Identification and Validation of a Novel Model: Predicting Short-Term Complications After Local Flap Surgery for Skin Tumor Removal

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Background: The aim was to analyze the risk factors for the occurrence of complications after local flap transfer and to construct a simple prediction model to help surgeons in the perioperative screening of high-risk patients.

Material/Methods: Short-term complications were defined as any postoperative infection, dehiscence, bleeding, subcutaneous effusion, fat liquefaction, arteriovenous crisis, and tissue necrosis that required medical consultation or intervention. To explore 16 factors influencing short-term complications after local flap transfer, least absolute shrinkage and selection operator (LASSO) logistic regression was used to reduce the dimensionality of the data and to screen for predictors. Independent risk factors affecting the development of complications after local flap transfer were analyzed using logistic multiple regression models. The consistency (C-)index, receiver operating characteristic (ROC) curves, and calibration curves were used to check the model's discrimination and calibration. Decision curve analysis (DCA) curves were used to evaluate the clinical applicability of this model, and internal validation was assessed using bootstrap validation.

Results: The C-index of the nomogram model to predict short-term complications after local flap transfer was 0.763 (95% CI: 0.702-0.824), the area under the ROC curve was 0.763, and the internal validation C-index was 0.747. The calibration curve showed good agreement between observed and predicted values, and the DCA showed the model can benefit patients.

Conclusions: The model identified the relevant factors influencing short-term complications after local flap transfer, facilitating the identification and targeted intervention of patients at high risk of flap complications after surgery.

Keywords: Nomograms • Surgical Flaps • Validation Study

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Background

Skin tumors are very common, and whether malignant tumors are represented by squamous cell carcinomas, basal cell carcinomas, or benign lesions such as nevi, solar keratoses, or keloid scars, surgical excision is the most effective treatment modality. For skin defect wounds left after surgical excision, the use of local flap repair is the preferred modality to achieve similar thickness and color [1]. However, whether postoperative flaps can be subjected to complications and whether they can heal properly is a concern for most physicians.

Therefore, the analysis of risk factors affecting flap healing is an important task for surgeons. Relevant studies on exploring the influencing factors related to flap necrosis have been conducted. Some scholars [2-6] concluded that a higher body mass index (BMI) or obesity is detrimental to normal flap healing, while Crippen [7] et al argued that obesity had a protective effect on flaps in some cases. Smoking and lower protein levels were more consistently identified as risk factors for flap healing [8-13]. Other factors considered to be associated with flap prognosis include radiation history [14], diabetes [15], age [16], defect site and flap size [17], and hypertension [8]. In our clinical work, we cannot reject patients with histories including smoking, advanced age, or poor nutritional status. When faced with these patients, we can be aware that the incidence of adverse postoperative outcomes will be higher. During surgery, conditions such as deeper tumor invasion, fewer distal flap bleeding sites, and wound sutures with tension can raise concerns about the flap’s ability to heal successfully. Therefore, a model that can predict flap outcomes is needed. However, most previous studies were limited to the reconstruction of breast defects, and the type of flap studied was mostly the free flap; few studies were conducted on the local transposition flap, which is more widely used in clinical practice. In this review, we conducted a retrospective analysis of 416 patients who underwent local flap transposition. We aimed to identify risk factors after local transposition flap reconstruction and to construct a simple and intuitive risk prediction model to assist surgeons in perioperative clinical decision-making and to reduce the occurrence of postoperative complications. The aim of this paper was to analyze the risk factors for the occurrence of complications after local flap transfer and to construct a simple prediction model to help surgeons in the perioperative screening of high-risk patients.

Material and Methods

We consecutively collected clinical data related to patients with various skin lesions admitted to the institution from July 2019 to March 2022 who underwent excision of skin lesions combined with local flap grafting. The inclusion criteria were (1) all patients who underwent local flap grafting in the institution from July 2019 to March 2022 and (2) the surgical procedure was performed by the same surgical team in the institution. The exclusion criteria were preoperative trauma or infection around the surgical incision, preoperative systemic infectious disease, and incomplete clinical information. We collected the following variables: demographic characteristics of age, sex, BMI, and smoking history and basic disease conditions, such as diabetes, hypertension, anemia, low prealbumin levels, and hypoproteinemia. Characteristics of the surgery that were collected were whether it was a secondary operation or not, surgical position, pathological nature of the lesion, residual defect-area, whether the bone was infringed, and laboratory indicators, glucose (GLU) and white blood cell (WBC) count. The definition of a secondary surgery was the same operative area received a second surgery within 1 month. Hypoproteinemia was defined as a serum albumin level below 35 g/L. A low prealbumin level was considered as serum prealbumin <150 mg/L. The definition of smoking history was smoking more than 1 cigarette per day for more than 6 months. The study was approved by the ethics committee of the institution, and informed consent was obtained from all patients or their legal guardians.

In the case of a normal data distribution, the quantitative variables were expressed as the mean ± standard deviation using the t test; otherwise, they were expressed as the median (quartile distance) using the Mann-Whitney test. Count data were expressed as frequencies or percentages and analyzed using the chi-square or Fisher exact test. Predictors were first screened using least absolute shrinkage and selection operator regression (LASSO), which was used to identify those candidate parameters considered to be clinically important. We then included the predictors in a multifactorial logistic regression analysis to construct a prediction model and plot the nomogram. Next, we assessed the discrimination and goodness-of-fit of the prediction model by the consistency index (C-index) and the area under the receiver operating characteristic (ROC) curve (AUC) and calibration curve implementation. The nomogram was internally validated using 1000 bootstrap resamples and by calculating a relatively corrected C-index. Finally, decision curve analysis (DCA) was used to assess the clinical usefulness and net benefit of the nomogram. P<0.05 was considered statistically significant. In this study, SPSS Statistics (version 26.0) and R software (version 4.2.0) were used.

Results

Clinical Baseline Data

A total of 416 patients were included, 203 men and 213 women, with a mean age of 59.10±27.30 years, of whom 344 were
### Table 1. Demographic and clinical characteristics of the complications group and no complications group.

| Variable               | Complications (n=72) | No complications (n=344) | Total (n=416) | P value |
|------------------------|----------------------|--------------------------|---------------|---------|
| Sex                    |                      |                          |               | 0.316   |
| Female                 | 33 (15.5%)           | 180 (84.5%)              | 213 (51.2%)   |         |
| Male                   | 39 (19.2%)           | 164 (80.8%)              | 203 (48.8%)   |         |
| Age (years)            |                      |                          |               | 0.556   |
| Mean±SD               | 60.53±21.23          | 58.80±28.42              | 59.10±27.30   |         |
| BMI (kg/m²)            |                      |                          |               | 0.005   |
| Mean±SD               | 23.44±4.01           | 22.02±3.82               | 22.27±3.89    |         |
| Diabetes               |                      |                          |               | 0.313   |
| Yes                    | 7 (24.1%)            | 22 (75.9%)               | 29 (7.0%)     |         |
| No                     | 65 (16.8%)           | 322 (83.2%)              | 387 (93.0%)   |         |
| Smoking history        |                      |                          |               | 0.011   |
| Yes                    | 10 (34.5%)           | 19 (65.5%)               | 29 (7.0%)     |         |
| No                     | 62 (16.0%)           | 325 (84.0%)              | 387 (93.0%)   |         |
| Hypertension           |                      |                          |               | 0.32    |
| Yes                    | 30 (19.7%)           | 122 (80.3%)              | 152 (36.5%)   |         |
| No                     | 42 (15.9%)           | 222 (84.1%)              | 264 (63.5%)   |         |
| Secondary-operation    |                      |                          |               | <0.001  |
| Yes                    | 29 (28.2%)           | 74 (71.8%)               | 103 (24.8%)   |         |
| No                     | 43 (13.7%)           | 270 (86.3%)              | 313 (75.2%)   |         |
| Defect-area (cm²)      |                      |                          |               | <0.001  |
| Median (IQR)           | 16.5 (9-29.5)        | 6 (3-11.75)              | 7 (4-14.75)   |         |
| Anemia                 |                      |                          |               | 0.183   |
| Yes                    | 13 (21.6%)           | 42 (76.4%)               | 55 (13.2%)    |         |
| No                     | 59 (16.3%)           | 302 (83.7%)              | 361 (86.8%)   |         |
| Hypoproteinemia        |                      |                          |               | 0.003   |
| Yes                    | 9 (40.9%)            | 13 (59.1%)               | 22 (5.3%)     |         |
| No                     | 63 (16.0%)           | 331 (84.0%)              | 394 (94.7%)   |         |
| Low-prealbumin         |                      |                          |               | 0.01    |
| Yes                    | 14 (31.1%)           | 31 (68.9%)               | 45 (10.8%)    |         |
| No                     | 58 (15.6%)           | 313 (84.4%)              | 371 (89.2%)   |         |
| GLU                    |                      |                          |               | 0.392   |
| Median (IQR)           | 5.41 (4.82-5.99)     | 5.34 (4.92-5.83)         | 5.35 (4.92-5.84) |         |
| WBC                    |                      |                          |               | 0.59    |
| Mean±SD               | 6.28±2.02            | 6.16±1.70                | 6.18±1.76     |         |
Table 1 continued. Demographic and clinical characteristics of the complications group and no complications group.

| Variable                        | Complications (n=72) | No complications (n=344) | Total (n=416) | P value |
|---------------------------------|----------------------|--------------------------|---------------|---------|
| Infringement-of-bone            |                      |                          |               | <0.001  |
| Yes                             | 15 (48.4%)           | 16 (51.6%)               | 31 (7.5%)     |         |
| No                              | 57 (14.8%)           | 328 (85.2%)              | 385 (92.5%)   |         |
| Surgical position               |                      |                          |               | <0.001  |
| Face                            | 26 (11.0%)           | 211 (89.0%)              | 237 (57%)     |         |
| Scalp                           | 16 (24.2%)           | 50 (75.8%)               | 66 (15.9%)    |         |
| Chest-wall                      | 2 (13.3%)            | 13 (86.7%)               | 15 (3.6%)     |         |
| Waist                           | 2 (16.7%)            | 10 (83.3%)               | 12 (2.9%)     |         |
| Back                            | 0 (0.0%)             | 10 (100.0%)              | 10 (2.4%)     |         |
| Foot                            | 4 (44.4%)            | 5 (55.6%)                | 9 (2.2%)      |         |
| Joint                           | 3 (42.9%)            | 4 (57.1%)                | 7 (1.7%)      |         |
| Perineum                        | 2 (28.6%)            | 5 (71.4%)                | 7 (1.7%)      |         |
| Lower-leg                       | 2 (28.6%)            | 5 (71.4%)                | 7 (1.7%)      |         |
| Hips                            | 3 (50.0%)            | 3 (50.0%)                | 6 (1.4%)      |         |
| Retrocochlear                   | 1 (16.7%)            | 5 (83.3%)                | 6 (1.4%)      |         |
| Abdomen                         | 1 (16.7%)            | 5 (83.3%)                | 6 (1.4%)      |         |
| Neck                            | 0 (0.0%)             | 5 (100.0%)               | 5 (1.2%)      |         |
| Thigh                           | 2 (50.0%)            | 2 (50.0%)                | 4 (1.0%)      |         |
| Finger                          | 0 (0.0%)             | 4 (100.0%)               | 4 (1.0%)      |         |
| Toe                             | 1 (25.0%)            | 3 (75.0%)                | 4 (1.0%)      |         |
| Groin-area                      | 2 (66.7%)            | 1 (33.3%)                | 3 (0.7%)      |         |
| Forearm                         | 2 (66.7%)            | 1 (33.3%)                | 3 (0.7%)      |         |
| Upper-arm                       | 0 (0.0%)             | 2 (100.0%)               | 2 (0.5%)      |         |
| Back-of-hand                    | 2 (100.0%)           | 0 (0.0%)                 | 2 (0.5%)      |         |
| Palm                            | 1 (100.0%)           | 0 (0.0%)                 | 1 (0.2%)      |         |
| Pathologic nature of the lesion |                      |                          |               | <0.001  |
| Basal cell carcinoma            | 10 (9.3%)            | 97 (90.7%)               | 107 (25.7%)   |         |
| Squamous cell carcinoma         | 25 (32.9%)           | 51 (67.1%)               | 76 (18.3%)    |         |
| Nevus                           | 3 (6.5%)             | 43 (93.5%)               | 46 (11.1%)    |         |
| Keratoacanthoma                 | 2 (5.3%)             | 36 (94.7%)               | 38 (9.1%)     |         |
| Cicatricial tissue              | 2 (9.1%)             | 20 (90.9%)               | 22 (5.3%)     |         |
| Seborrheic keratosis            | 1 (5.6%)             | 17 (94.4%)               | 18 (4.3%)     |         |
| Neurofibroma                    | 8 (57.1%)            | 6 (42.9%)                | 14 (3.4%)     |         |
in the group without complications and 72 in the group with complications. The complication rate was 17.3%. Statistically significant differences existed between the 2 groups in terms of whether secondary surgery was performed, defect area, smoking history, hypoproteinemia, low prealbumin level, BMI, whether the bone was infringed, surgical position, and pathological nature of the lesion (P<0.05). There were no statistical differences in terms of sex, age, diabetes, hypertension, anemia, GLU, and WBC (P>0.05). Detailed information is shown in Tables 1 and 2.

### Table 1 continued. Demographic and clinical characteristics of the complications group and no complications group.

| Variable                          | Complications (n=72) | No complications (n=344) | Total (n=416) | P value |
|-----------------------------------|----------------------|--------------------------|---------------|---------|
| Dermatofibrosarcoma-protuberans   | 2 (20.0%)            | 8 (80.0%)                | 10 (2.4%)     |         |
| Other soft tissue sarcoma*        | 8 (66.7%)            | 4 (33.3%)                | 12 (2.9%)     |         |
| Hyperkeratosis                    | 0 (0.0%)             | 12 (100.0%)              | 12 (100.0%)   |         |
| Solar keratosis                   | 0 (0.0%)             | 8 (100.0%)               | 8 (1.9%)      |         |
| Malignant melanoma                | 3 (50.0%)            | 3 (50.0%)                | 6 (1.4%)      |         |
| Wart                              | 1 (25.0%)            | 3 (75.0%)                | 4 (1.0%)      |         |
| Others**                          | 7 (16.3%)            | 36 (83.7%)               | 43 (10.3%)    |         |

* Including: hemangiosarcoma*1, myxoid fibrosarcoma*2, synovial sarcoma*1, undifferentiated sarcoma*1, sarcomatoid carcinomas*2, malignant mesenchymal sarcomas*2, and fibrosarcoma*3. ** Including: xanthoma*2, fibroma*4, hemangioma*4, Pagets disease*3, sweat gland tumor*6, epidermoid cyst*3, lipoma*3, calcification*9, Bowen disease*1, Merkel cell carcinoma*1, epithelial tumor*1, sebaceous gland hyperplasia*1, hamartoma*1, basal cell papilloma*1, high-grade serous carcinoma*1, Pleomorphic adenoma*1, plexus schwannoma*1. BMI – body mass index; GLU – glucose; WBC – white blood cell.

### Table 2. Distribution of postoperative complications.

| Patients                          | Numbers (%) |
|-----------------------------------|-------------|
| Complications group               | 72 (17.3%)  |
| Distal skin flap necrosis         | 27 (37.5%)  |
| Total necrosis                    | 4 (5.6%)    |
| Venous crisis                     | 18 (25.0%)  |
| Arterial crisis                   | 3 (4.2%)    |
| Infection                         | 4 (5.6%)    |
| Bleeding                          | 3 (4.2%)    |
| Wound dehiscence                  | 4 (5.6%)    |
| Subcutaneous hydrops              | 6 (8.3%)    |
| Fat liquefaction                  | 2 (2.8%)    |
| Injury of adjacent organs         | 1 (1.4%)    |

**Independent Risk Factors for Short-Term Complications After Flap Transfer**

The screening was performed from the 16 variables collected based on the non-zero coefficients of the LASSO regression analysis, thus reducing the complexity of the prediction model. Six potential predictors were selected when the log(lambada) was taken as a minimum; namely, secondary operation, hypoproteinemia, smoking history, infringement of bone, BMI, and defect area, as shown in Figure 1. Incorporating these 6 predictors into a multifactorial logistic regression showed that hypoproteinemia, smoking history, infringement of bone, BMI, and defect area were independently associated with the occurrence of complications (Table 3).

**Construction and Validation of the Nomogram**

The independent risk factors for the complications hypoproteinemia, smoking history, infringement of bone, BMI, and defect area were incorporated into the model to construct a nomogram for the prediction of postoperative complications after local flap surgery. Considering the extensive nature of secondary operations in the removal of body surface tumors, the same was included in the model (Figure 2). The stability of the model was evaluated using the C-index, calibration curve, and ROC curve. The C-index of the model constructed in this study was 0.763 (95% CI: 0.702-0.824), the internal validation C-index was 0.747, and the area under the ROC curve was 0.763 (Figure 3A), indicating the model had good discrimination. The calibration correction curve showed a good agreement between the actual and simulated prediction
curves (Figure 3B), suggesting that the model had good prediction performance. The DCA curve showed that thresholds in the 4% to 69% interval had a significant net benefit in using this model to predict postoperative complications of the local flap (Figure 4).

Discussion

Proximity flap transfer is an effective method for repairing body surface soft tissue defects; however, its postoperative complications include infection, dehiscence, bleeding, subcutaneous effusion, fat liquefaction, arteriovenous crisis, and tissue necrosis, which result in poor health outcomes and increased health care costs. In contrast to short-term complications, long-term complications of the flap are often related to the appearance of the flap, such as scar contracture, hyperpigmentation, and flap bloat, and this is also a topic worth investigating; however, the focus of this study was on short-term complications to aid in early intervention. LASSO regression is considered suitable for approximate subtraction screening of high-dimensional data [18] and has been widely used clinically to select the best characteristics among risk factors. Nomograms have been widely used in clinical studies as convenient risk prediction tools due to their intuitiveness and accuracy. We developed and validated a new nomogram based on patient-related clinical variables. This model contained 6 variables: secondary surgery, hypoproteinemia, smoking history, whether or not the bone was infringed, BMI, and defect area. Coincidentally, the distribution of the variables we screened were statistically

| variable                   | $\beta$  | Odds ratio (95% CI)      | $P$ value |
|----------------------------|----------|--------------------------|-----------|
| Secondary operation Yes    | 0.587    | 1.799 (0.980-3.303)      | 0.058     |
| Hypoproteinemia Yes        | 1.258    | 3.517 (1.252-9.880)      | 0.017     |
| Smoking History Yes        | 0.914    | 2.493 (1.003-6.196)      | 0.049     |
| Infringement of bone Yes   | 1.599    | 4.947 (2.152-11.369)     | <0.001    |
| BMI                        | 0.087    | 1.091 (1.007-1.028)      | 0.019     |
| Defect area                | 0.017    | 1.018 (1.007-1.028)      | 0.001     |

$\beta$ is the regression coefficient. BMI – body mass index.
significantly different in the 2 groups (Table 1), which we be-
lieve reflects the rationality of our screening process. We be-
lieve that this model can help physicians assess patients at
high risk of complications on the day after surgery, visually
present patients with relevant risk factors, and improve pa-
tient awareness of the treatment process.

According to our results, hypoproteinemia was retained in
LASSO regression, and the inclusion of multifactorial logistics
regression showed that patients with hypoproteinemia were
3.517 times more likely to have postoperative complications
than were patients without hypoproteinemia, indicating that
hypoproteinemia can significantly influence the occurrence
of postoperative complications in the local flap. The clinical
role of albumin as a marker for the evaluation of nutrition-
al status has received increasing attention for its functions of
maintaining colloid osmotic pressure, cell membrane integri-
ty, and acid-base balance. Hypoproteinemia has been wide-
demonstrated to be associated with the prognosis of flap
reconstruction, with Fang et al [8] suggesting that postoper-
ative hypoproteinemia is a risk factor for poor flap healing
complications, and Shum et al [9] suggesting that lower pre-
albumin levels are a risk factor for microvascular free flap fail-
ure. In a study by Xu et al [10], supplementation of albumin

Figure 2. The nomogram for complications of the local flap is shown. The complications of the local flap
risk nomogram were developed by incorporating the following characteristics: secondary operation, hy-
proproteinemia, smoking history, infringement of bone, body mass
index, and defect area. Figure created with R software (version 4.2.0).

Figure 3. Internal validation of the nomogram. (A) Calibration diagram of the line diagram. The Y-axis is the actual incidence of
complications diagnosis. The X-axis is the complication’s predicted risk. The dashed diagonal line represents the perfect
prediction of the ideal model. The solid line shows the bias correction performance of the nomogram, whereas the dotted
line closer to the diagonal shows a better prediction. (B) Area under the receiver operating characteristic curve analysis was
used to determine the accuracy of the identification model for complications. Figure created with R software (version 4.2.0).

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in the perioperative period to increase albumin levels was effective in reducing local flap complications and shortening the length of hospital stay. The redox properties possessed by albumin can effectively resist tissue damage or the increase of inflammatory reactive oxygen species [19], which may be related to the mechanism by which albumin promotes wound healing and reduces flap complications. Therefore, serum albumin levels in patients undergoing local flap transfer should be regulated to the normal range whenever possible to minimize adverse flap outcomes.

In our study, bone invasion was screened as an independent risk factor for complications of local flaps when multifactorial logistics regression was performed. Few previous investigators have seen this as an influential factor in flap prognosis, and we believe that the inclusion of this factor in the prediction model would facilitate a better and more accurate prediction of flap prognostic outcomes. When the lesion is resected to the bone, or even when the periosteum needs to be removed to ensure negative cut margins, the flap used to cover the defect will not have a blood supply from the base due to the lack of vascularity on the bone surface, which will increase the risk of graft ischemia. Free tissue grafts are an alternative but require a high level of microvascular expertise [20]. Artificial dermis can be applied when large areas of bone are exposed, but this also requires burring of the bone until there is sufficient bleeding for sarcomere to obtain a well-vascularized wound bed [25]. The blood flow of a local flap is not entirely dependent on the base, but mainly on the tip, which makes it an option for defect repair when the resection depth reaches the bone. However, again, local flap transposition over bone faces a higher risk of poor outcomes due to the poor blood supply to the periosteal surface.

We also found that smoking was detrimental to normal flap healing, which is consistent with previous study results. Smoking can lead to more complications, and the mechanism may be related to the induction of skin vasoconstriction and increased platelet aggregation. In a report by Hwang et al [11], the incidence of necrosis, hematoma, and fat necrosis after flap grafting was higher in smokers than in nonsmokers. Wang et al [12] demonstrated that both current and previous smoking can contribute to the development of acute complications after flap surgery. The mechanisms by which smoking is detrimental to tissue grafting have also been extensively studied: nicotine is thought to have adrenergic effects that induce peripheral vasoconstriction, thereby decreasing tissue blood flow, oxygen tension, and aerobic metabolism [22,23]. In an animal study, Lawrence et al [24] observed a significant decrease in flap survival in rats exposed to cigarette smoke, supporting the idea that smoking after surgery is also detrimental to flap survival.

Another factor considered is patient weight. In the present study, due to higher patient age and history of tumors, patients often did not reach the criteria of overweight in terms of BMI, so it is inaccurate to conclude on this basis that obesity was a risk factor. We did not classify the overall BMI of patients as normal, overweight, or obese. Instead, we used it as a numerical variable and, after testing normality, we applied the t test, which showed significant differences between the 2 groups. Then, after LASSSO regression analysis, this variable was retained. We then included the variables screened by the LASSO analysis in a multifactorial logistic regression, resulting in a P value of 0.019 for BMI. Therefore, we believe that the inclusion of BMI in the final model was beneficial in improving the accuracy of the model. Many scholars have different opinions regarding the role of BMI in flap reconstruction. Most believe that patients with a high BMI face a higher likelihood of complications after flap reconstruction [4-6,25], but Crippen et al [7] concluded that obesity does not increase the risk of postoperative flap complications and can even have a protective effect, whereas underweight can lead to a decreased flap reconstruction ability. The existing studies are limited to mostly flap reconstruction of the breast or head and neck, and the flap types are mostly free flaps. There are fewer reports of localized adjacent flaps in multiple sites. In the present study, we collected extensive cases of adjacent flap reconstruction.
in various parts of the body, and the results showed that increased BMI was positively associated with the incidence of postoperative complications after local flap surgery.

During this study, the association between the size of the defect area and the risk of postoperative complications was quantified to more accurately predict the extent to which an increase in defect size affected the rate of complications. It is easy to understand that the defect area becomes a predictor of prognosis in local flap surgery. A larger defect area implies a larger flap area and a more distant proximal tip of the flap from the distal marginal tissues, which poses a challenge to the blood supply to the distal tissues of the flap. Also, the marginal tissues will need to establish de novo capillaries with the surrounding tissues or base to obtain oxygen supply. Defects and flap size were also found to be associated with postoperative complications of flap reconstruction in a study by Lee et al [26].

The results of our study showed a higher risk of postoperative complications in patients undergoing the second surgery than in those undergoing an initial surgery. This can be easily explained as follows. The blood supply to the flap is affected by the second surgery due to the destruction of local blood vessels during the initial surgery, the probability of complications, such as infection and delayed healing are increased, and the tension of the surrounding tissues is increased by performing multiple local flap translocations, which is also a risk factor [27]. Although the variable of secondary surgery was excluded during multifactorial logistic regression, we reintroduced it into the model, considering the prevalence of secondary surgery in the removal of body surface tumors. The timing of secondary surgery should be chosen more carefully to account for the limitations of the first surgery and the evolution of the patient’s general condition. In the vast majority of our cases, secondary surgery was undertaken because postoperative pathology after the first conventional excision of the lesion suggested unexpected malignancy or the presence of malignant residual tumor at the margins of the excised specimen, making a second extended excision and local flap transfer necessary.

In fact, there are more factors than just patient-related factors that affect flap outcomes. A study by Kraemer et al [28] showed that a decrease in peripheral temperature significantly reduced mean microcirculatory capillary blood flow, which led to arterial thrombosis or venous compromise. Another factor is the method of packing. In order for the flap to fit securely to the base, we usually applied appropriate pressure bandaging, and care must be taken not to compress the tip of the flap, which is an important source of blood supply to the flap. The level of care has also been reported to have an impact on the prognosis of the flap [29]. More factors are still to be discovered.

There were limitations to our study. For example, due to imperfect clinical data, we were unable to obtain an accurate geometry of the defect remaining after lesion excision. Therefore, the same defect area with different geometries would result in different flap designs, such as a narrow-shaped defect, implying a larger aspect ratio of the flap, which would put pressure on the distal blood supply to the flap. Nevertheless, the model we developed is still of good clinical interest.

Conclusions

In this study, we established a predictive model containing 6 variables, facilitating the identification and targeted intervention of patients at high risk of flap complications after surgery.

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Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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