ISSN : 0974 - 7435 Volume 10 Issue 9

2014

BioTechnology
An Indian Journal

FULL PAPER
BTAIJ, 10(9), 2014 [4013-4019]

Relationship between the ratio of length to width of the slender narrow pedicle and the survival area of the random flap

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ABSTRACT

This study explored the relationship between the area of survival and the length/width ratio of slender narrow pedicles to random flaps to assess their clinical safety. Twenty-five pigs were randomly divided into five groups (n=5 in each group). The length/width ratios of the narrow pedicles in all five groups were 0/2(cm), 1 /2 (cm), 2/2 (cm), 3/2 (cm), and 4/2(cm) respectively, and these were created in five random flaps of different sizes on both sides of the back of each pig (Flap A [control]: 2cm×2cm; B: 3cm×3 cm; C: 4cm×4cm; D: 5cm×5 cm; and E: 6cm×6cm). Flap A was the “traditional” flap. All flaps survival areas were evaluated by general observation, intravenous fluorescent dye, blood flow ECT (Emission Computed Tomography) analyses, and histopathological examinations. The clinical course and pathological processes within the traditional flaps (Flap A) and the slender narrow pedicle flaps were consistent. An increasing flap area and a constant length/width ratio, or vice versa, preserved the area of graft survival. However, when the flap area reached a certain limit, the distal flap necrosis without decreasing the overall flap survival area in the same group; when the length/width ratio reached a certain limit, the distal flap necrosis with decreasing the overall flap survival area in the same group. The width of the pedicle can safely be significantly smaller than the width of the flap, and the flap pedicle can be designed to be slender. This type of pedicle facilitates flap rotation. However, there is a maximum flap survival area that the slender narrow pedicle can support.

KEYWORDS

Pedicle; Narrow; Random flap; Survival area; ECT.

INTRODUCTION

Due to the flexible design and simple operation, the random flap is the most commonly used flap for repairing tissue defects. For a long time, the clinical application of such flaps has been seriously affected due to the limit on the ratio of its length to width (length/width ratio) [1-7]. In recent years, there have been reports of the study and application on random flaps that differ from the traditional form [8-14].

Based on the studies of the Eleventh Five-Year Plan of China with regards to narrow pedicle lateral jaw-neck flaps, we designed this experiment to study the relationship between the length/width ratio of slender narrow pedicles and the random flap survival area so as to have a clear understanding of the relationship between this ratio of the pedicle and the consequent survival area of the random flap. The aim of this study was to expand the application of random flaps with slender narrow pedicles and to provide a reference for the clinical application of such flaps.

MATERIALS AND METHODS

Animals

25 white pigs that weighed between 25-30 kg were used.

Experiment grouping and flap design

The 25 pigs were randomly divided into five groups, with five pigs in each group. The length/width ratios of flap pedicle in the five groups were as follows: 0/2(cm), 1 /2 (cm), 2/2 (cm), 3/2 (cm), and 4/2 (cm). Each slender narrow pedicle with one of the five different length/width ratios were performed in 5 random flaps with the following sizes: flap A: 2cm×2cm; B: 3cm×3 cm; C: 4cm×4cm; D: 5cm×5 cm; and E: 6cm×6 cm, and these random flaps were named as A, B, C, D, and E respectively. Flap A was the control flap (the traditional flap) for the experimental flaps B-E. Flaps. A-E were made in on both sides of the back of each pig; the distance between each flap was 4 cm, the distance between the pedicle and the midline of the back was 4 cm, and the order was arranged randomly. The design of one of the groups (such as a pig in group III) is as follows (Figure. 1). The rest design of each group can be inferred by analogy. Grouping was designed as the ratio of length to width of each pedicle. The nature of these groupings is shown in TABLE 1.

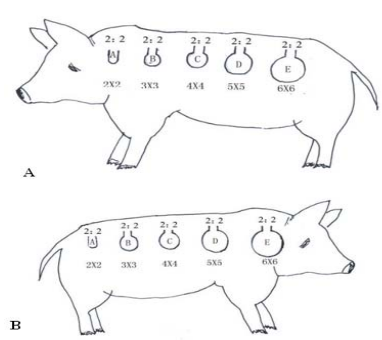


Figure 1 : The design of one of the groups (group III)

TABLE 1 : Experiment grouping

Group	W:l (cm)	A w×l (cm)	B w×l (cm)	C w×l (cm)	D w×l (cm)	E w×l (cm)
I	2:0	2×2	3×3	4×4	5×5	6×6
II	2:1	2×2	3×3	4×4	5×5	6×6
III	2:2	2×2	3×3	4×4	5×5	6×6
IV	2:3	2×2	3×3	4×4	5×5	6×6
V	2:4	2×2	3×3	4×4	5×5	6×6

Surgical technique

The flap was lifted in the superficial layer of the deep temporal fascia. The incision was sutured after hemostasis was achieved within the base. The flap was packed with a topical dressing and a pressure bandage was applied underneath an abdominal belt. After surgery, each pig was kept in separate cage and given antibiotic (Intramuscular injection penicillin, 800,000 unit/times, daily 2 times) for 1 week.

Observation index

i) General observation: the color, capillary reaction, mottling, and evidence of necrosis of the flaps in each group were observed clinically at specific time periods on the first day, the third day, the fifth day, the seventh day, the fourteenth day from the operation.

ii) Intravenous fluorescent dye: The pigs received an intravenous injection with 10% fluorescence sodium (25 mg/kg) into the auricular vein immediately after the operation. After 10 minutes, the range of the fluorescent dye dispersal was observed within the flap and the length and surface area of flap survival was predicted using the distribution of ultraviolet light.

iii) Determination of the ECT (Emission Computed Tomography) blood flow within the flap: Two pigs from each group were used for this part of the experiment. An intravenous injection of 99^{m}Tc-labeled was given 20 minutes after the operation to label the erythrocytes; trace A, B, C, D, E, the 5 kinds of flaps' changes in radiation parameters dynamically; An image from each flap was obtained every 30 seconds over a period of 30 minutes after injection. When the labeling reached a static equilibrium, the quantity of radiation within each flap was determined, and the distribution of the isotope within the blood flow within the flap was observed.

iv) Histopathological changes within the skin flap: The skin flaps from groups A-E were resected at different times (on the first day, the third day, the fifth day, the seventh day, the fourteenth day from the operation) to conduct a pathological observation with the method of HE staining. The animals for histology were divided into two groups: the slender narrow pedicle flap group and the traditional flap group. The traditional flaps and a comparative analysis was made between the traditional flaps and the flaps with slender narrow pedicles with regards to evidence of revascularization and inflammatory responses.

v) The survival results of the skin flap: This was observed after 14 days, and the surface area of viable tissue that had survived flap formation was determined with the use of standard grid paper. The results were shown as the mean ± standard deviation, the line of analysis of variance and SPSS (Statistical Package for the Social Science) test; the area of graft survival was then calculated. The pigs were slaughtered two weeks after the operation with anesthesia.

RESULTS

General observation

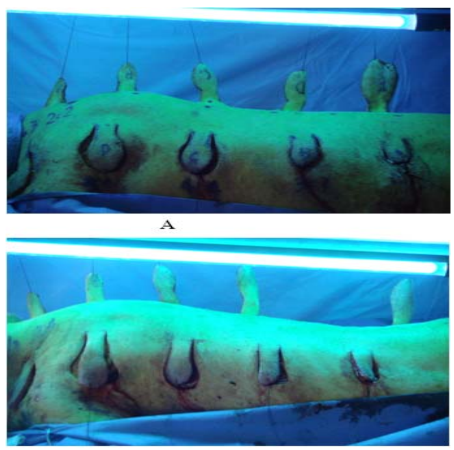
All the flaps were observed to undergo the postoperative seq5uence of congestion, edematous change, an inflammatory response, the resolution of edema, and wound healing. Fourteen days after the flap was formed, flaps A, B, C, D, and E in groups I, II and III showed complete survival. Flaps A, B, and C in groups IV and V also survived, but the distal parts of flaps D and E necrosis (Figure. 2). However, in these latter two cases, the overall survival area of the flaps was not reduced in comparison to the totally healthy flaps. There were no significant differences between the flaps D and flaps E that survived area in the same group (group IV and V) ($P > 0.05$).

Intravenous fluorescent dye of the flap

The extent of fluorescent staining within flaps A, B, C, D, and E in groups I, II and III was 100%. The extent of staining in flaps A, B, and C in groups IV and V was also 100%. The extent of staining of flap D and E was approximately more than 90%, which was almost the same as the real survival area of flaps D and E (Figure. 3).

A B

Figure 2 : A) After 14 days all flaps of one pig in group 3 completely survived. B) After 14 days in group V the distal part of flaps D and E were necrotic.



A B

Figure 3 : Fluorescence examination of flaps. A) one of the third group pigs; B) one of the fifth group pigs.

Dynamic ECT determination of flaps

For the flaps within the same group, when the length/width ratio of the pedicle was fixed, the time required for perfusion the flap near the tail of the pig to reach equilibrium was longer than the flap near the head of the pig, which was an observation that was maintained in flaps of the same size. For example, flap E near the tail of the pig in group V took approximately 17 mins for perfusion to reach equilibrium, compared to 12 mins for the flap near the head of the pig. When flaps in different groups were compared (flaps of the same size with different length/width pedicle ratios), the equilibration time for perfusion significantly different. Longer pedicles demonstrated a longer period for perfusion equilibrium than short pedicles. The length/width ratio for flap E in group III was 2/2 (cm), and the time the perfusion to reach equilibrium was 9 mins; Compared with flap E in group V, the time was 12 minutes. However, judging from the radioactive curves showed in the dynamic ECT test in the flaps in all five groups, the arterial and venous flow reached dynamic equilibrium within 8-17 mins.

Static ECT showed that the radioactive nuclide concentration decreased progressively from the proximal to the distant part of the flap in all five groups. Flap A-E in groups I, II and III and flaps A, B, and C in groups IV and V were covered with radionuclides. With the increase of the flap area, there was almost no radionuclide distribution in the distal part of flaps D and E in groups IV and V, and the scope of the distribution within the flap correlated with the area of survival results of each type of flap.

Pathological changes

The slender narrow pedicle flaps (experimental flap) and the conventional flap (control flap) showed consistent pathological processes: (1) on the third day after the operation, many new capillary buds and several newly formed fiber cells (Fibroblast) could be seen, and they grew in a vertical orientation to the surface of the wound; (2) on the fifth postoperative day, typical granulation tissue was observed and a small amount of interstitial collagen fibers were seen; (3) by the seventh postoperative day, a gradual reduction in the amount of granulation tissue was seen, and the quantity of collagen fibers increased; (4) the fourteenth postoperative revealed that the novel capillary blood vessels had gradually closed, were degraded, and were replaced by smaller arteries and veins whose walls thickened gradually; fibroblasts cells were transformed into fiber cells (Fibroblast), and the wounds healed.

Survival results of the flaps

In the 14th day after operation, flap A, B, C, D, E in groups I, II and III were all survived. Flap A, B, C in groups IV and V all survived. With the increase of the flap area, the distal part of flaps D, E in groups IV and V necrosis, but the survival area of the flaps was not reduced in the same group. When the size of the flap remained unchanged, the survival area of the flap was not affected with an increasing length/width ratio of the slender narrow pedicles. However, by a certain limit, the distal flap necrosis, and the survival area of the same flap in different group was reduced. The results were shown as the mean ± standard deviation, the line of analysis of variance and SPSS (Statistical Package for the Social Science) test. There were significant differences between the survival area of flaps in all groups ($P < 0.05$) (TABLE 2, Figure. 2).

TABLE 2 : The survival area of the flaps in each group after operation ($\bar{x}$ ±s, cm²)

Group	n	A 2×2	B 3×3	C 4×4	D 5×5	E 6×6
I 2:0	10	3.14±0.00	7.07±0.00	12.56±0.00	19.63±0.00	28.26±0.00
II 2:1	10	3.14±0.00	7.07±0.00	12.56±0.00	19.63±0.00	28.26±0.00
III 2:2	10	3.14±0.00	7.07±0.00	12.56±0.00	19.63±0.00	28.26±0.00
IV 2:3	10	3.14±0.00	7.07±0.00	12.56±0.00	18.56±0.76	18.55±0.56
V 2:4	10	3.14±0.00	7.07±0.00	12.56±0.00	18.35±0.65	18.34±0.45

Compare flap A with flap B, C, D, E in each group, P<0.05.

DISCUSSION

From the macroscopic and pathological observations, there was a strong similarity between the processes of flap survival and pathology between the traditional flaps and the flaps with slender narrow pedicle. The two kinds of flaps underwent the re-establishment of vascular circulation up to the wound edges [15-20].

Ischemic tissue necrosis still remains a troublesome complication of skin flap surgery. Unfortunately, the pathogenesis of ischemia has not been described clearly. Various mechanisms have been described including vasospasm, arteriovenous shunt flow [21-27]. The processes of flap revascularization are comprised of three stages: the capillary bud formation stage, the formation of granulation tissue and the microcirculation, and the establishment of vascular modifications. The survival processes of the flaps were not delayed when the pedicle was slender and narrow, which suggests that the length/width ratio of the pedicles were not the determining factor for flap survival. As it could be seen from the above results, when the length/width ratio of the narrow pedicle was fixed, the survival area of the flap would increase as long as the area of the flap increased; but when it reached to a certain degree, the distal part of the flap underwent necrosis, but the survival area of the flap was not reduced in the same group. In this experiment, when the length/width ratio of the flap pedicle was 3/2 (cm) or 4/2 (cm), the flap which area were 2cm×2cm, 3cm×3 cm and 4cm×4cm can survive; the distal part of flaps which area were 5cm×5cm, 6cm×6cm necrosis, but the survival area of the flap was not reduced in the same group. When the size of the flap remained unchanged, the survival area of the flap was not affected with an increasing length/width ratio of the slender narrow pedicles. For example, when the length/width ratio of the flap pedicle was 0/2(cm) to 2/2(cm), the flap which area was 6cm×6cm can survive. However, by a certain limit, the distal flap necrosis, and the survival area of the same flap in different group was reduced. For example, when the length/width ratio of the flap pedicle was 3/2(cm) to 4/2(cm), and the flap which area was 5cm×5cm and 6cm×6cm, the distal of the flap necrosis, the survival area of the same flap in different group was reduced. This upper limit of length/width ratio far exceeded the limit of the ratio of the traditional random flap. Similarly, from the results of these studies and clinical applications in the past, the width of pedicles of the flap could be much smaller than the width of the flap and the length/width ratio of both the pedicles and flaps could be much larger than traditional random flaps.

A slender and narrow pedicle facilitates the rotation of the flap, in a similar manner to an island skin flap. These studies also proved that the limit of the length/width ratio of the pedicle of traditional random flaps was challenged to a certain degree. Our results of analysis of the flaps with fluorescence and ECT agreed with the hypothesis of Cheng Hongbing that the survival length of the flap depended on the perfusion pressure of the blood vessels within the flap [28].

This showed that the survival area of the flap was closely related to the blood perfusion within the pedicle and the range of perfusion. The slender narrow pedicles flaps that we designed were in the shape of a table tennis bat with the slender pedicle resembling the handle of the table tennis bat. The experimental flaps had a greater degree of mobility, scope for rotation, and a larger potential area of coverage. However, due to the unknown vasculature of the pedicle, this new shape of flap was classified as a variety of random flap according to the categorization. The flaps with slender narrow pedicles broke the traditional restrictions on the length/width ratio of flap, expanding the scope of the application of the random flaps by providing a more practical and convenient method for repairing tissue defects. The traditional restrictions on the length/width ratio of flap limited the clinical application of the random flap and so encouraged surgeons to find ways of removing these restrictions [8-14]. Judging from a series of research findings and clinical applications, there is no relationship between the duration of flap survival and the width of the pedicle; the length/width ratio should no longer be considered as the most important standard measure. More accurate methods for the design of flap pedicles include the method that Taylor [29]. And others have adopted, or other methods such as Doppler.

In conclusion, this study has given supporting evidence to show that random flaps with slender narrow pedicles are safe in an animal model in terms of flap survival. This type of flap has a greater rotational range and coverage than traditional random flaps. The design can be more flexible and a greater distance from the defect, providing a simple but practical method of repairing tissue defects. We have already successfully applied these kinds of flaps in some patients, and the preliminary results have proved that these advantages correlate to clinical conditions. Further research is now required to promote the revascularization of the slender narrow pedicle flaps and examine the maximum survival area of the flap that a certain limit length/width ratio of the pedicle can support. If those aspects can be improved by further animal and clinical studies, a simple and practical new method will be offered for clinical wound healing.

ACKNOWLEDGEMENTS

The following are supported by research funding:

1. Suzhou Science and Technology Development Planning Project (SYSD2012091)
2. Young Workers Scientific Pre-hospital Research Fund (SDFEYQN1308)
3. Clinical Science and Technology Projects (BL2014041)

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