30 mL) and gently shake at room temperature for 5 minutes. Remove water droplets completely by gently applying suction with a pipette to remove water droplets. Do not touch the array, only the sides.

Quantibody Human Cytokine Image and Analysis

Imaging: The signals can be visualized through use of a laser scanner equipped with a Cy3 wavelength (green channel) such as Axon GenePix, or Innopsys Innoscan. Make sure that the signal from the well containing the highest standard concentration (Std1) receives the highest possible reading yet remains unsaturated. Data extraction can be done using the GAL file that is specific for this array along with the microarray analysis software (GenePix, ScanArray Express, ArrayVision, MicroVigene, etc). GAL files can be found here: https://www.RayBiotech.com/Gal-Files.html.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for Social Sciences, version 25.0 (SPSS, Chicago, USA). Continuous variables are expressed as means or medians and were compared using ANOVA and *t* tests according to the normality of data and the homogeneity of variance test. Categorical variables are expressed as proportions and were compared using the Chi-square and Fisher's exact tests. Two-sided P values < 0.05 were considered as significant.

Results

Patient Screening and Clinicopathological Information

Between December 2022 and March 2024, patients undergoing mastectomy with immediate implant-based reconstruction were recruited from the comprehensive breast care center of the second affiliated hospital of Xi-an Jiaotong University and the general surgery department at Beihuan Hospital. All patients who were subsequently recommended adjuvant radiotherapy received intraoperative Tiloop mesh. Of 301 cases meeting the inclusion criteria, the complete data were available for 232 patients, with drainage fluid specimens collected from 106 patients (Table S1). In our study, we excluded the patients with intraoperative skin injury due to the direct risk for implant expose or loss. All enrolled patients were female. Among them, 67 patients were under 45 years old, 62 were classified as overweight, 16 were smokers, 30 received postoperative radiotherapy and 70 received prepectoral implant reconstruction (Table S1).

Screening for Predictive Factors of Implant Failure

Previous studies had exhibited a bunch of risk factors that might contribute to breast implant failure, including obesity, diabetes, hypertension and excessively large breast volume.[8,10,13] However, no cytokine was reported to predict the implant failure of breast reconstruction. Our research aimed to identify the predictive factors of implant failure via analyzing drainage fluid. We selected 3 breast cancer patients receiving immediate implant reconstruction without implant loss (Group 1) and 3 breast cancer patients receiving immediate implant reconstruction with implant loss (Group 2), who between two groups were matched based on age, tumor stage, subtypes, operation time and disease history. The timing of drainage fluid collection was illustrated in Figure 1, with samples obtained at 24 hours postoperatively, immediately prior to drainage removal and at the time of implant exposure or loss. For patients in group 1, they were sampled at two time points (Figure 1). A high-throughput protein microarray was employed to detect over 400 cytokines in the drainage fluid (Figure 2A), spanning more than 80 signaling pathways (Figure 2B).

As an ideal predictive cytokine for implant loss, it was ought to satisfy several criteria. Firstly, in group 2, cytokine level in the drainage fluid at drainage removal exhibited a significant change relative to that at the time of 24 hours postoperatively. Secondly, cytokine level at drainage removal in the group 2 should resemble that at the time of implant failure. Thirdly, a significant difference in cytokine level at drainage removal should be evident between the group 1 and group 2. Based on these criteria, we employed a cytokine microarray to screen for candidate cytokines. In the implant

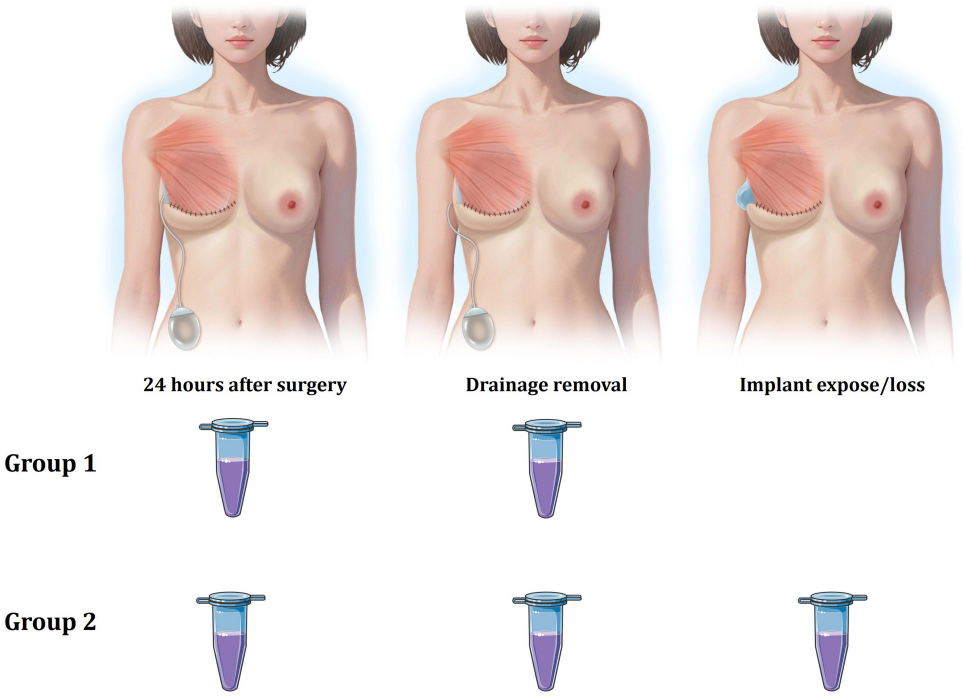

Figure 1 Schematic for drainage fluid samples in the group 1 and group 2.

loss group, we observed that 81 cytokines were significantly upregulated and 11 were significantly downregulated at drainage removal compared to 24 hours postoperatively (Table S2 and Figure 3A). Further analysis comparing these cytokine levels at drainage removal with those at the time of prosthesis failure identified 8 cytokines with similar expression patterns (Table S3). Ultimately, when directly comparing the cytokine levels at drainage removal between two groups, only intercellular adhesion molecule-1 (ICAM-1) was significantly upregulated in the group with prosthesis failure (Table S4 and Figure 3B), making it the single cytokine that fulfilled all three criteria. In summary, ICAM-1 might be the ideal cytokine identified in our study.

Population-Based Validation of Predictive Factors Associated with Prosthesis Failure

Our results indicated that postoperative 24-hour ICAM-1 expression level in group 1 was comparable to that in group 2 (Figure 4A), suggesting that postoperative 24-hour ICAM-1 expression did not differ in the group with or without prosthetic failure. Additionally, within group 2, ICAM-1 expression significantly increased at the time of drainage removal, reaching similar level to that observed at the time of prosthetic failure (Figure 4A). This observation further underscored the importance of assessing ICAM-1 expression at the time of drainage removal to predict prosthetic failure.

A total of 106 patients with breast cancer undergoing immediate prosthetic reconstruction were enrolled in this study. Among these, 68 patients who did not receive any intervention maintained intact samples, although 8 experienced implant failure (Figure 4B). We evaluated the expression levels of ICAM-1 in the drainage fluid of all patients prior to drainage removal (Figure 4C) and observed that 9 patients exhibited a significant elevation in ICAM-1 level, 8 of whom subsequently experienced implant failure. Further analysis of the specificity and sensitivity of ICAM-1 as a predictive marker, based on the receiver operating characteristic (ROC) curve, confirmed that ICAM-1 levels in the drainage fluid at the time of drainage removal served as a critical indicator of implant failure (Figure 4D). Additionally, the multivariate analysis demonstrated that elevated ICAM-1 level at drainage removal was significantly associated with implant failure (Figure 5). Based on these preliminary observations, we established a cut-off value of 15.0 IU/mL for ICAM-1 at drainage removal to predict implant failure. These findings had significant clinical implications and potential applications for breast cancer patients undergoing immediate implant-based breast reconstruction.

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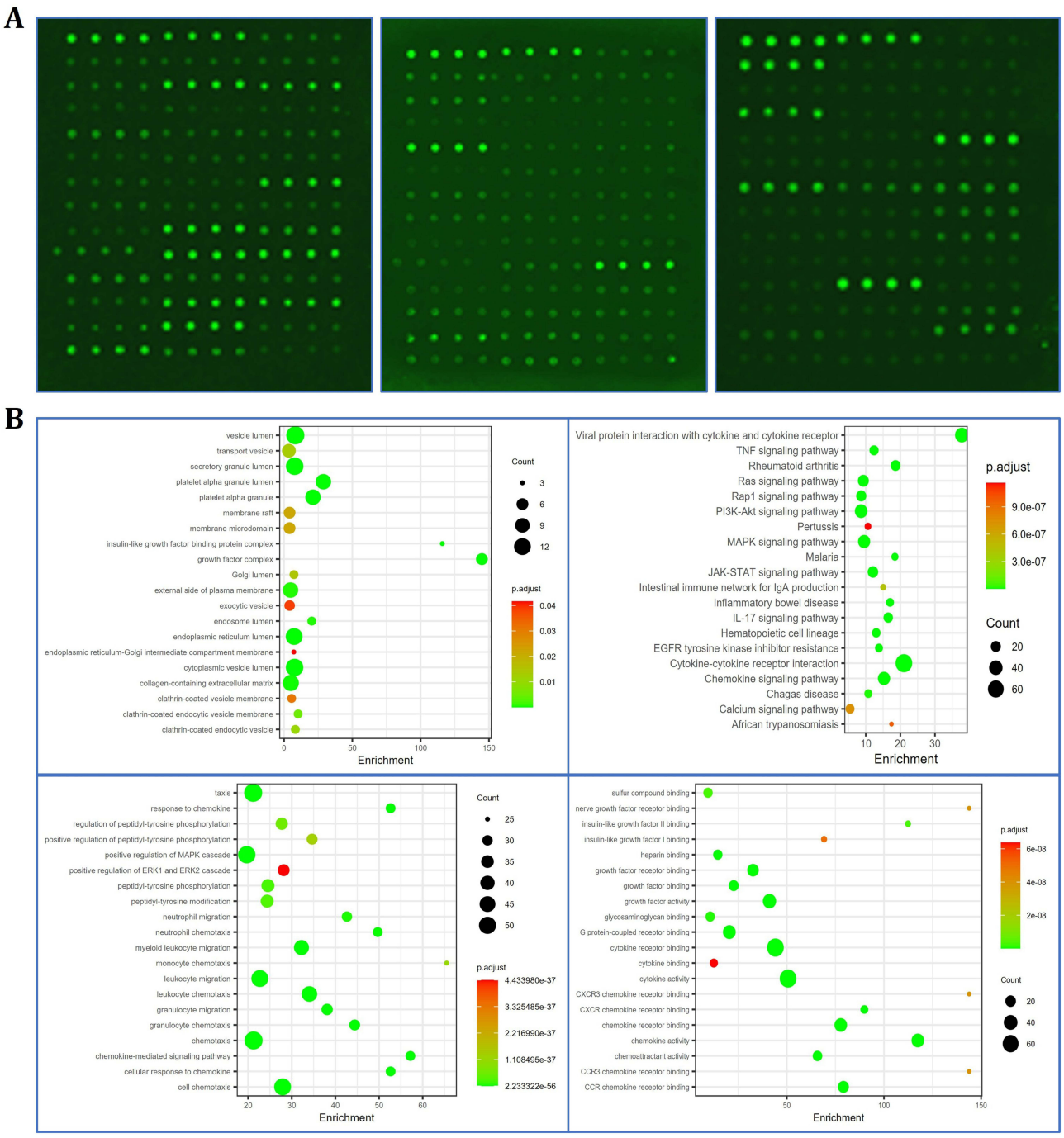

Figure 2 Cytokine chip analyzed the predictors for implant loss in the drainage fluid. (**A**) Cytokine chip analysis for the predictors for implant loss. (**B**) Signaling pathway involved in the cytokine chip.

The Preventive Effect of Intracavity Irrigation on Prosthetic Failure

We investigated previously reported risk factors for prosthetic failure, including obesity, diabetes, prosthesis size, and surgical approach.[8–10] However, we did not observe a strong association between these factors and prosthetic failure (Figure 5). By contrast, elevated level of ICAM-1 in the drainage fluid at the time of drainage removal was clearly associated with prosthetic failure (Figure 5). Although infection was generally considered a primary contributor to prosthetic failure,[14,15] routine bacterial cultures performed at drainage removal yielded 10 positive cases among the

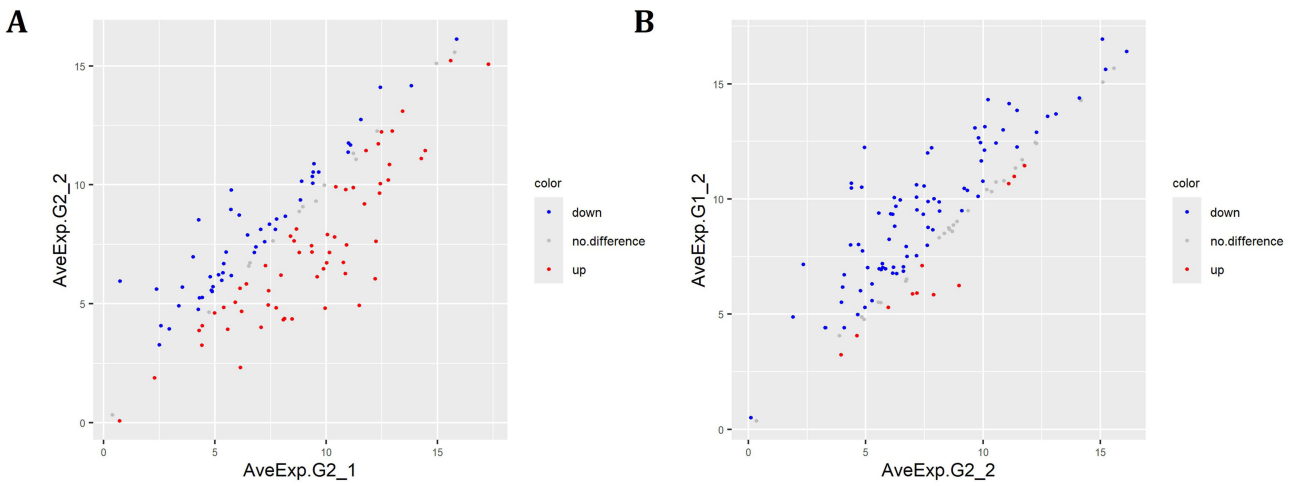

Figure 3 Cytokines difference in the drainage fluid. (**A**) Cytokines differences between drainage removal and 24 hours postoperatively in the group 2. (**B**) Cytokines differences between drainage removal in the group 2 and drainage removal in the group 1.

patients in our study (Figure 6A). Among these, Staphylococcus epidermidis was the most frequently isolated bacterium, accounting for 60% of culture-positive cases (Figure 6A). Following antibiotic treatment, the infections were resolved successfully, and no cases of prosthetic failure were observed (Figure 6A), suggesting that infection might not directly lead to prosthetic failure.

ICAM-1 plays a crucial role in leukocyte homing and human immunity, and it also serves as a key inflammatory molecule.[16,17] Dexamethasone is a widely used anti-inflammatory drug in clinical practice,[18,19] and we hypothesized that this molecule might ameliorate the elevation of ICAM-1 and reduce the risk of prosthetic failure. In our study, 38 patients who underwent intracavity irrigation of prosthesis were enrolled, and none of these patients experienced prosthesis loss (Figure 6B). It was noteworthy that ICAM-1 level decreased in all patients who received intracavity irrigation (Figure 6C). Among them, 28 patients had already exhibited ICAM-1 level reaching the threshold for prosthetic failure before irrigation. However, ICAM-1 level returned to normal level after irrigation, and no prosthesis failure occurred. These results indicated that dexamethasone irrigation could effectively prevent prosthetic failure.

Discussion

Recently, we have witnessed rapid advancements in the surgical management of breast cancer. BCS has been widely adopted in clinical practice due to the minimal invasiveness and favorable prognosis.[20,21] Nevertheless, 30–40% of breast cancer patients remain ineligible for BCS, leaving mastectomy as their primary treatment option. In China, nearly 50% of patients underwent the total mastectomy for prosthetic breast reconstruction.[22,23] This surgical approach was characterized as low risk, rapid recovery and excellent short-term cosmetic outcomes. All patients who underwent breast prosthetic reconstruction were at risk of prosthetic loss, which represented the most severe complication that both clinicians and patients should confront. Approximately 5% of patients with prosthetic reconstruction experienced prosthesis loss. Although meta-analyses have been conducted to synthesize the factors associated with prosthetic loss,[8–10,13,24,25] the definitive risk factors remained unclear.

Prosthesis failure is invariably accompanied by wound dehiscence or skin breakdown, and the fundamental cause of this outcome lies in skin or flap ischemia.[26,27] Currently, SPY Elite fluorescence angiography technique was available to visualize skin blood supply, enabling clinicians to detect early-stage ischemia of breast skin and resect the ischemic tissue during surgery.[28,29] However, this technique is currently limited in application due to high costs. In breast cancer patients undergoing immediate prosthetic reconstruction, the manifestations of skin ischemia were often delayed, posing significant challenges for postoperative management. Our team hypothesized that the drainage fluid from the breast prosthesis pocket might be the earliest indicator of skin ischemia. We aimed to use this fluid as a breakthrough to explore

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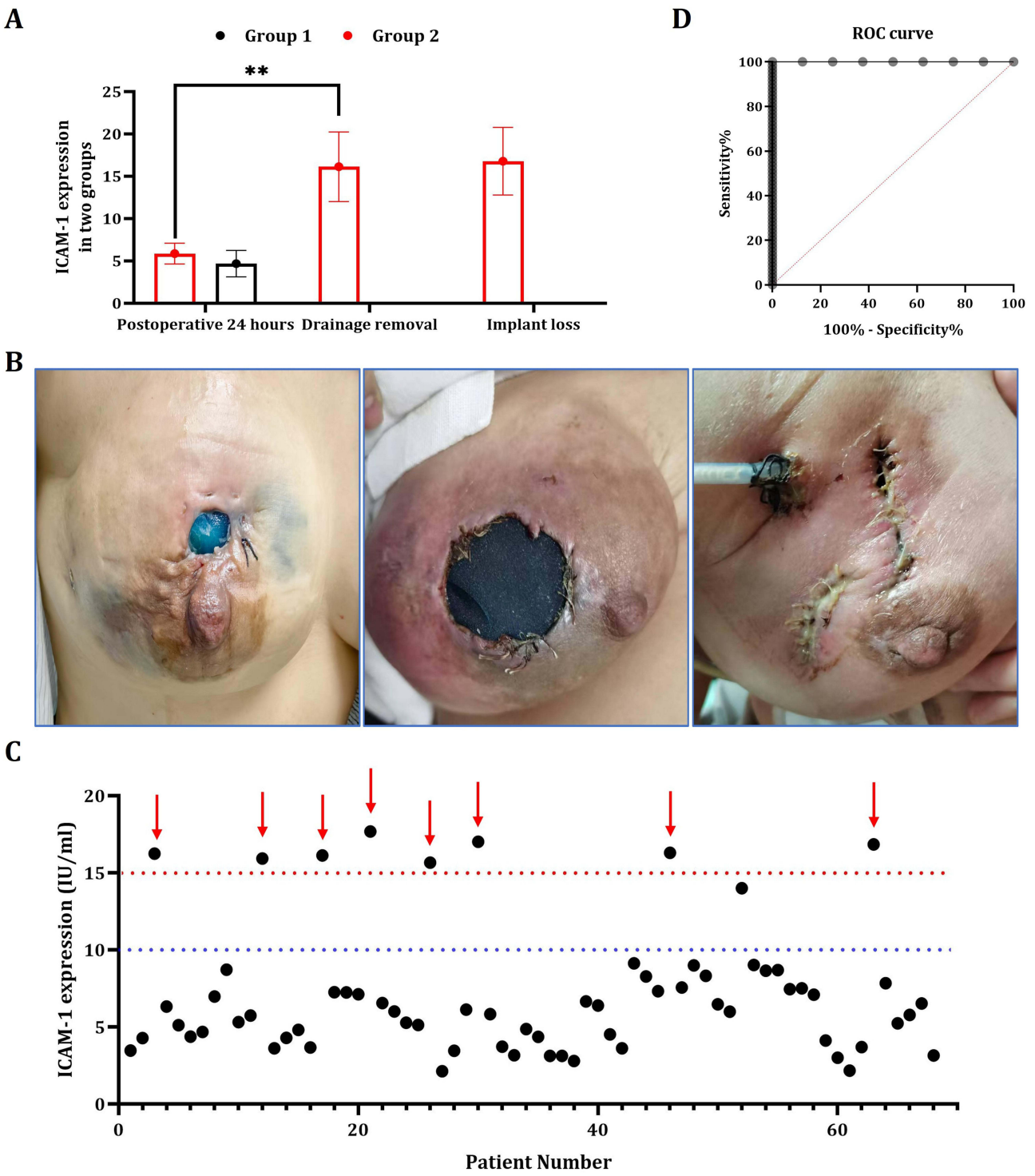

Figure 4 Population-based validation of predictive factors associated with prosthesis failure. (**A**) ICAM-1 expressions at different times as indicated in both two groups. $^{**}p < 0.01$. (**B**) Representative photos for patients with implant loss. (**C**) ICAM-1 expressions in the patients with breast cancer. The red arrows indicate the levels of ICAM-1 in the drainage fluid from the eight patients who experienced prosthesis failure. (**D**) ROC curve for the predictor of ICAM-1 for prosthesis failure at the time of drainage removal.

the mechanisms underlying prosthesis failure. We employed a protein microarray to detect over 400 factors and ultimately identified that ICAM-1 served as a predictive marker for prosthesis failure of breast reconstruction. Our study spanned nearly 2 years, with a final total of 8 prosthesis failure cases. This relatively low number was attributed to the low prosthesis failure rate at our center, which remained around 3%—in contrast to 5–8% commonly reported in the

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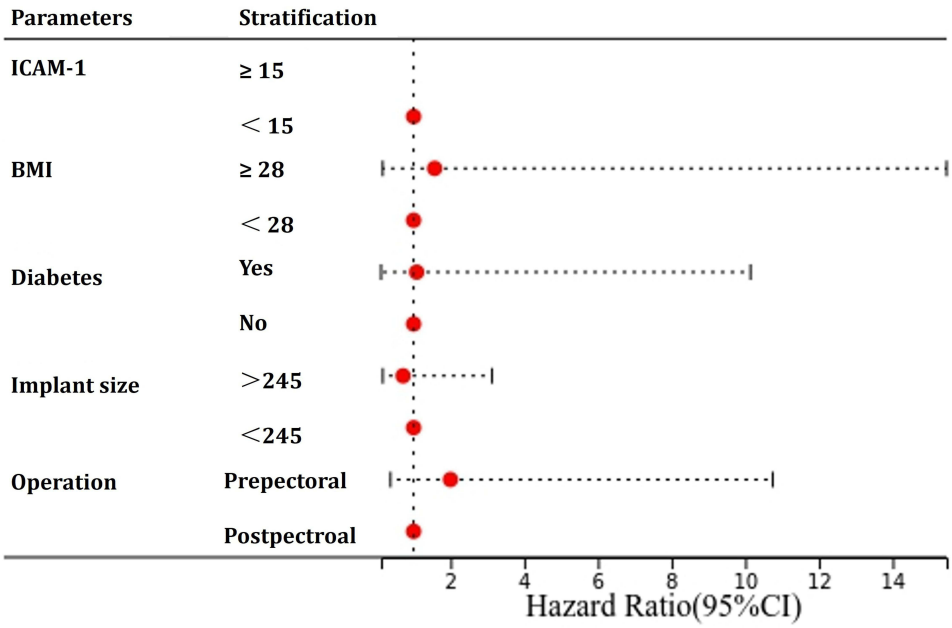

Figure 5 Multivariate analysis for the risk factors of breast implant failure.

literatures.[9,13] The primary reasons for this favorable outcome included the strict control of prosthetic indications and the rigorous adherence to standardized surgical procedures at our center.

ICAM-1 is a cell surface adhesion molecule that plays a crucial role in intercellular signal transduction, maintenance of cell tight junctions and leukocyte immune functions,[16,17,30,31] which is mainly expressed on the surface of endothelial cells, macrophages and neutrophils.[30,31] Its primary release mechanism was through direct cleavage, while a small number of studies have reported its release via exosomes. During wound healing and ischemic changes, ICAM-1 expression is upregulated in multiple cell types to mediate inflammatory responses.[30,31] Following breast implant placement, a capsule formed around the implant.[32] The inner layer of this capsule was rich in inflammatory cells, including macrophages and neutrophils.[32] These inflammatory cells secreted cytokines that stimulated the activation of myofibroblasts in the middle layer, which in turn secreted collagen—a process characterized as a chronic inflammatory response (Figure 7).[33] As an inflammatory mediator, ICAM-1 may be released into the drainage fluid (Figure 7). Our protein microarray analysis also detected the elevated levels of other inflammatory factors, such as IL-8, IL-6, and TNF-α. However, none of these showed a correlation with prosthesis failure. Dexamethasone was a widely used anti-inflammatory agent in clinical practice. It has been reported to inhibit ICAM-1 expression at the cellular level.[34] Our team was the early adopters of the prosthetic pocket dexamethasone irrigation for patients with suspected flap ischemia, and promising outcomes were observed. According to our findings: 28 patients had ICAM-1 level indicative of impending prosthesis failure before irrigation. After intra-pocket irrigation, ICAM-1 levels returned to normal and no prosthesis loss was required. This not only confirmed that ICAM-1 was a key predictive marker for prosthesis failure but also led us to propose a corresponding solution. When administered via non-intravenous routes (such as local irrigation), dexamethasone exhibited minimal side effects.

Compared with previous studies,[35] our research did not focus on the expression of cytokines in drainage fluid. Instead, it centered on the correlation between cytokine levels in drainage fluid and implant failure. The small cohort size of this study was primarily attributable to the limited number of eligible patients, which resulted from the significant improvement in flap ischemia with the advancement of surgical techniques. The data from this study preliminarily confirmed the potential of ICAM-1 as a predictive factor for breast implant failure.

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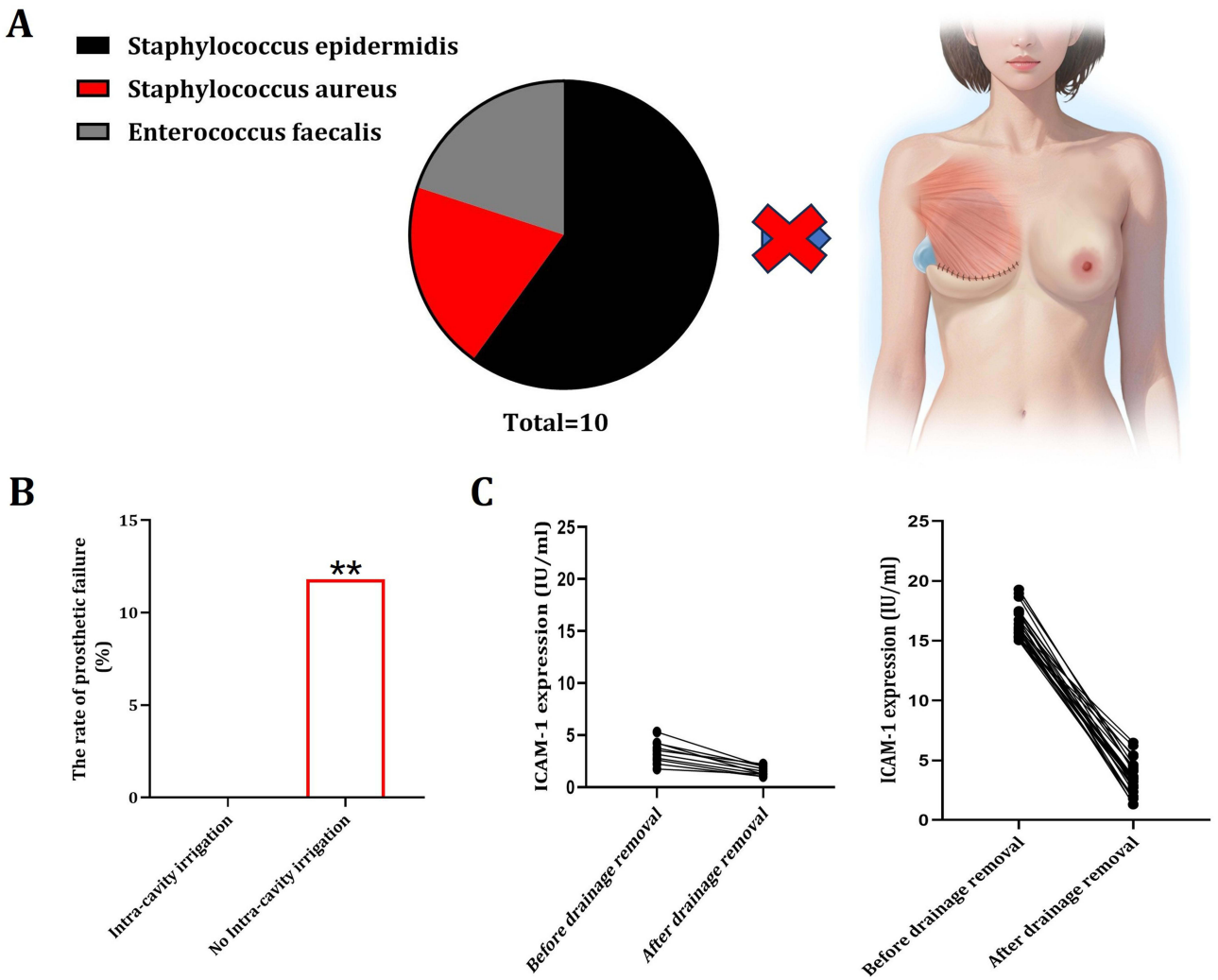

Figure 6 The preventive effect of intracavity irrigation on prosthetic failure. (**A**) Infection in the drainage fluid was unequal to implant failure. (**B**) The prosthetic failure rate of breast cancer patients with or without intracavity irrigation. $^{**}p < 0.01$. (**C**) ICAM-1 in the drainage fluid before and after intracavity irrigation.

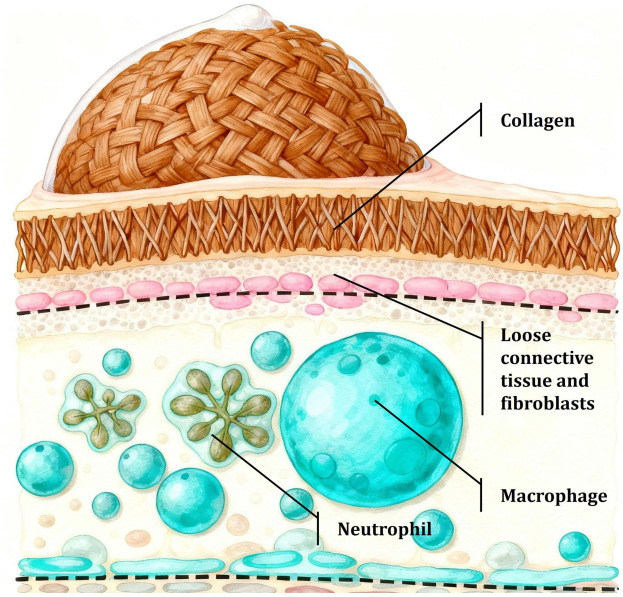

Figure 7 The diagrammatic hypothesis of this subject.

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Conclusion

This study demonstrates that intercellular adhesion molecule-1 (ICAM-1) in prosthetic pocket drainage fluid may serve as a potential early predictive biomarker for implant failure following immediate breast reconstruction in breast cancer patients. Our findings suggest that local inflammatory activation precedes clinically evident flap ischemia and wound complications, thereby providing a critical window for early intervention. Furthermore, postoperative intrapocket dexamethasone irrigation in high-risk patients with elevated ICAM-1 levels effectively reduced ICAM-1 expression and successfully prevented prosthesis loss, indicating that localized dexamethasone irrigation may represent an effective salvage strategy for impending implant failure.

Owing to the extremely low incidence of implant failure, the number of failure events and the cohort size for target factor screening were limited, and no external validation cohort was available, which may introduce selection bias. Despite these limitations, our study provides preliminary evidence supporting ICAM-1 as a predictive marker for prosthesis failure and proposes a corresponding clinical intervention. Future multicenter prospective studies are warranted to validate these findings and establish standardized protocols, thereby facilitating earlier and more precise perioperative management in breast reconstruction.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki. The procedures of this study were approved by the ethics committee of the second affiliated hospital of Xi'an Jiaotong University (Ethics Code: 2025LL100). Informed consent was obtained from the participants following a briefing on the study objectives, granting access to their medical records.

Consent for Publication

All authors consent for publication. Consent forms have been signed.

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A lot of thanks for AI software Doubao for translation from Chinese to English and modify our figures. A lot of thanks for Pingan Zhang who was our researcher and required for anonymity.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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