# Predictors affecting anterolateral thigh flap in reconstruction of upper extremity

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## Abstract

Our study is aim to explore predictors for failure of anterolateral thigh (ALT) flap in the reconstruction of upper extremity.

We performed a retrospective study for 509 patients who underwent ALT flap in the reconstruction of upper extremity. Among them, 27 patients suffered from necrosis of ALT flap (necrosis group, NG) and 482 gained survival of this flap (survival group, SG). We collected possible factors including 3 aspects: demographic variables – age, sex, body mass index (BMI), history of hypertension, diabetes, heart disease, smoking and alcohol, trauma mechanism, and postmenopausal; surgical-related variables – surgical duration, blood loss, number of reconstructed veins, flap size, perforator type, diameter of perforator, and vein graft; blooding variables – hemoglobin, D-dimer, white blood cell, red blood cell, and platelet count (PLT). We compared the above data between NG and SG by univariate, multivariate, and Kaplan–Meier method coupled with a log-rank test linear regression analysis.

The survival incidence of ALT flap repairing upper extremity was 94.7% (482 of 509). The outcome of univariate analysis showed that age (53.5±9.2), BMI (26.7±4.5), larger flap size (24.3*9.2), D-dimer (0.58±0.10), and PLT (278.1±34.4) in NG were significantly higher than these (44.2±7.9, 22.3±4.2, 19.1*7.9, 0.48±0.08, 236.6±30.5) in SG. However, diameter of perforator (1.07±0.02) in NG was markedly smaller than that (1.12±0.02) in SG. Additionally, female patients, postmenopausal, patients with using venous stapler or 1 reconstructed vein had a higher failure rate. Multivariate and Kaplan–Meier method implied the same results.

In summary, many factors were related with failure of ALT in the reconstruction of upper extremity. Postmenopausal, D-dimer, and PLT were the first considered as risk factors for ALT flap repairing upper extremity.

**Abbreviation:** ALT = anterolateral thigh.

**Keywords:** anterolateral thigh flap, survival analysis, upper extremity

## 1. Introduction

Due to complex anatomy in the upper extremities, it is a huge challenge for surgeons to reconstruct complex soft tissue defects. These defects may be very large, separated, or eccentrically located, which can add to the complexity of the surgery. Up to now, different types of flaps have been introduced to repair these complex defects. In 1984, the anterolateral thigh (ALT) flap has been first reported by Song,[1] mainly featured with superior vascular supply to the skin and versatility in flap design. Due to above merits, ALT flap has been considered an optimal option for surgeons when reconstructing complex soft tissue defects. Many

subtypes of the ALT flap have also been developed. Of these, the chimeric ALT flap can be used for repairing multiple separated defects of the upper limbs.

Yoshiro Abe[2] tried the factors impacting delayed healing of ALT at donor site and demonstrated that patients with high BMI, a history of smoking and skin graft were easier to suffer from delayed healing. Skin graft was suggested to be avoided at donor site for patients with high BMI or a history of smoking. Rossell-Perry[3] concluded based on his experience that failure of flap may be related with kinking or sectioning of the pedicle, anatomical variations, tension, vascular thrombosis, type of cleft, used surgical technique, surgeon's experience, infection, and malnutrition. As far as we know, few published articles focused on risk factors related with failure of ALT in the reconstruction of upper extremity. The purpose of this article is to assess factors effecting failure of ALT repairing upper extremity.

## 2. Patients and methods

### 2.1. Ethics statement

The study was approved by the institutional review board of our hospital before data collection and analysis. Because of a retrospective study, informed was no need to be obtained.

### 2.2. Patients

Five hundred nine patients who received ALT flap were included in this study from January 2010 to January 2018 in our hospital. Among them, 27 patients suffered from failure of ALT flap and 482 did not. We considered necrosis of ALT flap as necrosis

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group (NP) and survival of it as survival group (SG). The included criteria were as follows:

1. soft tissue defects of upper extremity;
2. just one ALT flap repairing upper extremity;
3. more than 18 years old.

The exclusion criteria were as follows:

1. traumatic history in upper extremity;
2. history of surgery in upper extremity;
3. using two ALT flaps repairing soft tissue defects.

### 2.3. Possible risk factors

The possible factors included 3 aspects: demographic variables – age, sex (male/female), body mass index (BMI, kg/m$^2$), history of hypertension (yes/no), diabetes (yes/no), heart disease (yes/no), smoking (yes/no) and alcohol (yes/no), trauma mechanism (cutting/crushing/avulsion), postmenopausal (yes/no); surgical-related variables – surgical duration (min), blood loss (mL), number of reconstructed vein (1/≥2), flap size (cm*cm), perforator type (myocutaneous/septocutaneous), diameter of perforator (mm), and vein graft (yes/no); blooding variables – hemoglobin (HB, g/L), D-dimer (mg/L), white blood cell (WBC,$10^9$/L), red blood cell (RBC, $10^{12}$/L), and platelet count (PLT,$10^9$/L) (blood variables were regular test before surgery).

## 3. Methods

The methods were carried out in accordance with the approved guidelines. Two authors identified and collected all the data of patients according to inclusion criteria and exclusion criteria. In addition, two authors were responsible for data analysis. All data were presented as the mean ± standard deviation (SD). When data satisfied criteria for normality and homogeneity of variance, statistical analysis between groups was performed using independent samples $t$ test. Otherwise, statistical analysis was performed using Mann–Whitney $U$ test. For count data, chi-square test was used for data analysis. To identify the best predictors, univariate, multivariate analysis, and Kaplan–Meier method coupled with a log-rank test linear regression analysis, which was used to assess the relationship between time and factors, were computed. Statistical significance level was considered to be $P < .05$. All statistical analysis was carried out using SPSS, version 21.0 (SPSS Inc., Chicago, IL).

## 4. Results

Table 1 showed that there was no significant difference in patient with history of smoking, alcohol, hypertension, heart disease, diabetes, and trauma mechanism between two groups. However, age (53.5 ± 9.2 years old) and BMI (26.7 ± 4.5 kg/m$^2$) were markedly higher in NG than these (44.2 ± 7.9 years old, 22.3 ± 4.2 kg/m$^2$, all $P < .05$) in SG. Female patients or postmenopausal was easier to have higher failure rate of ALT flap.

Table 2 showed that there was no significant difference in surgical duration, blood loss and perforator type between two groups. Flap size (24.3 cm*9.2 cm) was markedly higher in NG than that (19.1 cm*7.9 cm) in SG. However, diameter of perforator (1.07 ± 0.02 mm) in NG was obviously smaller than that (1.12 ± 0.02) in SG. Additionally, 1 reconstructed vein and application of venous stapler in recipient site could significantly

increase the failure rate of ALT flap in comparison with 2 reconstructed veins and without venous stapler.

Table 3 showed that there was no significant difference in HB, WBC, and RBC between two groups. Nevertheless, D-dimer (0.58 ± 0.10 mg/L) and PLT (278.1 ± 34.4 $10^9$/L) were markedly higher in NG than these (0.48 ± 0.08 mg/L, 236.6 ± 30.5 $10^9$/L) in SG.

Table 4 summarizes the multivariate analysis for ALT flap failure. Our results showed that age (OR = 2.14 95%CI [1.68, 2.40], $P < .0001$), gender (OR = 1.63 95%CI [1.20, 2.00], $P = .001$), BMI (OR = 2.72 95%CI [1.99, 3.49], $P = .003$), postmenopausal (OR = 2.15 95%CI [1.50, 2.85], $P = .01$), D-dimer (OR = 1.12 95%CI [1.02, 1.22], $P < .0001$), PLT (OR = 1.64 95%CI [1.42, 1.90], $P = .02$), 1 reconstructed vein (OR = 5.56 95%CI [4.44, 6.54], $P < .0001$), flap size (OR = 2.45 95%CI [1.87, 3.23], $P < .0001$), diameter of perforator (OR = 7.12 95% CI [3.62, 8.68], $P < .0001$), and venous stapler (OR = 4.22 95% CI [2.60, 5.88], $P < .0001$) were independent predictors for ALT flap necrosis.

Figures 1 and 2 show graphs established by Kaplan–Meier calculations to evaluate the relationship between time and factors associated with failure of ALT flap in univariate analysis. From data in log-rank test, patients with >50 years old (HR = 2.45; 95% CI [1.62, 4.38]; $P = .0012$), BMI > 24 kg/m$^2$ (HR = 2.64; 95% CI [1.88, 3.52]; $P = .0195$), female patients (HR = 0.45; 95% CI [0.32, 0.58]; $P = .0065$) or postmenopausal (HR = 0.46; 95% CI [0.22, 0.66]; $P < .0001$), 1 reconstructed

### Table 1

Comparison of possible factors impacting necrosis of anterolateral thigh flap between necrosis group (NG) and survival group (SG).

| Factors | NG (n = 27) | SG (n = 482) | P |
|---|---|---|---|
| Age (years) | 53.5 ± 9.2 | 44.2 ± 7.9 | .01 |
| Gender (male/female) | 7/20 | 233/249 | .023 |
| Smoking (yes/no) | 9/18 | 197/285 | .437 |
| Alcohol (yes/no) | 7/20 | 119/363 | .885 |
| Hypertension (yes/no) | 5/22 | 110/372 | .603 |
| Heart disease (yes/no) | 3/24 | 55/427 | .962 |
| Diabetes (yes/no) | 4/23 | 99/383 | .471 |
| Body mass index (kg/m$^2$) | 26.7 ± 4.5 | 22.3 ± 4.2 | .01 |
| Trauma mechanism | | | .597 |
| Cutting | 2 | 19 | |
| Crushing | 12 | 198 | |
| Avulsion | 13 | 265 | |
| Postmenopause (yes/no) | 14/6 | 60/189 | <.0001 |

### Table 2

Surgical factors impacting necrosis of anterolateral thigh flap between necrosis group (NG) and survival group (SG).

| Factors | NG (n = 27) | SG (n = 482) | P |
|---|---|---|---|
| Surgical duration (min) | 229.6 ± 30.3 | 231.6 ± 29.5 | .61 |
| Blood loss (mL) | 242.2 ± 24.5 | 239.2 ± 22.3 | .216 |
| Number of reconstructed veins (1/≥2) | 14/13 | 55/427 | <.0001 |
| Flap size (cm*cm) | 24.3*9.2 | 19.1*7.9 | <.0001 |
| Perforator type (MC/SC) | 22/5 | 377/105 | .688 |
| Diameter of perforator (initial vessel, mm) | 1.07 ± 0.02 | 1.12 ± 0.02 | <.0001 |
| Venous stapler (yes/no) | 16/11 | 155/327 | .004 |

MC = myocutaneous, SC = septocutaneous.

**Table 3**

Comparison of blooding variables impacting necrosis of anterolateral thigh flap between necrosis group (NG) and survival group (SG).

| Factors | NG (n = 27) | SG (n = 482) | P |
|---|---|---|---|
| HB (g/L) | 4.73 ± 0.78 | 4.83 ± 0.83 | .668 |
| D-dimer (mg/L) | 0.58 ± 0.10 | 0.48 ± 0.08 | <.0001 |
| WBC ($10^9$/L) | 6.13 ± 0.93 | 6.23 ± 0.97 | .249 |
| RBC ($10^{12}$/L) | 132.2 ± 15.6 | 135.1 ± 16.2 | .374 |
| PLT ($10^9$/L) | 278.1 ± 34.4 | 236.6 ± 30.5 | <.0001 |

HB = hemoglobin, PLT = Platelet count, RBC = red blood cell, WBC = white blood cell.

**Table 4**

Factors impacting necrosis of anterolateral thigh flap by multivariate analysis.

| | P | 95% CI |
|---|---|---|
| X1 = age | <.0001 | 2.14 (1.68, 2.40) |
| X2 = gender | .001 | 1.63 (1.20, 2.00) |
| X3 = body mass index | .003 | 2.72 (1.99, 3.49) |
| X4 = postmenopause | .01 | 2.15 (1.50, 2.85) |
| X5 = D-dimer | <.0001 | 1.12 (1.02, 1.22) |
| X6 = platelet count | .02 | 1.64 (1.42, 1.90) |
| X7 = 1 reconstructed veins | <.0001 | 5.56 (4.44, 6.54) |
| X8 = flap size | <.0001 | 2.45 (1.87, 3.23) |
| X9 = diameter of perforator | <.0001 | 7.12 (3.62, 8.68) |
| X10 = venous stapler | <.0001 | 4.22 (2.60, 5.88) |

vein (HR = 1.41; 95% CI [1.02, 1.83]; $P < .0001$), venous stapler (HR = 5.02; 95% CI [3.22, 6.90]; $P = .0047$), D-dimer > 0.55 mg/L (normal range from 0 to 0.55 mg/L) (HR = 3.02; 95% CI [1.68, 4.52]; $P < .0001$) and PLT > 300*109/L (normal range from 0 to 300*109/L) (HR = 2.14; 95% CI [1.72, 2.45]; $P < .0001$) were found to be significant factors for failure of ALT flap.

## 5. Discussion

ALT flap is widely popular in area of reconstruction due to these advantage that pedicle, flap design, and operative technique.[2,3] ALT flap played an important role in covering the complex soft tissue defect since it was first published by Song.[1] Flap necrosis is one of the most serious complications of ALT flap. Previous studied has been reported that survival rate of ALT was over 90%.[4] Spindler[5] discovered that patients with a history of smoking and diabetes were easier to suffer from flap necrosis in comparison with patient without these. Nevertheless, Spindler just explored four factors might be associated with flap necrosis. As far as we know, few studies focused on risk factors impacting failure of ALT flap, so we tried to study on this topic by univariate, multivariate, Kaplan–Meier method coupled with a log-rank test linear regression analysis.

In our study, the data showed that age, BMI, larger flap size, D-dimer, PLT and diameter of perforator, female patients, postmenopausal, patients with using venous stapler or 1 reconstructed vein were found to be statistically significant
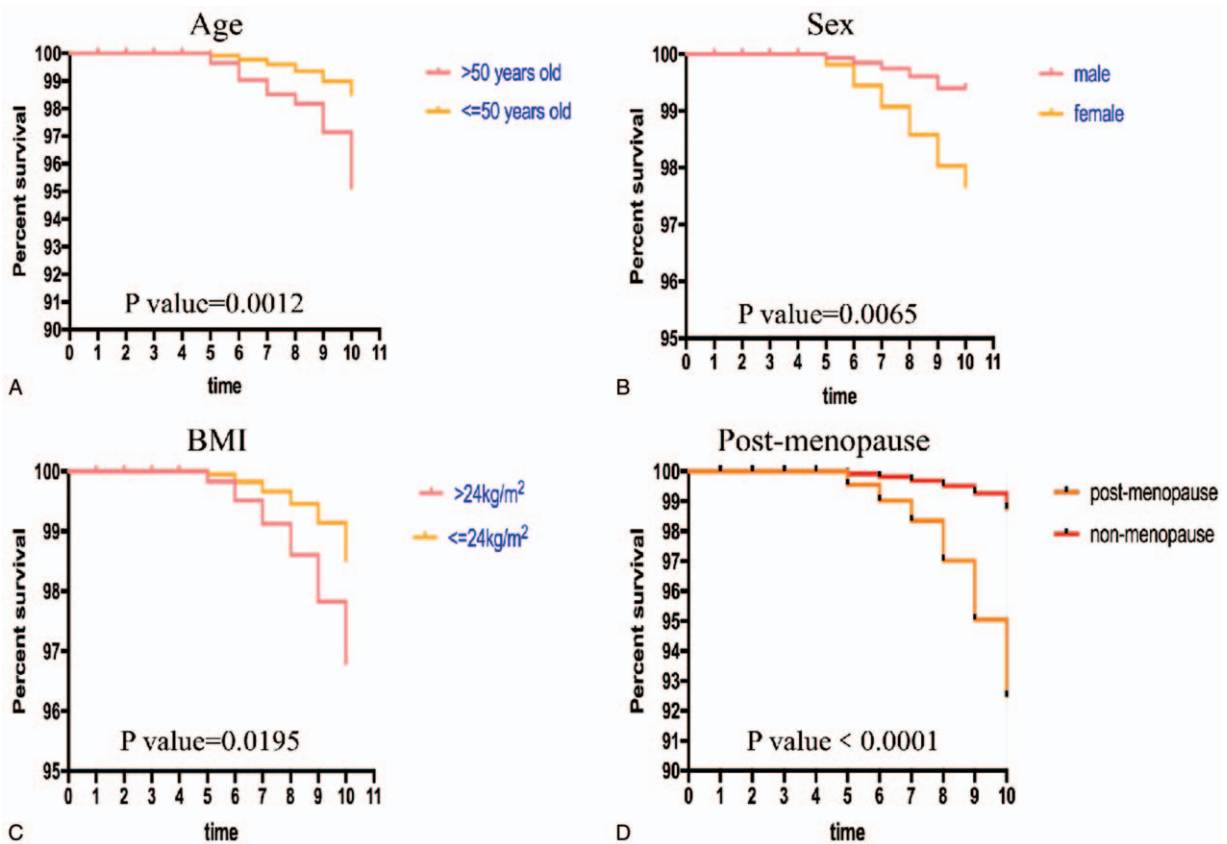


**Figure 1.** Kaplan–Meier method coupled with a log-rank test linear regression analysis to evaluate the relationship between time and factors associated with failure of ALT flap in univariate analysis. From data in log-rank test, patients with >50 years old, BMI > 24 kg/m², female patients or postmenopausal, 1 reconstructed vein, venous stapler, D-dimer > 0.55 mg/L, and PLT > 300*$10^9$/L were found to be statistically significant factors for failure of ALT flap.
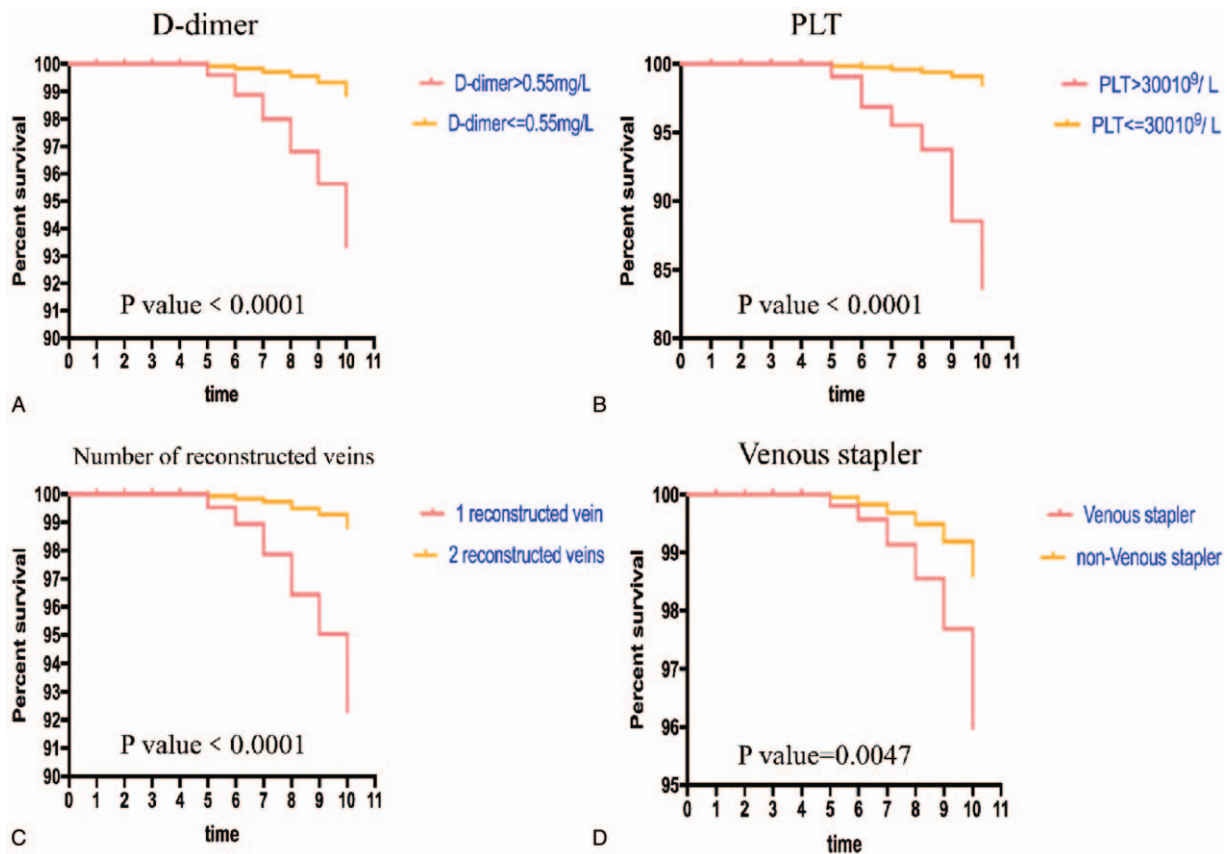
**Figure 2.** Kaplan–Meier method coupled with a log-rank test linear regression analysis to evaluate the relationship between time and factors associated with failure of ALT flap in univariate analysis. From data in log-rank test, patients with >50 years old, BMI > 24 kg/m², female patients or postmenopausal, 1 reconstructed vein, venous stapler, D-dimer > 0.55 mg/L, and PLT > 300*10⁹/L were found to be statistically significant factors for failure of ALT flap.

factors by univariate, multivariate, Kaplan–Meier method coupled with a log-rank test linear regression analysis.

The survival rate of ALT flap was 94.7%, which was higher than that as previous studies reported.[5,6] The study of Spindler[5] showed that age and BMI were not the significant risk factors for flap necrosis. However, in our study, patients in failure group were older and had higher BMI. It is well known that quality of the blood vessels is poor when patients are older, which may directly impact survival rate of flap. The main drawback of patients with higher BMI is thickness of the flap, especially in women. Thick flap needs more blood volume in comparison with thin one for the same size. We also found that female patients or postmenopausal could markedly increase failure rate, which was not reported in previous studies. Tu[7] studied on how concentration of estrogen influencing vascular endothelial cells and found that physiological concentration of estrogen had a certain protective effect on vascular endothelial cells. It is well understood that women have a low level of estrogen postmenopausal, which may be associated with flap failure. Above data offers some advice for surgeon that patients with advanced age, high BMI, female or with postmenopausal should carefully consider before surgery.

Regarding surgical-related variables, larger size of flap needs more blood volume, but smaller diameter of perforator could not be able to provide enough blood volume, causing skin flap in state of relatively ischemic. Due to vascular anatomic variation, some patients had only one perforator vein or one of two veins had

blind end, so we just closed 1 vein in ALT flap. It was apparent that 1 reconstructed vein could supply less venous reflux for the flap in comparison with 2 reconstructed veins, which could obviously increase failure rate of flap. In our study, 16 of 181 patients with venous stapler suffered from flap necrosis, which was related with venous crisis. We also performed Kaplan–Meier method coupled with a log-rank test linear regression analysis and found that from 5 days after surgery, failure rate significantly increased in patients with 1 reconstructed vein and using venous stapler as compared with patients with 2 reconstructed veins and without venous stapler. Above mentioned suggest us that we should close 2 veins and do not use venous stapler as far as possible.

Our data showed that when PLT exceeded 300*109 cells/L or D-dimer surpassed 0.55 mg/L, failure rate was as high as 44.4% and 18.1%, respectively. Above mentioned implied the negative effect of a high level of PLT or D-dimer on the survival of the ALT flap. Chi-square analysis showed that patients with a high level of PLT or D-dimer had a greater tendency to flap failure in comparison with those with a normal or lower level. Additionally, we applied for multivariate analysis to find that both PLT and D-dimer were the independent risk factors for survival of ALT flap. What's more, Kaplan–Meier method coupled with a log-rank test linear regression analysis showed that from 5 days after surgery, failure rate significantly increased in patients with a high level of PLT or D-dimer as compared with patients with normal level. According to this finding, we suggest that augmentation of

anticoagulation in patients with a high level of PLT and D-dimer count should be adopted for the ALT flap repairing upper extremity.

Although this study provides several novel findings, it has some limitations. First, this is just a retrospective and single-center study. The outcome of research requires further validation in a larger set of patients, preferably in a multi-center study; second, another possible factor like low-molecular-weight heparin and leaving bed after surgery causing flap necrosis should be analyzed in further study; third, there were 6 surgeons performed ALT flap in this series, but any surgeons were skillful and worked in hand surgery for more than 15 years. Fourth, some risk factors (flap size and diameter of perforator) for ALT flap failure by univariate and multivariate analysis could not by analyzed by Kaplan–Meier method coupled with a log-rank test linear regression analysis. However, to the best of our knowledge, this is the first study reporting on postmenopausal and blood blooding variables including D-dimer and PLT as predictor of ALT flap failure.

In conclusion, many factors were found to be associated with failure of ALT flap by univariate, multivariate analysis, and a log-rank test. Our results showed that patients with postmenopausal, D-dimer and PLT, as vital predictors, were first reported for failure of ALT flap. This article could give some inform and guide for surgeons and measure would be taken before ALT flap necrosis to lower incidence after surgery.

## Author contributions

**Visualization:** Feng Long.
**Writing – original draft:** Di Li.
**Writing – review & editing:** Ming Lei.

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