Application of a simple skin flap to repair large defects in a patient with radiotherapy-induced skin squamous cell carcinoma after breast cancer surgery: A case report

YUE-YUE TENG[1,2], SHENG-CHAO HUANG[1,2], PU QIU[1,2], ZE-MING YAN[1,2], CHUN-YAN CHEN[2], MIAO YU[2], ZHONG-ZENG LIANG[1,2], JIAN-WEN LI[1,2] and YUAN-QI ZHANG[1,2]

[1]The First School of Clinical Medicine, Guangdong Medical University, Zhanjiang, Guangdong 524000, P.R. China; [2]Department of Vascular-Thyroid-Breast Surgery, Affiliated Hospital of Guangdong Medical University, Zhanjiang, Guangdong 524000, P.R. China

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Abstract. Radiotherapy is a leading treatment intervention for cancer and has been shown to improve the prognosis of patients with malignant tumors. However, there are several side effects associated with radiotherapy that require attention. The present case study describes the case of a patient who underwent breast-conserving surgery after receiving a diagnosis of right-sided breast cancer, following which they received conventional radiation therapy. A skin nodule was found on the right side of the breast 3 years later, which was pathologically confirmed to be a highly differentiated skin squamous cell carcinoma after surgical local excision. The patient presented with poor skin healing 2 months after the operation, and a myocutaneous flap of the descending branches of the thoracodorsal vessels was used to repair the defect and improve the breast shape. Although skin cancer induced by radiotherapy is relatively rare, physicians should remain cautious when treating skin injuries after radiotherapy, and recovery should be closely monitored. For patients with skin nodules after radiotherapy, a biopsy should be performed as early as possible to clarify the diagnosis and to develop appropriate treatment programs. For such skin cancer patients who have received radiotherapy in the past, it is necessary to consider the potential radiotherapy-related skin injuries they may have suffered after previous radiotherapy, the skin flap should be comprehensively evaluated before the operation and an appropriate surgical method should be selected to reduce the necessity of a second operation.

Correspondence to: Dr Yuan-Qi Zhang, Department of Vascular-Thyroid-Breast Surgery, Affiliated Hospital of Guangdong Medical University, 57 Renmin Avenue South, Xiashan, Zhanjiang, Guangdong 524000, P.R. China
E-mail: 31428319@qq.com

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Introduction

Breast cancer is globally the most common cancer among women (1), and existing treatments mainly include surgery, chemotherapy, endocrine therapy, targeted therapy and radiotherapy. Radiotherapy is typically administered to patients who have undergone breast conserving surgery, those with lymph node metastasis and those who possess large (≥5 cm) masses (2). Radiotherapy induces double-stranded DNA breaks through ionizing radiation, and as healthy cells have a stronger DNA repair ability, radiotherapy typically targets and kills tumor cells (3). Although radiotherapy significantly improves the prognosis of patients with malignant tumors, exposure to radiation damages the skin. Radiation-induced skin injury (RSI) is divided into two types: i) Acute RSI with skin desquamation, necrosis, ulceration and hemorrhage; and ii) chronic RSI with chronic ulceration, radiation-induced keratosis pilaris, capillary dilatation, fibrosis and skin cancer (4). Radiation-induced non-melanoma skin cancer (NMSC) occurs more frequently in patients undergoing radiotherapy on the face, neck and head, while skin cancer induced by postoperative radiotherapy for related breast cancers is rare (5). In addition, RSI is described as latent, progressive and persistent, and usually causes irreversible damage to the microvessels and vascular endothelial cells in the skin. Specifically, radiation-associated fibrosis damages the lymphatic vessels and blood vessels in the irradiated area, which can lead to skin ulcers and difficulties in wound healing. It has been reported that 30% of patients who receive radiotherapy to the breast or chest wall will develop severe skin fibrosis (6). Patients with breast cancer who undergo breast conserving surgery typically require postoperative radiotherapy, which often results in side effects that also affect the postoperative aesthetics of the patient. The present case report describes the case of a patient with squamous cell carcinoma (SCC) of the skin induced after postoperative radiotherapy for breast cancer (Fig. 1), and discusses the causes and solutions to the postoperative wound healing difficulties for skin cancer.

Case report

Patient. A 43-year-old woman noticed a palpable nodule at the 9 o'clock position on the right breast in January 2020. In March

2020, the patient sought medical attention at the Affiliated Hospital of Guangdong Medical University (Zhanjiang, Guangdong, China), where a breast core needle biopsy was performed, revealing ductal carcinoma *in situ* (DCIS) of the right breast (the pathological findings revealed cells with irregular nuclear size and shape, increased chromatin, and the presence of cancer cells within the mammary ducts; Fig. 2A), with focal invasion suspected. After 5 days, the patient underwent simultaneous breast-conserving surgery for right-sided breast cancer and a right axillary sentinel lymph node biopsy.

The results of the postoperative pathology led to a diagnosis of invasive carcinoma of the right breast with ductal carcinoma *in situ*, with the diameter of the invasive lesion being 0.5 cm and no metastasis present in the sentinel lymph nodes (0/6). The immunohistochemistry (IHC) results were as follows: Estrogen receptor (ER) (no expression in the invasive carcinoma and carcinoma *in situ*), progesterone receptor (PR) (no expression in the invasive carcinoma and carcinoma *in situ*), human epidermal growth factor receptor 2 (HER2) (3+) and Ki-67 (50% in the carcinoma *in situ* and 60% in the invasive carcinoma). The patient was diagnosed with right breast invasive carcinoma with ductal carcinoma *in situ* [pT1N0M0 stage IA with HER2 overexpression, according to the Eighth Edition of the AJCC Cancer Staging Manual: Breast Cancer (7)] at 6 days post-surgery. Based on the postoperative pathology, the patient had indications for both chemotherapy and targeted therapy. After surgery, the patient received chemotherapy and targeted therapy, including 4 cycles of 110 mg docetaxel and 900 mg cyclophosphamide, plus trastuzumab (initially 8 mg/kg, then 6 mg/kg from the second cycle for the follow-up) every 21 days for 1 year.

According to the Chinese Society of Clinical Oncology Breast Cancer diagnosis and treatment guidelines (2), patients who undergo breast-conserving surgery require postoperative radiotherapy. The radiotherapy modality for this patient was volumetric modulated arc therapy. The patient received radiotherapy in July 2020 according to the following scheme: Planning target volume (PTV), 5,000 cGy/25 fractions/5 weeks; PTVboost, 6,000 cGy/25 fractions/5 weeks (subsequent skin cancer appeared in the PTVboost area). The patient presented with erythema, dry flaky skin and a small amount of wet flaking skin [grade 2; in accordance with the grading system developed by The Radiation Therapy Oncology Group and The European Organization for Research and Treatment of Cancer (8)] after radiotherapy, and was instructed to keep their skin dry, protect it from light and prevent friction. At 3 months post-radiotherapy, the skin erythema had resolved, and the skin was only slightly dry, with no dry or wet flaking observed. All treatments for the patient were completed at the Affiliated Hospital of Guangdong Medical University. After the completion of treatment, the patient did not require any additional special treatment and only needed regular follow-up examinations. Follow-ups were conducted every 3 months in the first and second years, and every 6 months from the third year onward. No abnormalities were detected during the follow-up period from March 2020 to July 2023.

At a total of 3 years post-surgery, the patient complained of a skin nodule at the right breast scar, which was noticed while taking a shower in July 2023, with no obvious triggers. This condition persisted for 2 months. The surface of the skin nodule was initially ulcerated and then gradually crusted over. During this period, the patient did not visit the hospital for medical care, nor was any treatment administered. In September 2023, breast ultrasonography at the Affiliated Hospital of Guangdong Medical University showed an isoechoic nodule in the right breast at the 9 o'clock direction of the surgical scar, measuring ~1.1x0.9 cm in size [breast imaging-reporting and data system class 4B, according to the second edition of the American College of Radiology BI-RADS US (9); Fig. 2B]. There were no signs of local or distant metastases in the head magnetic resonance imaging scans (Fig. 2C), or the chest (Fig. 2D) and upper abdomen (Fig. 2E) enhanced computed tomography scans.

Physical examination results. A round raised nodule was observed at the scar in the right breast, measuring ~1.1x0.9 cm in size with a hard texture and unclear boundary. The nodule presented as a central black scab with a dark red periphery, with no breakage or bleeding. There was a hard texture to the surrounding skin and soft tissues, poor mobility and no sense of tenderness. No obvious enlarged lymph nodes were detected in the right axilla and the upper and lower fossae of the clavicle (Fig. 2F).

Course of treatment and postoperative pathology. In September 2023, the patient underwent excision and biopsy of the right breast skin nodule due to the possibility of breast cancer recurrence, which could not be ruled out. During the operation, the nodule and surrounding 1 cm of skin tissue were removed. The intraoperative frozen-section examination showed that the right breast skin had focal ulcer formation, squamous epithelial hyperplasia and inflammatory cell infiltration. The results of the postoperative routine pathology were as follows (Fig. 3A and B): The right breast nodule was formed of skin tissue and the formation of a necrotic ulcer was observed locally; the peripheral squamous epithelium had significant hyperplasia with keratinization, and some of the epithelium was scattered within the stroma. The results of the IHC were as follows (Figs. 3 and 4): Insulin-like growth factor 2 mRNA-binding protein 3 IMP3(partial+), Ki-67(~30%), tumor protein p53 (wild-type expression), tumor protein p63(+), cytokeratin (CK)(+), CK5/6(+) and HER2(-). The combination of these results were consistent with highly differentiated SCC, the surgical horizontal resection margins and basal margins are negative. The postoperative diagnosis was a follows: i) Skin SCC of the right breast (pT1N0M0 stage I); and ii) after breast conserving surgery for right breast cancer (pT1N0M0 stage IA HER2 overexpression type).

In November 2023, the patient identified an ulcer located at the scar after the excision of the right breast skin nodule (Fig. 4E), measuring ~2x1 cm in size, that secreted a foul-smelling purulent fluid, with red, swollen and painful surrounding skin. A skin biopsy (H&E staining) indicated that the surface epithelium of the submitted skin tissue was hyperplastic with hyperkeratosis, parakeratosis, and local inflammatory exudation and necrosis (Fig. 4F). Considering that conservative treatment of this ulcer is not effective, a partial mastectomy of the right breast, an excision of the descending branch of the thoracodorsal vasculature

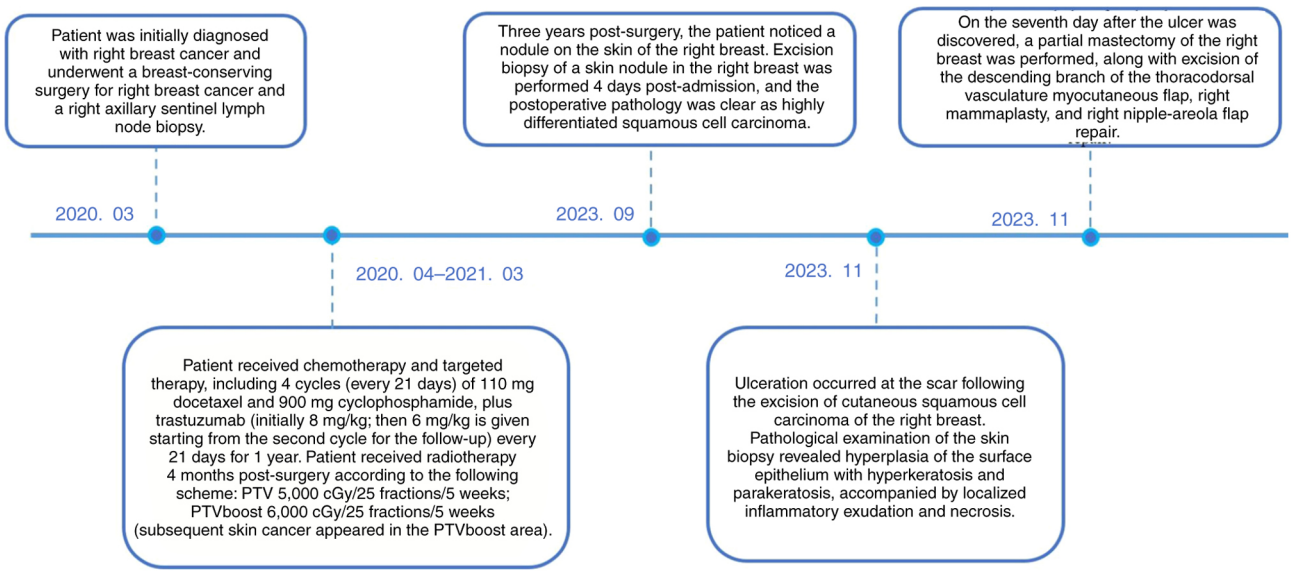

Figure 1. Timeline of patient treatment.

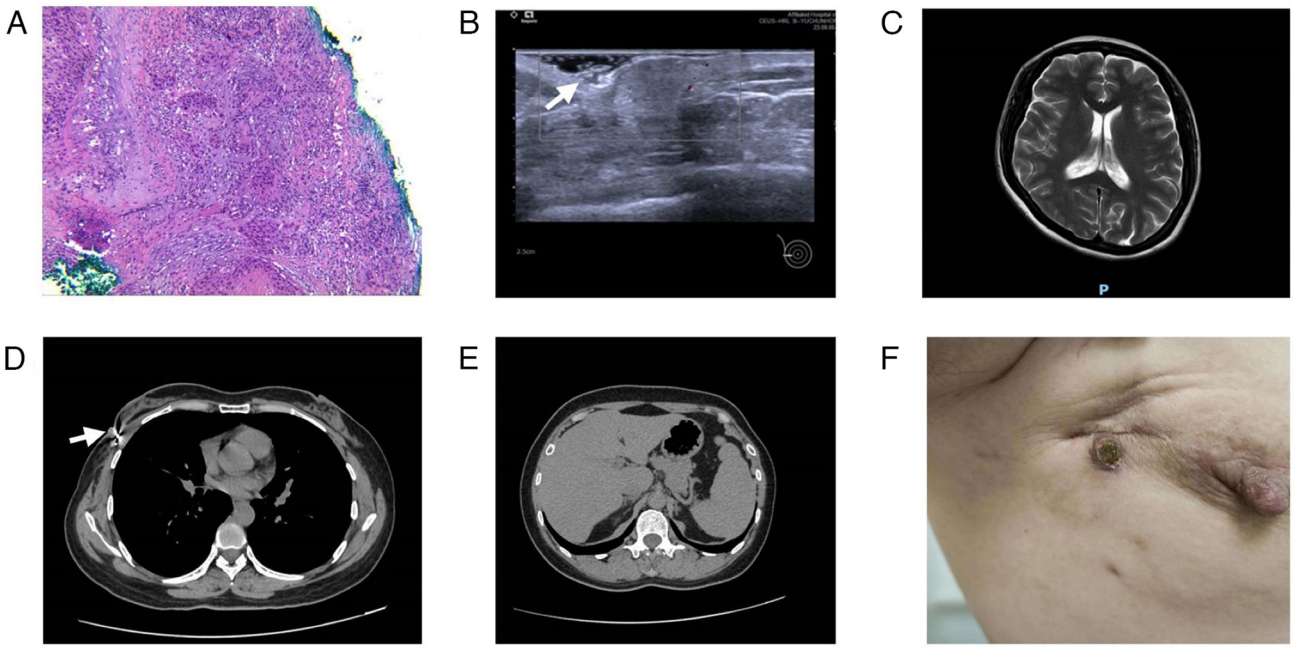

Figure 2. Pathological findings from the initial diagnosis of breast cancer and preoperative imaging results of skin cancer. (A) Breast core needle biopsy pathology (magnification, x100; H&E staining). (B) Ultrasound image of the nodule at the 9 o'clock position in the right breast. (C) Head magnetic resonance imaging. (D) Chest computed tomography (arrow indicates the location of the nodule, and the adjacent highlighted shadow is a titanium clip placed during the previous breast-conserving surgery to mark the tumor bed for radiotherapy planning). (E) Upper abdominal computed tomography. (F) Skin nodule in the right breast.

myocutaneous flap, a right mammaplasty and a right nipple areola flap repair were performed 6 days after the patient was admitted. The postoperative pathology demonstrated that: i) The right breast skin ulcer had formed accompanied by local tissue necrosis of the skin, hyaline degeneration and inflammatory cell infiltration of the surrounding stroma, and that large hyperchromatic deformed cells were observed in local areas (Fig. 5A and B); ii) no tumor was found in the upper, lower, inner, basal or incisional margin tissues of the right breast submitted for examination during the operation (Fig. 5C); and iii) reactive hyperplasia was observed in one lymph node that was sent for examination (Fig. 5D).

Surgical methods. Prior to the operation, the size of the skin ulcer surface at the 9 o'clock position on the right chest wall, the scar tissue area around it and the fibrotic tissue after radiotherapy were measured. A color Doppler ultrasound was used to locate the position of the thoracodorsal vessels, and the location of the descending branch flap of the thoracodorsal

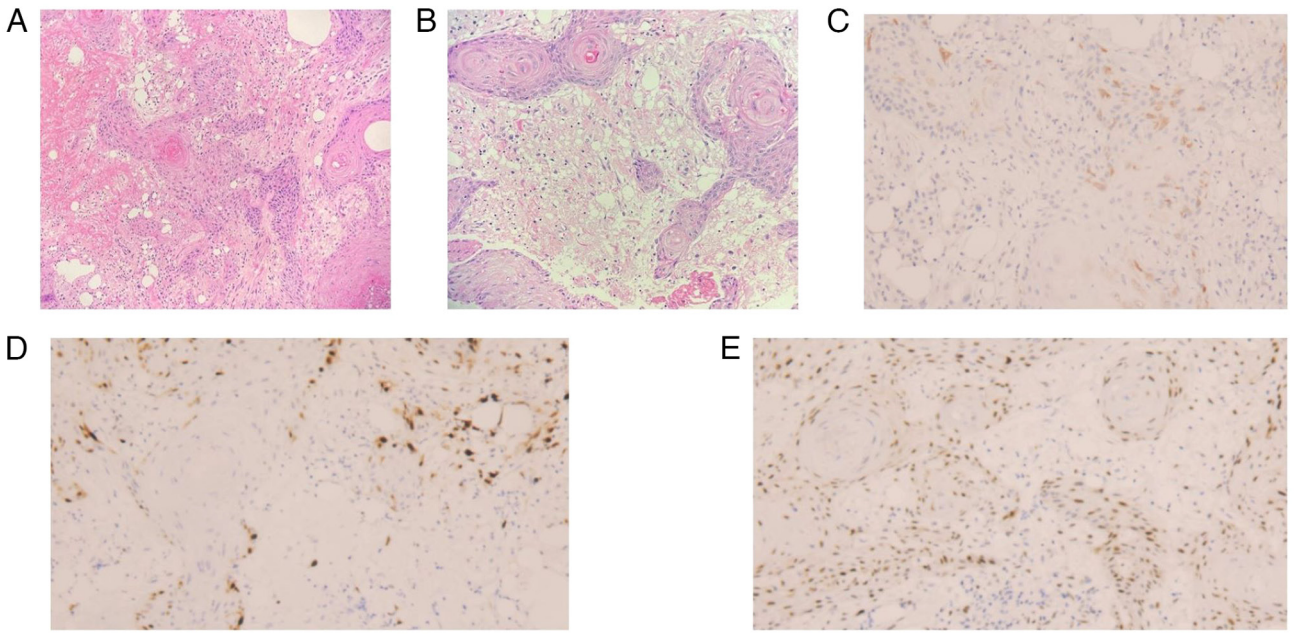

Figure 3. Pathological findings of SCC and results of the immunohistochemistry analysis (magnification, x100). (A and B) Pathology of SCC of the skin at (A) x40 and (B) x100 magnification (H&E staining). (C) Insulin-like growth factor 2 mRNA-binding protein 3 IMP3(partial+). (D) Ki-67(~30%). (E) Tumor protein p53 (wild-type expression). SCC, squamous cell carcinoma.

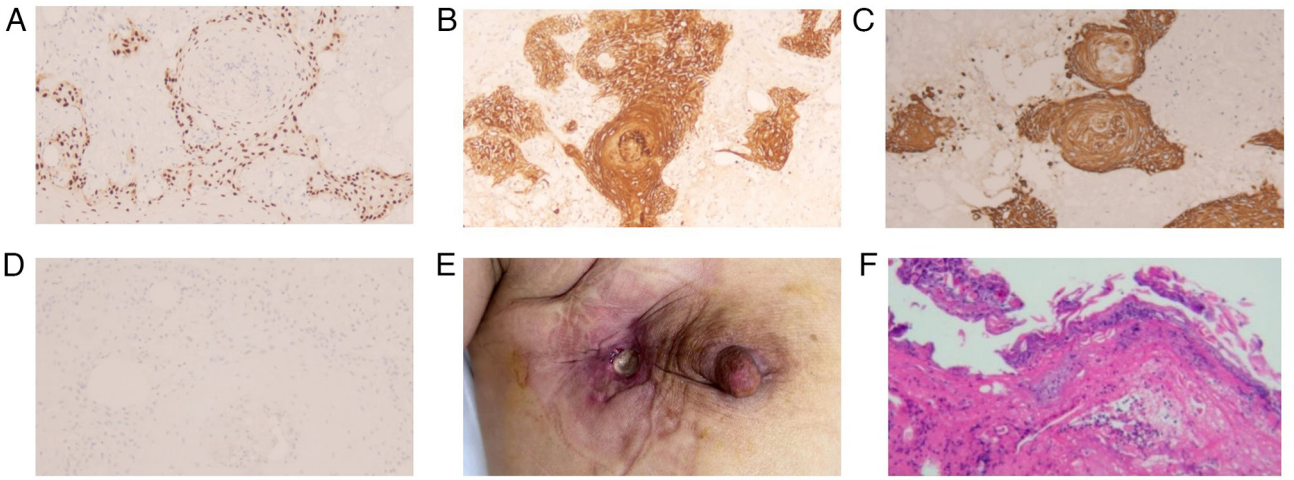

Figure 4. Immunohistochemistry results of skin cancer, poor postoperative wound healing and pathological biopsy of the wound. (A) Tumor protein p63(+), (B) CK(+), (C) CK5/6(+) and (D) HER2(-). (E) Breast image at 57 days post-excision of skin squamous cell carcinoma. (F) Skin biopsy pathology of the ulcer (magnification, x100; H&E staining).

vessels was used as a horizontal axis. A section ~10 cm below the axillary fold on the right chest wall area was used as a fusiform flap with a length of ~11 cm and a width of ~5 cm (Fig. 6A). After demarcation, attention was paid to the tension of the flaps on both sides to avoid the occurrence of skin flap necrosis due to excessive tension.

Before the operation, gentian violet was used to demarcate the incision range on the skin, that is, an oval incision centered on the ulceration. The extent of the excision included breast tissue and scar tissue in the outer quadrant of the breast, including part of the chest muscle, measuring 5x8 cm.After the incision, the remaining necrotic tissue and deep surface underwent debridement, and the bleeding tissue was exposed without abnormality (Fig. 6B).

Subsequently, the thoracodorsal vascular muscle flap was separated as follows: i) The skin and subcutaneous tissues were incised sequentially along the preoperative right lateral thoracic wall to the surface of the latissimus dorsi muscle. ii) the main trunk of the thoracodorsal vessels was exposed after exploration, and then the descending branches of the thoracodorsal vessels were found along its course. The surrounding tissues and small branch vessels were separated, paying attention to the position of the thoracodorsal nerves during the process to avoid injury. iii) The flap of the descending branch of the thoracodorsal vessels and a small portion of the latissimus dorsi muscle were separated together, and after separation, indocyanine green was injected intravenously to clarify the flap blood flow (Indocyanine Green Fluorescence Imaging

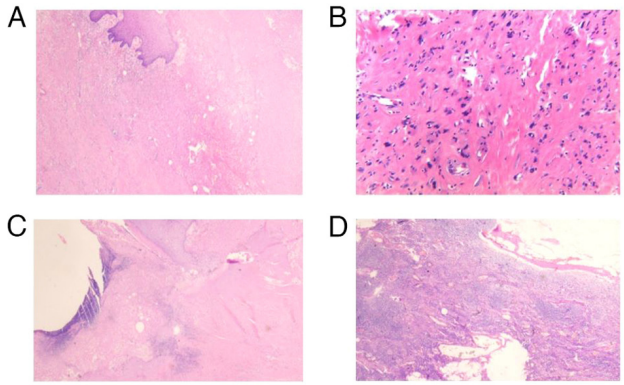

Figure 5. Pathological findings after partial mastectomy of the right breast (H&E staining). (A) Right breast skin ulcer, accompanied by local tissue necrosis of the skin (magnification, x40). (B) A large number of hyperchromatic and deformed cells are observed in local areas (magnification, x100). (C) No carcinoma is visible at the margins (magnification, x40). (D) The lymph node shows reactive hyperplasia (magnification, x40).

System; Fig. 6C and D). A suitable subcutaneous tunnel was made between the breast remnant cavity and the lateral descending thoracodorsal vascular muscle flap. The size of this tunnel was large enough to avoid vascular distortion and compression (Fig. 6E). The free descending thoracodorsal vascular flap was transferred to the breast remnant cavity and then the flap was plasticized and cut according to the trauma. The flap was fixed on the right side of the breast defect by absorptive suture and the retained flap was sutured with the skin to reshape the breast (Fig. 6F).

Post-operative follow-up. At the 6-month postoperative follow-up in May 2024, the patient exhibited successful wound healing of the flap and did not complain of discomfort. The flap showed no signs of hyperpigmentation or edema (Fig. 7). The patient's last follow-up was in December 2024, and no new tumors were found during the examination.

H&E staining and immunohistochemistry (IHC). Samples were fixed in 10% neutral buffered formalin at room temperature for 12 h. After tissue dehydration and clearing, the samples were immersed in melted paraffin at 60˚C twice, each for 1 h. Sections were cut to 5 μm, dewaxed and subjected to H&E staining. H&E staining were performed at room temperature for 5 min, and the slides were observed under an optical microscope.

For IHC, the following primary antibodies were applied: Anti-ER (ready-to-use antibody; catalog no.: 790-4324; incubation for 32 min; Roche Diagnostics GmbH), anti-PR (ready-to-use antibody; catalog no. 790-2223; incubation for 24 min; Roche Diagnostics GmbH), anti-HER2 (ready-to-use antibody; catalog no. 790-2991; incubation for 8 min; Roche Diagnostics GmbH), anti-IMP3 (dilution, 1:100; catalog no. MAB-0725; incubation for 40 min; Fuzhou Maixin Biotechnology Development Co., Ltd.), anti-Ki-67 (ready-to-use antibody; catalog no. 790-4286; incubation for 16 min; Roche Diagnostics GmbH), anti-p53 (ready-to-use antibody; catalog no. 790-2912; incubation for 32 min; Roche Diagnostics GmbH), anti-p63 (dilution, 1:150; catalog no. MAB-0674; incubation for 32 min; Fuzhou Maixin Biotechnology Development Co., Ltd.), CK (dilution, 1:100; catalog no. A1901; incubation for 30 min; Guangzhou LBP Medicine Science & Technology Co.,Ltd.) and CK5/6 (dilution, 1:150; catalog no. MAB-0692; incubation for 36 min; Fuzhou Maixin Biotechnology Development Co., Ltd.). The incubations were performed on the Roche Ventana automated IHC platform at 36˚C. Subsequently, the secondary antibody from the UltraView Universal DAB Detection Kit (ready-to-use; catalog no. 760-500; Roche Diagnostics GmbH) was automatically incubated using the Ventana platform for 8 min. Streptavidin-HRP (ready-to-use; catalog no. 760-500; Roche Diagnostics GmbH) was added and automatically incubated on the Ventana platform for 10 min. 3,3'-Diaminobenzidine (ready-to-use; catalog no. 760-700; Roche Diagnostics GmbH) was used as the chromogenic substrate and automatically developed on the Ventana platform for 8 min. Finally, the nuclei were counterstained with hematoxylin for 30 sec, and the slides were observed under an optical microscope (Olympus Corporation).

Discussion

The pathogenesis of cutaneous SCC (cSCC) mainly includes ultraviolet radiation, human papilloma infection, TP53 gene mutation, chronic scarring, transplantation-related immunity, ionizing radiation and low-dose arsenic exposure. Among them, prolonged ultraviolet radiation is the most common pathogenesis of cSCC, which is mainly found in exposed areas such as the scalp, face and backs of the hands (10).

In the present case, the diagnosis of the patient needed to be differentiated from other diseases. Firstly, the patient did not have a history of long-term ultraviolet (UV) radiation exposure on the chest wall, an area that is less exposed to UV radiation compared with other parts of the body. Therefore, the likelihood of primary cSCC occurring at this location was low. Additionally, the patient had a clear history of radiotherapy and presented with post-radiation skin fibrosis, which further supported the exclusion of primary cSCC. Secondly, the patient had a previous history of breast cancer. When the skin nodule was first detected, the possibility of breast cancer recurrence or metastasis could not initially be ruled out. However, based on the postoperative pathological findings, the tumor cells were arranged in nests or sheets with the presence of keratin pearls. IHC showed positive expression of CK5/6 and p63, indicating a squamous cell origin, which is inconsistent with the pathological features of breast cancer. Additionally, breast cancer recurrence or metastasis is often accompanied by other metastatic lesions, but no other abnormalities were found in the patient's examination results. Therefore, the possibility of breast cancer recurrence or metastasis was ruled out. Thirdly, the patient developed SCC of the skin in the irradiated area 3 years after radiotherapy, and it is noteworthy that this nodule was located in a scar. Cases of malignant transformation of scar tissue have been previously reported (11) and this condition is termed a Marjolin ulcer (MU) (12). In patients with MU, the primary cause of skin SCC is due to recurrent ulceration and persistent irritation of a non-healing wound. MU therefore often occurs in post-burn scarring and is often more aggressive, with research results showing that 20-36% of patients have lymph node metastasis at the time of initial

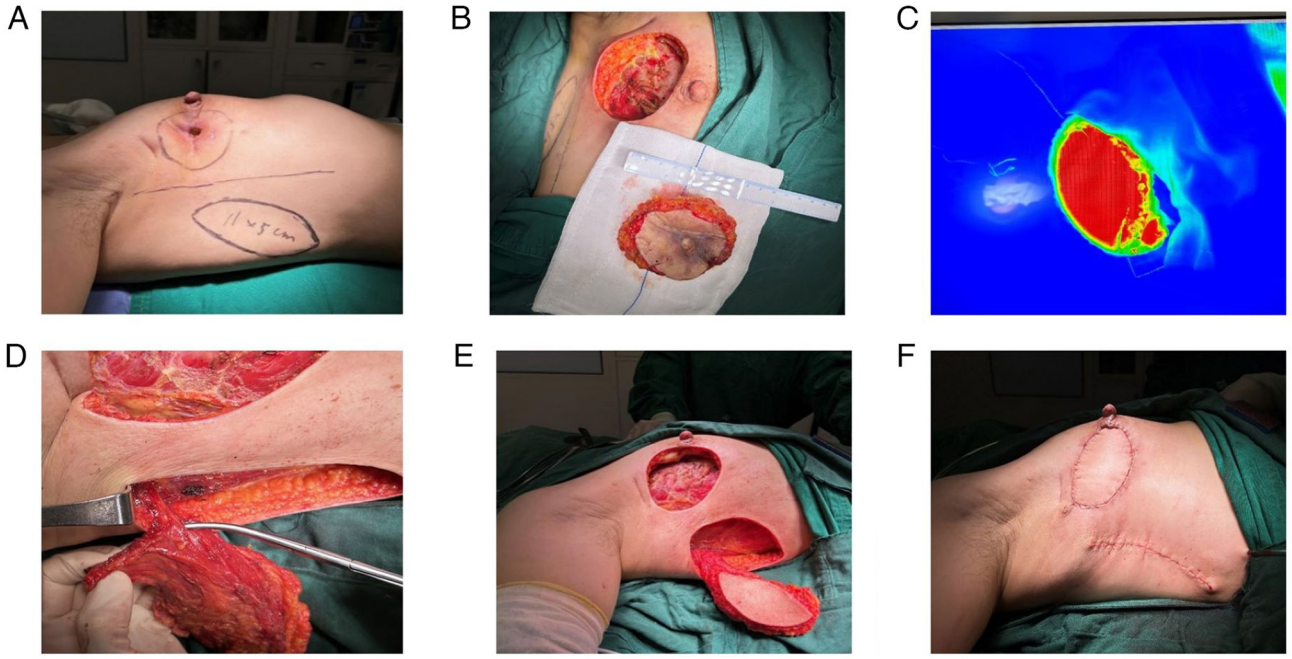

Figure 6. Surgical methods. (A) Preoperative flap design. (B) After partial excision of the right breast. (C) Intraoperative indocyanine green visualization of the flap with good blood flow (Indocyanine Green Fluorescence Imaging System). (D) Intraoperative position of the descending branches of the thoracodorsal vessels. (E) Flap acquisition. (F) Flap molding.

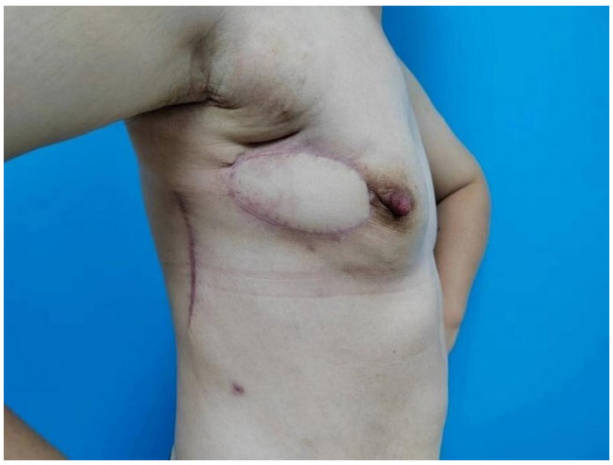

Figure 7. Physical appearance of the patient at 6 months post-surgery.

diagnosis (13). The clinical presentation of the present study patient was similar to that of MU. However, the patient did not present with ulceration or poor healing of the scar after postoperative radiotherapy. The patient's skin cancer was a well-differentiated cSCC without regional lymph node metastasis, which differs from the pathological characteristics of MU. In addition, the skin nodule initially found in this case was only ulcerated for a short period of time and gradually scabbed over. Therefore, it was hypothesized that the cSCC of the patient was not as a result of malignant transformation of the scar tissue.

There have been multiple previous reports on radiation-induced skin cancer. In 1995, Landthaler *et al* (14) retrospectively analyzed 612 radiation sites from 522 patients and observed 12 cases of basal cell carcinoma (2.0%) and 9 cases of SCC (1.5%). Subsequently, a prospective analysis of the Childhood Cancer Survivor Study cohort, which included 13,132 childhood cancer survivors, identified NMSC in 213 patients. Among these, 90% had received radiotherapy, and 90% of the tumors developed within the irradiated field (15). Basal cell carcinoma and SCC are the two main types of post-radiotherapy cutaneous malignancy, with a long latency period reported and being described as a late complication of ionizing radiation. Radiation-induced skin cancers can develop at any time from 2-65 years after radiation exposure (16). Although the probability of malignancy induced by radiation therapy is low, a study found a positive correlation between radiotherapy for breast cancer and cutaneous melanoma (17). A subsequent analysis by Rezaei *et al* (18), that included 875,880 patients with breast cancer (50.3% of whom received radiotherapy), found that patients who were treated with radiotherapy were more likely to develop skin cancer than those who did not receive radiotherapy (8% increase). Although this study did not include SCC or basal cell carcinoma of the skin, statistical analysis revealed that melanoma and angiosarcoma were the most common types of non-keratinocytic skin cancer among patients with breast cancer following radiotherapy or other treatments. In addition, a review of relevant literature also identified case reports of NMSC induced by postoperative radiotherapy for breast cancer, with pathological results consistently showing SCC (19-21). In the case reported by Loveland-Jones *et al* (19), the patient had undergone lumpectomy and whole breast radiation therapy. At 9 years after surgery, a non-healing ulcer of the right nipple was detected. The patient underwent a wide excision of the nipple-areolar complex, and pathological examination revealed a moderately to poorly differentiated invasive SCC. IHC showed positive expression results for CK5/6, p63 and CK, and negative expression results for ER, PR and HER2. The surgical approach in

this case was consistent with that of the present patient, and the SCC also developed within the radiation field. Similarly, IHC in this case showed positive expression of CK5/6 and p63, which are associated with SCC, and lack of expression of HER-2, which is associated with breast cancer. Therefore, based on the aforementioned reasons, we consider that the cSCC in the present patient was induced by radiation therapy.

With regard to the mechanism of radiation-induced skin cancer, firstly, radiation causes skin cancer mainly due to direct and indirect DNA damage, reactive oxygen species (ROS) production and local immune dysregulation. Cellular damage due to excessive ROS production is the result of interference with cell membranes, proteins and DNA, which alters the overall biological activity. As a result of these effects, oxidative products are formed that have mutagenic properties, which initiates the oncogenic process within the epidermal cells (4). Secondly, chronic stimulation is also a recognized theory, as research has found that inflammation is involved in the development of skin cancer (22). For example, chronic inflammatory stimulation due to radiation dermatitis and radioactive ulcers after radiotherapy is both a carcinogenic and a cancer-promoting factor. van Vloten *et al* (23) followed up 360 patients who had received radiotherapy for benign diseases of the head and neck, and found skin tumors in 21 of them. In 8 out of the 21 patients, 10 skin carcinomas were detected at recall. The study also concluded that the severity of radiation dermatitis was associated with a higher incidence of skin cancer. Furthermore, the dry contracture of the skin in the radiation area and the small amount of pigmentation observed in this area, as described in the present case report 3 years after radiotherapy, is in line with the clinical manifestations of chronic radiation dermatitis. Therefore, it was concluded that the patient described in the present case report developed SCC of the skin after radiotherapy, which may also be related to long-term stimulation of chronic radiation dermatitis. The diagnostic criteria for radiotherapy-induced skin cancer and malignant tumors induced by radiotherapy converge can be summarized as follows: i) A definite history of radiation exposure; ii) tumors occurring at the irradiated site; iii) a long latent period; and iv) pathological and histological confirmation or histological types different from the primary tumor (24).

Surgery is the primary treatment for skin SCC. For patients with early stage skin cancer, the radical cure rate of surgical resection can reach up to 95%; this consists of standard excision, Mohs micrographic surgery (MMS) and curettage and electrocautery, with standard excision being the most commonly used (25). For low- and high-risk cSCCs, radial resection margins of 4 and 6 mm, respectively, demonstrated 95% oncological clearance (25). For low-risk cSCC, National Comprehensive Cancer Network guidelines recommend that excision margins are 4-6 mm of the normal skin and that the margins are pathologically negative (10). For high-risk cSCC with multiple risk factors, there is insufficient clinical data and no definitive criteria for peripheral margins, but relevant studies have found that MMS is more effective than standard excision for high-risk cSCC (26). The main non-surgical treatment modalities for cSCC are radiotherapy, chemotherapy, photodynamic therapy (PDT) and cryotherapy (27). Among them, cryotherapy or PDT are only suitable for low-risk skin cancers without a clear histological diagnosis and proof of tumor clearance, while radiotherapy and chemotherapy are mostly used for patients with advanced cancers.

In the present case report, the skin nodule of the patient appeared on the right side of the postoperative scar from breast cancer surgery. The possibility of recurrence of breast cancer could not be excluded; however, combined with the wishes of the patient and the circumstances, surgical excision and intraoperative frozen section pathology were performed. In addition, the results of intraoperative frozen pathology only described squamous epithelial hyperplasia, and did not diagnose SCC of the skin clearly. Therefore, considering the limitations of the intraoperative frozen pathology and the fact that the patient had a history of radiotherapy, a standard excision of skin cancer was performed, and ~1 cm of normal skin around the skin nodule was excised. This was confirmed to be cSCC by postoperative routine pathology, and there was no tumor residue on the margins of the incision.

A total of 20 days after the excision of the skin SCC, the patient developed a wound ulcer. Therefore, the possibility of tumor remnants could not be excluded, and a biopsy of the skin tissue was performed. The results of the biopsy indicated that only skin ulcer formation had occurred, and it was hypothesized that the main cause of the ulcers was RSI after radiotherapy.

Radiotherapy-induced dermatofibrosis is a chronic and irreversible disease that occurs weeks to years after radiation exposure and is characterized by changes in skin appearance, loss of skin elasticity and contractures, and hardness of the skin that is difficult to pinch and crease, accompanied by capillary dilatation, pain and itching. Radiation-associated dermatofibrosis is also accompanied by damage to the vascular system, which is characterized by a decrease in the density of the microvascular network and vascular morphological changes (28). Therefore, it was considered that there were two main reasons for the poor wound healing in the patient described in the present case report. Firstly, the radiation damage destroyed the blood vessels and thus led to poor blood flow in the flap in this area, thus making it difficult to heal. Secondly, the radiation-related fibrosis led to high tension at the flap on both sides after the tumor resection, which ultimately led to the poor healing outcome. A previous study showed that early aggressive management of chronic non-healing wounds and peripheral flap grafting after excision of unstable scar tissue can improve the prognosis of patients with cSCC (29). Therefore, in the present study, part of the right breast where the ulcer had formed was excised and a free flap repair was performed.

The common flaps for this type of chest wall reconstruction are the latissimus dorsi muscle flap, localized arbitrary flap and rectus abdominis muscle flap (30). However, in the present study, due the condition of the patient and the extent of the right mastectomy, the descending thoracodorsal vascular flap was selected for the repair of the chest wall. The thoracodorsal vascular flap is also often used for reconstruction after breast-conserving surgery for breast cancer (31), and it must be noted that its use in the repair in a variety of soft-tissue defects has improved results (32). Furthermore, as the patient in the present study had undergone breast-conserving surgery in the past, and the amount of subcutaneous fat was insufficient, the descending branches of the thoracodorsal vascular

musculocutaneous flap were selected to repair the defect. The advantages of this type of musculocutaneous flap were firstly that the location of the incision, namely the lateral chest wall, was relatively hidden, and there was no need to change the position of the patient during the operation. Secondly, most of the latissimus dorsi muscle was preserved in our case, which reduced the likelihood of hematoma in the back and shoulder joint dysfunction, and there were fewer complications in the donor area. It must be noted that the thoracodorsal vascular flap has limitations, including the possibility of mutation of the branches emanating from the thoracodorsal vascular, the limited width of the flap and the time-consuming intraoperative fine separation (33,34), However, this type of repair is simpler than other flaps, has fewer postoperative complications, and can be used in other patients with chest wall skin cancer or localized chest wall ulcers after radiotherapy. In the present case report, the breast shape of the patient was improved while the patient underwent flap repair using the descending branches of the thoracodorsal vascular musculocutaneous flap. Radiotherapy has become a key part of postoperative treatment for breast cancer, and although SCC of the skin is rare after radiotherapy for breast cancer, physicians should remain vigilant. The area receiving the radiotherapy will have a postoperative scar and the side effects of radiotherapy can induce skin cancer. Therefore, a biopsy should be performed as early as possible to clarify the pathology and any follow-up treatment. In addition, in view of the poor wound healing described in the present case, radiotherapy may lead to the occurrence of skin fibrosis. As there is no effective prevention and treatment method for radiation fibrosis, immediate flap transfer repair should be considered at the time of surgery, especially for those patients who need surgical excision for skin cancer after breast-conserving surgery, in order to reduce the risk of adverse events and to improve the appearance of the breasts while obtaining improved therapeutic effects.

Finally, RSI has a long latency period and therefore should be prevented early. With the development of radiotherapy technology, intensity modulated radiation therapy, volumetric modulated arc therapy, helical tomotherapy, fixed field tomotherapy and other treatment modalities in clinical practice, research has found that the correct choice of radiotherapy modality can effectively reduce the side effects associated with radiotherapy (35,36). As radiotherapy-related skin damage can lead to skin cancer, and despite certain treatments delaying or reducing the risk of radiation-induced fibrosis (RIF), the key to preventing RIF is to reduce the radiation dose to exposed healthy skin areas. Future advancements in radiotherapy should focus on improving targeting precision and minimizing radiation exposure to healthy tissues, thereby enhancing patient quality of life.

Radiotherapy is a primary cancer treatment; however, relevant measures must be taken to prevent RSI and reduce the incidence of adverse reactions. Drugs that can aid this must be further researched and applied clinically. In addition, rational selection of radiotherapy techniques, individualized design, and early use of relevant drugs to treat and prevent chronic radioactive skin injury must be implemented, regardless of the severity of the RSI. Finally, patients should be followed up for a long period of time after radiotherapy. If skin nodules, ulcers or other chronic suspected wounds develop, biopsies should be performed early to exclude the possibility of malignant lesions. Any required follow-up treatment should be carried out as soon as possible, and the feasibility of surgical excision of the patient should be considered comprehensively based on the condition of the skin condition. In the future, in addition to the more commonly used surgical interventions, improved treatment options should be further explored.

In conclusion, radiotherapy can lead to the development of skin cancer, and its related skin injury may bring difficulties to the treatment of skin cancer induced after radiotherapy. Therefore, during radiotherapy, more attention should be paid to the treatment of RSI. In addition, following radiotherapy, more attention should be paid to the skin condition of the area where radiotherapy was received, in addition to the postoperative recurrence and wound recovery. If skin cancer has developed after radiotherapy, a comprehensive evaluation should be performed, and if surgical resection of the tumor is feasible, a simple flap repair or reconstruction surgery should be considered immediately after the skin cancer is resected, as described in the present study, to avoid the occurrence of adverse events.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

YQZ contributed to conception and design of the case report. JWL and PQ contributed to data collection and analysis. SCH and ZMY advised on patient treatment and performed the surgery. ZZL and MY obtained medical images (e.g. MRI, CT and ultrasound), YYT, CYC and ZZL contributed to data analysis and interpretation. YYT, SCH, PQ, ZMY, CYC, MY, ZZL, JWL and YQZ contributed to manuscript writing and final approval of the manuscript. All authors have read and approved the final version of the manuscript. SCH and YQZ confirm the authenticity of all the raw data.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Affiliated Hospital of Guangdong Medical University (Zhanjiang, China; (approval no. PJKT2024-116).

Patient consent for publication

Written informed consent was obtained from the patient for the publication of the present case report and any accompanying identifiable images.

Competing interests

The authors declare that they have no competing interests.

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