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Original Article

The superficial branch of the radial nerve and sensory disturbance in the radial forearm flap donor-site

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ABSTRACT

Introduction: Sensory disturbance due to injury of the superficial branch of the radial nerve (SBRN) is a donor-site morbidity of the radial forearm (RF) flap. The relationship between the SBRN preservation method and the post-operative sensation at the flap donor-site was retrospectively investigated.
Methods: We included 39 patients who underwent head and neck reconstruction with a free RF flap at Hyogo Cancer Center between April 2014 and March 2018. The patients were classified into the following three groups according to the SBRN preservation method: group 1, zero preservation, excision of the entire SBRN; group 2, main trunk preservation, excision of all branches except the main trunk of the SBRN; and group 3, complete preservation, preservation of the entire SBRN. Objective sensations and subjective symptoms at the flap donor-site were analyzed.
Results: The mean objective sensory scores were 3.18, 2.97, and 1.78 in groups 1, 2, and 3, respectively. Differences between groups 1 and 3 and between groups 2 and 3 were significant ($p = 0.0035$ and $p = 0.037$, respectively). The mean subjective symptom scores were 2.40, 1.33, and 1.40 in groups 1, 2, and 3, respectively. Differences between groups 1 and 2, and between groups 1 and 3 were significant ($p = 0.032$ and $p = 0.019$, respectively).
Conclusions: Zero preservation method had a higher risk of subjective symptoms and objective hypoesthesia development at the flap donor-site than the complete preservation method. Despite inevitable objective hypoesthesia, the main trunk preservation prevented the development of subjective symptoms. Complete preservation is optimal for RF flap harvest; however, in case of perforator crossing, main trunk preservation is another option.

1. Introduction

The radial forearm (RF) flap was first reported by Yang et al., in 1981 [1]. The RF flap is a thin, pliable, and long-pedicled skin paddle, thus making it one of the best choices for head and neck reconstruction, especially following the resection of tongue and buccal mucosal cancer. However, there are several complications associated with the RF flap donor-site, including skin graft loss, limited motor function, and sensory disturbance. In particular, sensory disturbance reduces the postoperative quality of life of patients.

The radial nerve bifurcates into deep and superficial branches at the cubital fossa. The superficial branch of the radial nerve (SBRN) is a sensory nerve innervating the radial half of the dorsal hand. Following an injury to the SBRN during RF flap harvest, the patient often complains of paresthesia and/or a painful sensation after surgery. These symptoms are usually transient, unless the SBRN is completely resected, and rarely interfere with the patient's daily life. However, some patients experience chronic neuropathic pain. Moreover, young and active patients with paresthesia have a high risk of developing a secondary injury. An existing case report warned of the risk of contact burn on the dorsal hand due to the decreased sensation [2]. Therefore, avoiding sensory disturbance during RF flap harvest is crucial.

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When harvesting the RF flap, the SBRN with small branches can be easily located in the supra-fascial plane at the distal forearm [3,4]. Previously, we sacrificed the SBRN as preservation required additional operative time. Furthermore, patients with paresthesia due to SBRN resection had a low satisfaction level regarding the flap donor-site, signifying the importance of preserving SBRN. Patient satisfaction has significantly improved with the preservation of the SBRN. However, cases in which the branch of the SBRN crosses a perforator from the radial artery (perforator crossing) are occasionally encountered (Fig. 1). In such cases, either the nerve or the perforator needs to be sacrificed. In the present study, we investigated how the SBRN preservation method influenced postoperative sensory disturbances at the flap donor-site.

2. Methods

2.1. Patients

This was a retrospective observational study. A total of 75 consecutive patients who underwent head and neck reconstruction with a free RF flap at Hyogo Cancer Center between April 2014 and March 2018 were included. Based on medical records, we evaluated the flap survival rate and post-operative sensation at the flap donor-site in patients who could be followed up for at least six months after surgery.

2.2. Ethical approval

This observational study was approved by the Ethics Committee of Hyogo Cancer Center (No. G-291).

2.3. Surgical technique

The RF flap was harvested from the patient's non-dominant forearm. The skin paddle was designed according to the size of the defect following tumor resection. According to Tahara's method [5], the vascular pedicle of the RF flap was harvested as long as possible. The radial artery was dissected up to the bifurcation point of the ulnar artery. The concomitant veins of the radial artery and cephalic vein, including the perforating vein near the cubital fossa, were then harvested. The flap donor-site was covered with a full-thickness skin graft from the inguinal area.

The flap was then transferred to the head and neck region where the vascular pedicle of the flap was anastomosed to the recipient vessels under a microscope. The blood flow of the transferred flap was assessed every 4 h until the fifth postoperative day. When vascular complication was suspected, the anastomosis site was immediately evaluated.

2.4. SBRN preservation method

The SBRN was identified subcutaneously on the distal side of the skin paddle. The nerve was dissected retrogradely until it entered the brachioradialis muscle. All patients with medical records regarding the SBRN preservation method were classified into the following three groups: group 1 (zero preservation method), in which the entire SBRN, including the main trunk and small branches, was excised; group 2 (main trunk preservation method), where all the small branches were excised, while the main trunk was preserved; and group 3 (complete preservation method), in which the entire SBRN was preserved.

2.5. Objective sensory scores

First, the patients were instructed to keep their eyes closed during the test. Subsequently, a Semmes-Weinstein monofilament® (SAKAImed, Co. Ltd., Tokyo, Japan) was used to measure the minimum recognizable target force at the flap donor-site (SW test). We performed the SW test at the interphalangeal joint (point 1), metacarpal phalangeal joint (point 2), carpometacarpal joint (point 3), and snuff box of the dorsal thumb (point 4) in both the flap donor-site hand (affected side) and the intact hand (unaffected

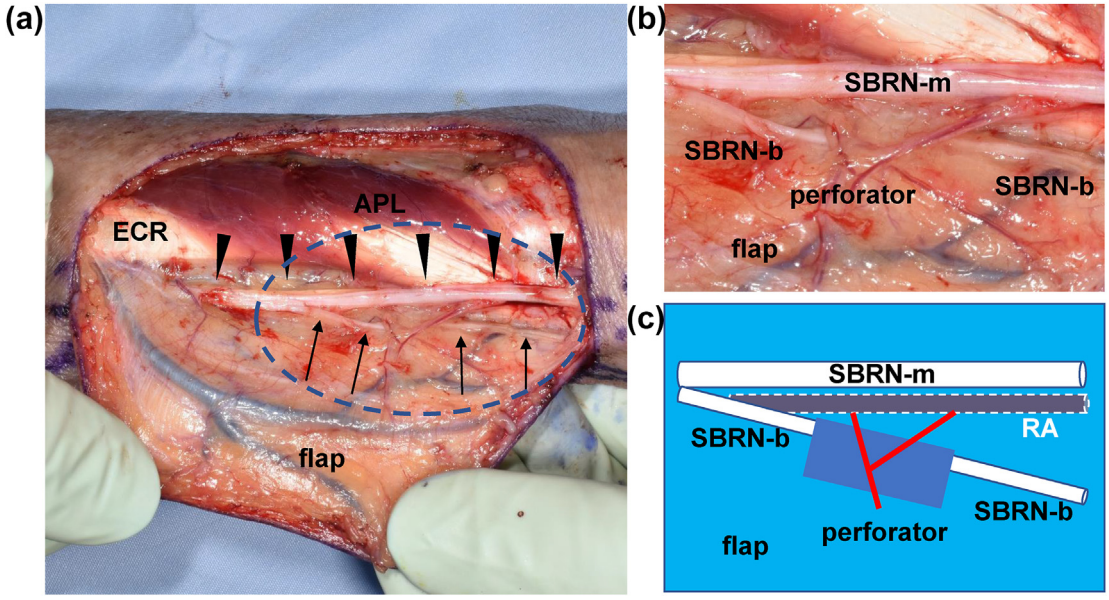

Fig. 1. A "perforator crossing" case a) The main trunk (arrowhead) and branch (arrow) of the SBRN are observed during RF flap harvest. The dotted circle denotes the area of the perforator from the RA crossing the branch of the SBRN (perforator crossing). b) High-magnification view of the perforator crossing site. We are required to excise either the branch or the perforator. c) A scheme of the perforator crossing site.
Abbreviations: APL, abductor pollicis longus; ECR, extensor carpi radialis; RA, radial artery; RF, radial forearm; SBRN, superficial branch of the radial nerve; -m, main trunk; and -b, branch.

side) (Fig. 2a). The results of the SW test were evaluated on a 5-point scale [6], where scores 1, 2, 3, 4, and 5 indicated normal perception, reduced tactile perception, reduced defensive perception, loss of defensive perception, and complete loss of perception, respectively. The average values of the scores were recorded as objective sensory scores and compared among the three groups.

2.6. Subjective symptom scores

We inquired the patients regarding their concerns regarding the flap donor-sites following surgery. The patients rated their symptoms, including pain, numbness, and disability, on a 5-point scale. The scores were as follows: 1 (asymptomatic), no obvious differences in symptoms before and after surgery; 2 (mild), occasional slight discomfort that did not affect daily life; 3 (moderate), persistent slight discomfort that did not affect daily life; 4 (severe), persistent severe discomfort that restricted some daily activities; and 5 (serious), persistent severe discomfort that prevented the performance of daily activities.

2.7. Statistical analysis

The EZR software [7] was used for the statistical analysis. One-way analysis of variance (ANOVA) was used to compare the mean subjective symptom score and objective sensory scores among the three groups. If the result of ANOVA was significant, Tukey's post-hoc test was conducted to determine which of the specific groups' mean values were different. Besides, the Student's *t*-test was performed to compare the difference between two independent groups. A p-value <0.05 was defined as a statistically significant difference.

3. Results

3.1. Patient characteristics

Of the 75 patients, 36 were excluded from the study because of the lack of an appropriate follow-up period or consent to sensory testing. Eventually, 39 patients (including 21 males and 18 females) with a mean age of 66.3 years (Table 1) were classified into three groups based on the SBRN preservation method. Groups 1, 2, and 3 consisted of 15, 9, and 15 patients, respectively. The mean flap size of groups 1, 2, and 3 was 6.3, 6.6, and 6.4 cm horizontally and 7.0, 7.4, and 7.3 cm longitudinally, respectively. Of the 15 patients in group 1, a 55-year-old male patient (6.7%) had flap failure due to an arterial thrombus that resulted in salvage surgery with a new forearm flap. In groups 2 and 3, there were no confirmed cases of flap failure. The mean follow-up period following reconstructive surgery was 1111.3, 365.4, and 483.0 days in groups 1, 2, and 3, respectively.

3.2. Objective sensory scores

Fig. 2b to e depict the objective sensory scores for the four points. In groups 1, 2, and 3, the mean objective sensory scores for the affected side were 3.18, 2.97, and 1.78, respectively (Fig. 3). One-way ANOVA revealed a statistical significance ($p = 0.0031$). Tukey's multiple comparisons of mean values indicated a statistically

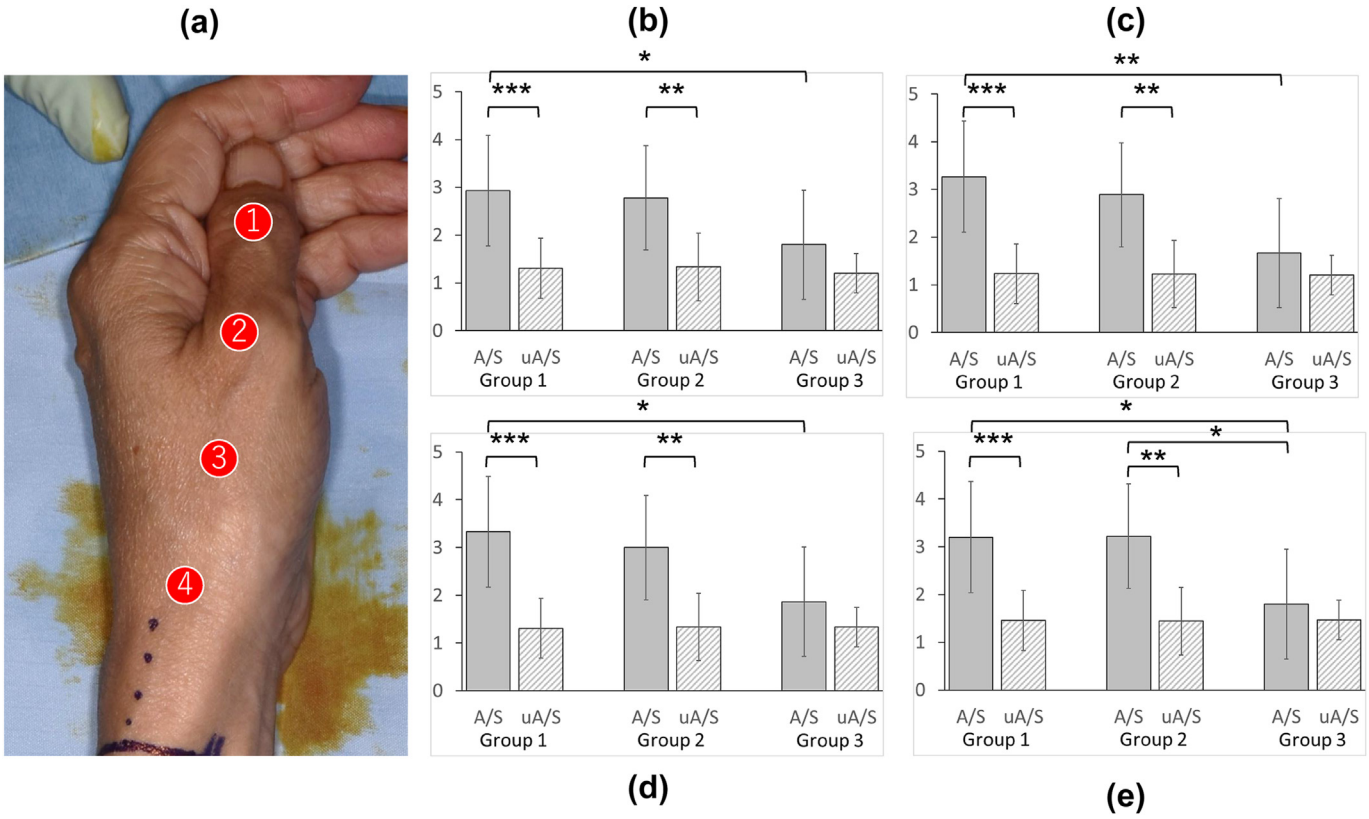

Fig. 2. Objective sensory scores for points 1 to 4 a) The four examination points: point 1, interphalangeal joint; point 2, metacarpal phalangeal joint; point 3, carpometacarpal joint; and point 4, snuff box of the dorsal thumb. b) The objective sensory scores at point 1. The gray bars represent the affected side (A/S), and the gray dashed bars represent the unaffected side (uA/S). The scores for c) point 2, d) point 3, and e) point 4. The objective sensory scores display a similar tendency among the four points, despite some minor differences.
*p < 0.05, **p < 0.005, and ***p < 0.0005.

Table 1
Patient characteristics.

Group	n	Age (year-old)	Sex (%male)	Horizontal flap size (cm)	Longitudinal flap size (cm)	Flap Survival (n, %)		Follow-up (days)
1	15	65.7	53.3	6.3	7.0	14	93.3%	1111.3
2	9	69.9	66.7	6.6	7.4	9	100%	365.4
3	15	64.7	46.7	6.4	7.3	15	100%	483.0
total or mean	39	66.3	53.8	6.4	7.3	38	97.4%	697.5

significant difference between groups 1 and 3 and between groups 2 and 3 ($p = 0.0035$ and $p = 0.037$, respectively). In groups 1, 2, and 3, the mean objective sensory scores for the unaffected side were 1.32, 1.33, and 1.30, respectively. One-way ANOVA did not reveal statistical significance ($p = 0.99$). Student's *t*-test demonstrated that the affected side had higher scores than the unaffected side in groups 1 and 2 ($p = 0.000019$ and $p = 0.0016$, respectively), whereas there was no significant difference in group 3 ($p = 0.10$).

3.3. Subjective symptom scores

The mean subjective symptoms scores of groups 1, 2, and 3 were 2.40, 1.33, and 1.40, respectively (Fig. 4). One-way ANOVA revealed a statistical significance ($p = 0.0098$). Tukey's multiple comparisons of mean values demonstrated a statistically significant difference between groups 1 and 2 and between groups 1 and 3 ($p = 0.032$ and $p = 0.019$, respectively).

4. Discussion

Donor-site morbidities of the RF flap were classified into three categories: functional impairment, sensory disturbance, and aesthetic problems. Of these, most patients were concerned about sensory or aesthetic problems but rarely experienced functional impairment [8]. A review article on 16 studies of RF flap donor-sites that included a total of 513 patients reported that the incidence rate of sensory disturbance was 27% [9].

Preservation of the SBRN during RF flap harvest is the best way to avoid sensory disturbance at the flap donor-site. However, to date, no study has compared postoperative sensations at the flap donor-site with and without SBRN preservation. The results of the present study revealed that the zero preservation method clearly increased both subjective and objective symptoms compared with the complete preservation method. Therefore, we concluded that the SBRN should be preserved as much as possible to reduce the flap donor-site morbidity. Moreover, we observed that in the case of perforator crossing, the preservation of the main trunk of the SBRN was not associated with the development of subjective symptoms. Although the objective sensory score after the preservation of the main trunk of the SBRN was lower than that after the complete preservation of the SBRN, the subjective symptom scores were not significantly different.

We were concerned that in cases of perforator crossing, sacrificing the perforator of the radial artery would decrease the blood

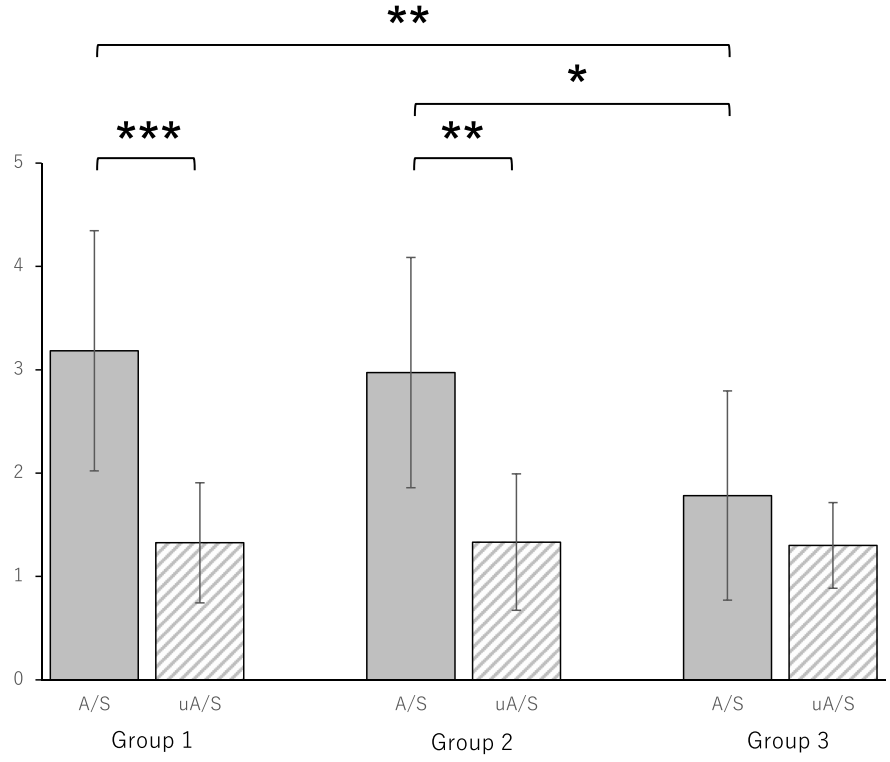

Fig. 3. Mean objective sensory scores
The mean objective sensory scores (the average scores for points 1 to 4) of the three groups are denoted as gray bars on the affected side (A/S), and as gray dashed bars on the unaffected side (uA/S). For the A/S, a significant difference is evident between groups 1 and 3 and between groups 2 and 3 but not between groups 1 and 2.
*p < 0.05, **p < 0.005, and ***p < 0.0005.

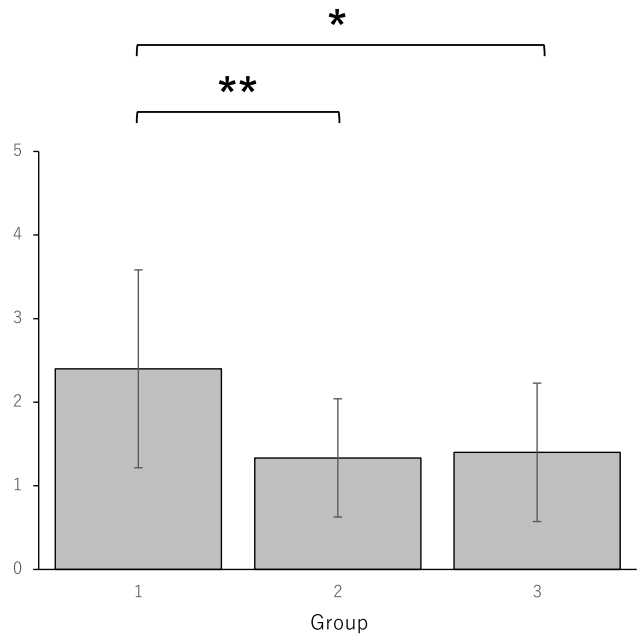

Fig. 4. Subjective symptom scores
* $p < 0.05$, **$p < 0.005$.

flow to the flap. However, there were no cases of flap necrosis in the main trunk and complete preservation groups, while one male patient of total flap necrosis in the zero preservation group. This result suggested that the crossed perforator did not have a significant influence on the blood supply to the flap. Indeed, most perforators from the radial artery are located in the distal third of the forearm [10]. Therefore, even if one perforator is sacrificed, the blood supply to the flap is maintained by the other perforators.

The preservation of the SBRN did not always prevent sensory disturbances at the flap donor-site. Occasionally, a minor nerve injury during flap harvest resulted in temporary sensory disturbances. In most cases, these symptoms were relieved spontaneously with the regeneration of the damaged axons of the injured nerve. In previous studies, many patients reported a gradual improvement in sensation at the flap donor-site [11,12]. Sensory recovery began several months after surgery and reached a plateau at or after two years [13]. Therefore, the average observation period in our study was approximately two years, and we excluded patients without a minimum postoperative follow-up period of six months. The long-term follow-up reduced time-dependent variance and clarified the influence of SBRN preservation on sensory disturbances. Group 1 had a longer follow-up period than those of groups 2 and 3 because the patients in group 1 were principally operated on during the early stages of our careers when we sacrificed the SBRN to reduce the operative time. However, this finding did not reduce the validity of our research because groups 2 and 3 had sufficient follow-up periods.

The incidence of sensory disturbance is not always associated with the development of clinical symptoms. Chambers et al. conducted subjective and objective sensory evaluations of the RF flap donor-site where the SBRN was preserved. Of the 17 patients studied, 14 (82.4%) had objective sensory deficits, but only three (17.6%) complained of any clinical symptoms [14]. It is necessary to evaluate both the subjective and objective sensory scores to clarify the significance of SBRN preservation during flap harvest. We performed an objective sensory evaluation using the SW test as well as a subjective symptom survey. The SW test is a non-invasive test that imposes no physical burden on the patients. This benefited the patients as they recognized the degree of sensory disturbance, which enabled them to prevent trauma in their daily lives.

Our strategy for SBRN preservation is shown in Fig. 5. We preserved the main trunk of the SBRN during the RF flap harvest. The branches of the SBRN were assessed to determine whether there was a perforator crossing site. If perforator crossing was evident, we chose whether the branch or perforator was preserved. Although the complete preservation of the SBRN (preserving the branch and sacrificing the perforator) was the best option to reduce flap donor-site sensory disturbances, the main trunk preservation method (sacrificing the branch and preserving the perforator) did not result in serious consequences.

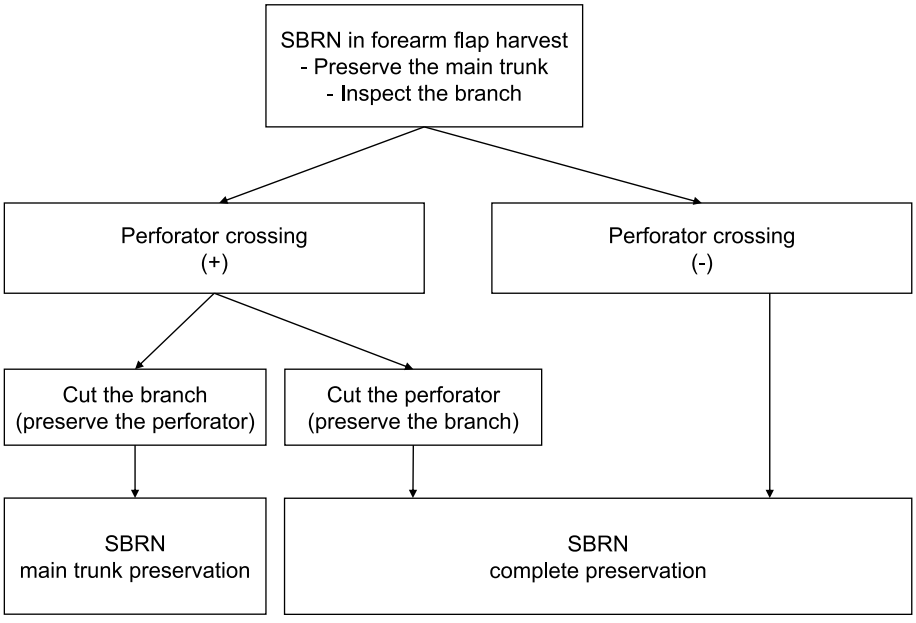

Fig. 5. SBRN preservation strategy
Abbreviations: SBRN, superficial branch of the radial nerve.

The limitations of the present study included its retrospective study design and several confounding factors. The follow-up period was not equalized among the three groups. In addition, the influence of dual innervation from several nerves was not considered. The dorsal thumb and snuff box were primarily innervated by the SBRN; however, they were also innervated by the digital nerve of the thumb (a branch of the median nerve) [15]. Despite no significance, the average SW threshold tended to be lower in the distal part of the thumb than in the proximal part of the thumb. This phenomenon could be explained by the influence of the digital nerve; however, it had a limited impact on the present findings.

5. Conclusion

We investigated the influence of the SBRN preservation methods on the postoperative sensory disturbances at the flap donor site. Despite identifying the complete preservation method as the best technique for RF flap harvest, the main trunk preservation method should be considered while excising the branch of the SBRN to preserve the perforator from the radial artery. However, sacrificing the perforator instead of the branch of the SBRN did not influence the flap survival rate.

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Declaration of competing interest

None.

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none.

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