Original Article

# Breast reconstruction with absorbable mesh sling: dynamic infrared thermography of skin envelope

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**Background:** To immediate reconstruct ptosis breasts, we used polyglactin (Vicryl; Ethicon Inc., Somerville, NJ, USA) mesh as an inferolateral sling. However, Vicryl mesh is absorbable and losing function as a supporting structure. We doubt about the stability of the blood supply to the inferior part of the flap when it is in direct contact with inner implant. In this study, we examine the complications and the safety of the skin flap of this absorbable mesh sling (AMS) procedure.

**Methods:** The outcomes of 80 cases were examined, and the 1-year safety record of 40 cases was assessed. Complications were divided into minor complications, major complications requiring surgical intervention, and major complications requiring the reconstructive surgery to be halted. In addition, we examined the blood perfusion of the skin flap by dynamic infrared thermography (DIRT).

**Results:** Among 80 patients with AMS procedure, 73 breasts were reconstructed immediately and in one-stage. Complication outcomes are presented; there were 4 cases of minor flap necrosis (5%) and 4 of major complications resulting in surgical correction (5%). One patient required additional surgery, and the implant was moved into the musculocutaneous flap (1.3%). In 40 patients 1 year after surgery, DIRT showed significant decreased of blood perfusion in the ipsilateral inferior sites in comparison with the superior sites.

**Conclusions:** Blood perfusion was comparably insufficient in the inferior area of the reconstructed breast mound with AMS, where the pectoralis muscle could not be used to line the inside of the envelope. However, there were no severe flap complications due to ischemia.

**Keywords:** Breast reconstruction; Vicryl mesh; one-stage; implant reconstruction; dynamic infrared thermography (DIRT)

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## Introduction

In 2013, Japanese public health insurance began to pay for prosthesis-based breast reconstruction. Commonly, to reconstruct a breast mound with an implant, a skin flap must be preserved that is wide enough and broad enough to completely cover the surface of the implant. A muscle also must be covered with an implant. The skin flap should not only be wide enough to cover the entire implant, but it should also be healthy, with a good blood supply. Covering the implant with muscle is also important to prevent flap necrosis, which could cause implant exposure. So implants have been placed in a submuscular space, and the subpectoral space is typically used in such implant-based procedures, including breast augmentation.

At the case of immediate reconstruction, these are two big matters. First, total mastectomy requires the removal of a large ellipse of skin that includes the nipple-areolar complex (NAC), so it is too tight to reconstruct breast immediately. Therefore, in 1991, skin sparing mastectomy (SSM) was first performed by Toth and Lappert (1). Also, in same year, Kroll reported on their experience with 100 breast cancer patients undergoing SSM and immediate reconstruction (2). Moreover, nipple-sparing mastectomy (NSM) technique was reported. It is similar to SSM, but spares the NAC, and hence (3), has an advantage over SSM in completely preserving the breast skin. The first matter was resolved by this technique. Second, in NSM followed implant-based reconstruction, it is difficult to make a complete muscle pocket (combined the pectoralis major muscle and the serratus anterior muscle), especially in the case of ptosis breast. So, the one-stage reconstruction method should be abandoned, and instead a tissue expander should be used to stretch the muscle-envelope, even if enough of the skin flap was conserved. To address this problem, Breuing reported a new procedure using an acellular cryopreserved dermal matrix [AlloDerm®: bioprosthetic material manufactured from human cadaveric or animal sources (4)] sling to reestablish the lower pole of the pectoralis major muscle (5). For this technique to be effective, a subpectoral-sub-AlloDerm pocket could be created that completely encloses the breast implant. Then, by tailoring the width of the AlloDerm, the degree of lower-pole fullness can be adjusted. Indeed, acellular dermal matrices have allowed greater pocket control (6,7), and have improved cosmetic outcomes (8). Unfortunately, this material is very expensive and is not available Japan. As a substitute for AlloDerm, Tessler used polyglactin 910 (Vicryl; Ethicon Inc., USA) mesh for an inferior-lateral sling in one-stage, prosthetic-based reconstruction and reported excellent results (9). However, Vicryl mesh is resorbed three to 4 weeks after implantation, consequently losing function as a supporting structure. There remain strong doubts about the stability of the blood supply to the inferior part of the flap when it is in direct contact with inner implant.

To assess the safety of the skin flap perfusion of this absorbable mesh sling (AMS) procedure, we performed thermography to measure flap temperature using dynamic infrared thermography (DIRT) technique (10,11). DIRT is based on the relationship between dermal perfusion and the rate of change in skin surface temperature following transient thermal changes (12,13).

In this study, we examine the complications and the results of DIRT in 40 patients, 1 year after undergoing breast reconstruction with the AMS procedure. And we consider the safety of the skin flap of this procedure.

## Methods

### *Patients*

We have performed implant based breast reconstruction in 202 patients since October 2010. In April 2014, we began using a Vicryl mesh sling to anchor the pectoralis major muscle to the chest wall. We have already performed the procedure on 80 patients (81 breasts) who underwent NSM, 73 of which, underwent immediate, one-stage breast reconstruction. After obtaining informed consent by each patients and approval from the institutional ethics board of the Japanese Red-Cross Society of Himeji, we conducted a retrospective review of all breast implant based reconstruction procedures.

After consensus was reached through discussion in our breast surgery team, oncologists, board certified in their specialty, made the final determination about patient selection, indications for mastectomy technique, and the ability to immediately perform expander or implant based breast reconstruction. Candidates for the NSM procedure were carefully selected according to the NCCN practitioner's guidelines: "*patients with early-stage, biologically favorable breast cancer that is peripherally located in the breast*" (14).

Also in cases that the NAC had to be removed, an effort was made to perform a one-stage reconstruction using an applicable cohesive gel when possible. If the flap became too tight, and was insufficient to cover the implant, the reconstruction-procedure was converted from a one-stage into a two-stage procedure using a tissue expander (5 cases in 80 cases, *Table 1*). Then, within 1 month to 2 months, we would inflate the expander, and enlarge the pocket enough to implant the desired cohesive gel. All procedures were completed before the next scheduled radiotherapy.

### *Surgical technique*

The operations were performed under general anesthesia. On a case-by-case basis, sentinel lymph node biopsy or axillary lymph node dissection was performed (*Table 1*). Surgery of the axilla did not influence the indication for, or the type of breast reconstruction procedure, aside from the skin incision. The surgeon made an incision in the skin on the inframammary line or the line around the nipple-areolar circle, and extending it to the axilla.

**Table 1** Characteristics (total n=80, 81 breasts)

| Characteristics | Data |
|---|---|
| Age, mean ± SD [range] (years) | 46.0±8.4 [22–66] |
| Main site (n) | |
| Center | 10 |
| Upper-median | 21 |
| Lower-median | 8 |
| Upper-lateral | 31 |
| Lower-lateral | 4 |
| Multiple | 6 |
| Nipple preserved (NSM) (n) | 61 |
| Nipple not-preserved (SSM) (n) | 19 |
| Axillary dissection (n) | |
| SLNB | 44 |
| Level II | 34 |
| Adjuvant chemotherapy done (n) | 44 |
| Adjuvant radiotherapy done (n) | 14 |
| Operation duration, mean ± SD [range] (min) | 151.6±43.7 [42–262] |
| Immediate, one-stage (n=73) | 153.0±39.9 [76–262] |
| Immediate, two-stage (n=5) | 173.6±46.6 [113–239] |
| Delayed [range] (n=2)* | 50 [40–60] |
| Blood loss, mean ± SD [range] (mL) | 139.4±92.8 [0–380] |
| Immediate, one-stage (n=73) | 139.8±87.7 [20–380] |
| Immediate, two-stage (n=5) | 190.0±122.8 [80–350] |
| Specimen volume, mean ± SD [range] (g) (uncertain n=3) | 203.4±103.8 [50–506] |
| Immediate, one-stage (n=73) | 201.9±106.9 [50–506] |
| Immediate, two-stage (n=5) | 207.2±44.9 [160–289] |
| Implant/specimen ratio, mean ± SD [range] (uncertain n=3) | 1.41±0.43 [0.78–2.63] |

*, Vicryl mesh was used to sew an open-seam in the muscle pocket, and reform the ruptured capsule. In these cases, a part of the capsule could be identified only around the pectoralis major muscle. NSM, nipple-sparing mastectomy; SSM, skin sparing mastectomy.

First, the breast was resected the layer of superficial fascia. After reaching the nipple, the sample specimen was removed for intraoperative pathological examination by frozen section. If the sample specimen showed signs of malignant cancer, the procedure was changed from NSM to SSM, and the NAC was resected. Including the nipple, if the immediate pathological examination revealed malignancy in the flap, e.g., at the site above the tumor, the skin resection was widened. If the area of the flap was of insufficient size to cover the entire implant, the procedure was converted from a one-stage reconstruction procedure to a two-stage procedure.

After completion of NSM, the reconstructive technique was begun with the elevation of a subpectoral pocket. Detachment of the pectoralis major muscle from the sternum, for example for the right breast, proceeded to the 6- and 10-o'clock levels, with adjustments made as necessary to accommodate the desired implant (*Figure 1A*).

In principle, at least one saline sizer, the best cohesive gel from the preselected candidates, was then chosen based on mastectomy weight and measurements of the patient's breast base diameter. The sizer was then placed into the partial subpectoral pocket and filled with normal saline to the desired volume. A marking pen was then used to trace the projected outline of the implant to assist tacking of the Vicryl knitted mesh in the proper position.

The knitted Vicryl mesh was then sutured into place using 4-0 Vicryl sutures, ensuring proper lateral and inferior fold placement. After securing the inferior and lateral mammary folds, the sizers were placed into the pocket. The skin flaps were stapled closed; and the patient was placed in a seated position to observe symmetry, contour, and proper fold placement. The patient was then returned to the supine position. The final implant was chosen and placed in the pocket, and the Vicryl mesh was secured to the pectoralis muscle with Vicryl 4-0 sutures (*Figure 1B*). Suction drains were placed through a tunnel of subcutaneous tissue and placed in the suprapectoral and subcutaneous spaces. Adjustments were made as necessary, hemostasis was ensured, and the wound was then closed.

### *Assessment of complications*

We examined the outcomes for 80 patients undergoing this AMS procedure, and safety was assessed in 40 patients 1 year after the procedure was performed. Complications were divided into minor complications, major complications requiring surgical intervention, and major complications requiring the reconstruction procedure to be halted, and examined according to onset in the post-operative period.

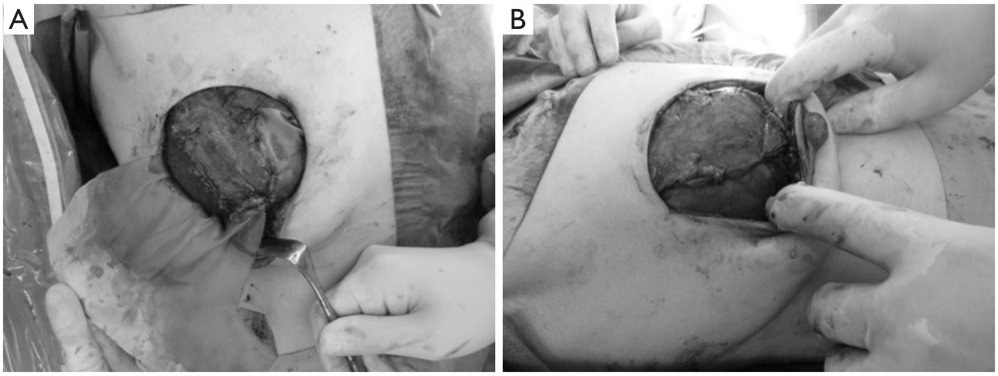
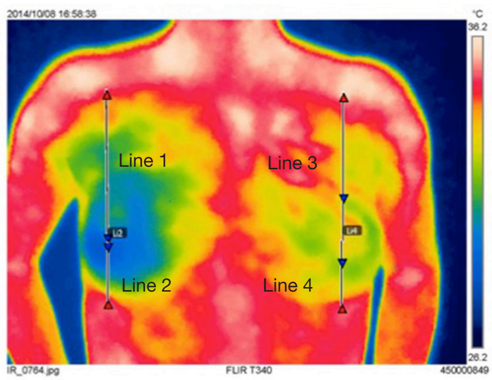



**Figure 1** This was a NSM performed on a 53-year-old patient. (A) The edge of Vicryl mesh was anchored in place, ensuring proper lateral and inferior mammary fold placement; (B) the mesh was trimmed to the shape of the pectoralis major muscle and desirable pocket size, and secured to the muscle stump. NSM, nipple-sparing mastectomy.




| Measure | | °C |
|---|---|---|
| Li1 | Max | 34.7 |
| | Mn | 29.0 |
| | Average | 31.5 |
| Li2 | Max | 34.9 |
| | Mn | 28.9 |
| | Average | 30.8 |
| Li3 | Max | 35.7 |
| | Mn | 32.4 |
| | Average | 33.4 |
| Li4 | Max | 34.8 |
| | Mn | 32.0 |
| | Average | 32.8 |

**Figure 2** This patient was performed NSM and immediate breast reconstruction of right breast 12 months ago. We monitored skin surface temperatures by a FLIR infrared camera and analyzed using the FLIR software (FLIR Tool®, FLIR System). Temperature data were obtained along four lines, from the nipple to the center of the clavicle (s-line) at ipsilateral and contralateral breast mounds each other (line 1, 3), and from the nipple to the inframammary line (i-line) at ipsilateral and contralateral breast mounds each other (line 2, 4). NSM, nipple-sparing mastectomy.

### *Assessment of perfusion in skin flap and DIRT*

The perfusion of skin flaps on reconstructed breast mounds was examined in terms of the appearance of a low-perfusion area by DIRT. A FLIR (FLIA T340, FLIR Systems Inc., 27700 SW Parkway Avenue, Wilsonville, OR 97070, USA. Email: webmaster@flir.com) infrared camera was used to monitor skin surface temperatures. An accuracy of 0.1 ℃ in measurements was obtained. Infrared thermal images were taken at regular intervals to analyze the rate and the pattern of rewarming. First, a picture was taken and thermography was performed on the breast, before cooling stress was applied, in the upright position. Next, the candidate was placed in the supine position and both breast mounds were covered with ice-water packs. The chest wall was cooled broadly and uniformly for 10 seconds. Then the patient was placed in the standing position to perform dermal thermography and monitor the changes in dermal temperature, immediately, 5, and 10 minutes after cooling.

Each thermographic scans were analyzed using the FLIR software (FLIR Tool®, FLIR System). Temperature data were acquired along two lines, from the nipple to the center of the clavicle (superior line: s-line), and from the nipple to the inframammary line (inferior line: i-line). The software calculated the following data: maximum, minimum, and average temperature on each line (*Figure 2*). Average temperatures were determined from the lines of the thermographs at the following points: initial (before cooling) and, immediately, 5, and 10 minutes after cooling and, from ipsilateral and contralateral breast mounds.

From the initial thermography, uniformity was assessed on each side and the difference between the upper and lower sides, and the symmetric property between the ipsilateral and contralateral sides.

When performing DIRT, we could not cool the flap uniformly in every patient. Therefore, a linear graph of the

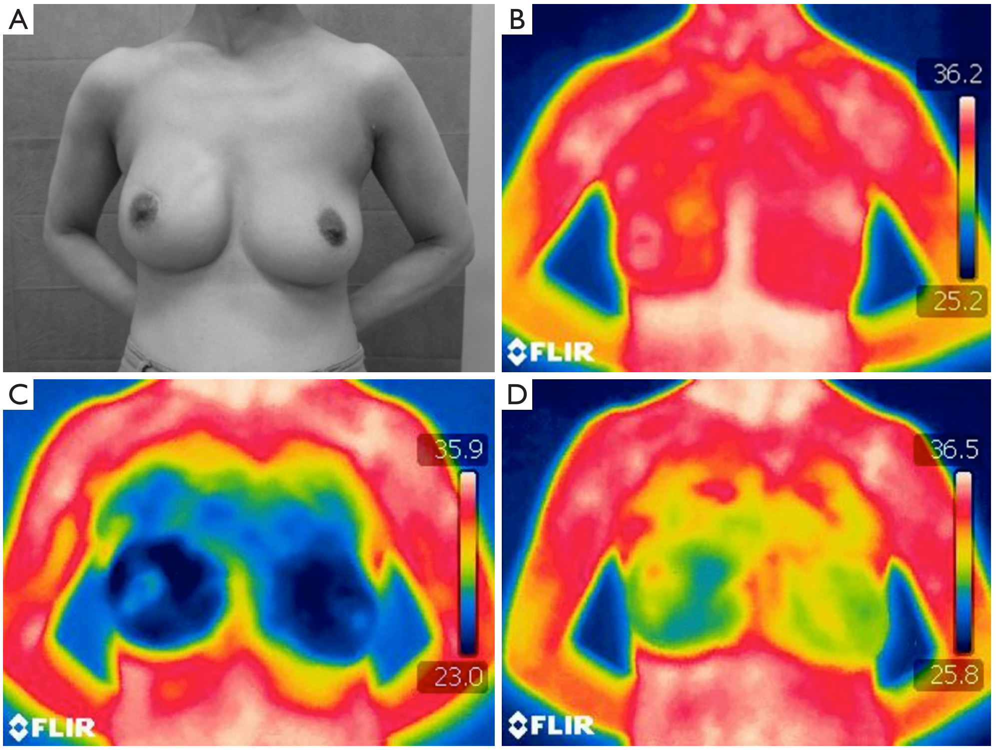



**Figure 3** We showed the sample of DIRT. She was 46-year-old, performed right NSM procedure 12 months prior. No surgical alterations were performed on the contra-lateral side. (A) A normal picture before cooling; (B) the thermography of the initial state, in the upright position. The skin temperature was almost symmetric; (C) a thermography scan just after cooling; (D) a thermography scan 10 minutes after cooling. We analyzed these pictures using the FLIR software and assessed the temperature of rewarming pattern. DIRT, dynamic infrared thermography; NSM, nipple-sparing mastectomy.

rewarming pattern was drawn using repeated measurements and compared by two-way ANOVA.

In *Figure 3A*, a case of breast ptosis is shown 1 year after NSM and one-stage reconstruction using the AMS procedure, on the right side breast, and the patient did not undergo adjuvant radiotherapy. The cosmetic outcome was excellent, including good flap condition. Before cooling, the skin temperature was almost symmetric, and no cold spot was observed (*Figure 3B*). Once both breasts were cooled using an ice-water bag (*Figure 3C*), and the rewarming pattern was assessed. The difference in rewarming speed, after removal of the cooling stress, between the ipsilateral (right) and contralateral (left) sides, and between the superior and inferior areas in the reconstructed mound are shown in the *Figure 3D*.

### *Statistical analysis*

Initial skin temperature at each site of both breasts (s-lines and i-lines on ipsilateral and contralateral breast) were analyzed with the Student's *t*-test (two-tailed), and normally distributed data are presented as mean ± SD. We performed repeated measurements of skin temperatures in the s-lines and i-lines at three time points (immediately, 5, and 10 minutes after cooling), and data summaries of two groups (e.g., the i-line on the ipsilateral side and the i-line on the contralateral side) were compared using two-way-repeated measures ANOVA. Mauchly's test of sphericity was used to evaluate whether the sphericity assumption was violated. Comparisons were considered significant if $P<0.05$. Statistical analysis was conducted with SPSS statistics, version 22, resource 22.0 for Windows.

## Results

In our center, 80 patients (81 breasts) underwent breast reconstruction using the AMS technique, and 1 year has passed since 40 of these patients underwent the procedure

**Table 2** Complications

| Complications | Number of breasts (%) | Onset (days after surgery) |
|---|---|---|
| Minor complications | | |
| Minor flap necrosis | 4 (5.00) | 4–13 |
| Nipple partial necrosis | 2 | – |
| Infection, conservative treatment | 2 (2.50) | 45, 50 |
| Seroma, treated by percutaneous drainage | 1 (1.25) | 20 |
| Pain/tightness | 1 (1.25) | 1 |
| Subcutaneous bleeding | 1 (1.25) | 20 |
| Major complications requiring surgical correction | | |
| Infection requiring surgical drainage | 3 (3.75) | 48, 52, 56 |
| Major flap necrosis requiring surgical correction | 1* (1.25) | 13 |
| Major complications requiring reconstruction procedure to be halted | | |
| Conversion to autologous-flap-based reconstruction | 1* (1.25) | 13 |
| Total | 8 (10.00) | – |

*, complications in the same patient; and, finally, due to thinning skin at the surgical site, the procedure was converted from implant-based to autologous-flap-based reconstruction.

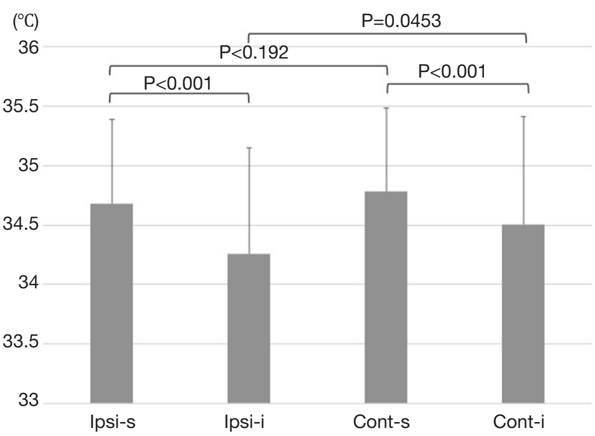


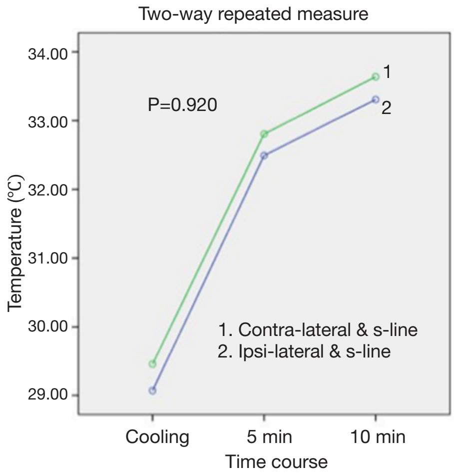

**Figure 4** Surface temperatures in four areas were compared in the initial condition (before cooling stress). The temperature was lowest on the ipsilateral side of the inferior aspect [ipsil-inferior (Ipsi-i) 34.26±0.71, ipsi-superior (Ipsi-s) 34.36±0.89, contra-superior (Cont-s) 34.78±0.70, contra-inferior (Cont-i) 34.50±0.91]. In a comparison of the ipsilateral and contralateral sides, there was a significant difference between the inferior sides (P=0.0453), but not the superior sides (P=0.192).

(*Table 1*). In 73 cases, reconstruction was performed immediately after surgery for breast cancer and in one-stage. Using the AMS technique, the ratio of implant volume to specimen weight was 1.41 on average (range, 0.78–2.63), for patients who underwent immediate, one-stage reconstruction.

Complication outcomes are presented in *Table 2*. Four cases with minor flap necrosis were treated with sharp debridement in the office. Of the 61 nipple-sparing mastectomies, two nipples were affected by partial necrosis, but did not require surgery.

Major complications occurred in 4 cases, requiring surgical correction (5%): *staphylococcus aureus* was isolated from implant pockets. Surgical-site infection occurred in 3 cases (3.75%). In all three cases, axillary dissection had been performed, and infection was diagnosed and confirmed more than 6 weeks after surgery (48, 52, 56 days: primary causative organism was staphylococcus aureus in all cases).

In skin-flap thermography, we compared the surface temperatures in four areas: the superior and inferior areas on the ipsilateral side, and the same on the contralateral side. The average of the line (the "s-line" was drawn from the nipple to the center of the clavicle, and the "i-line", to the center of the infra-mammary line, *Figure 2*) was used as a reference for the temperature of each area. In the initial condition (before cooling stress), the temperature was lowest in the inferior area on the ipsilateral side [ipsil-inferior (Ipsi-i) 34.26±0.71, ipsi-superior (Ipsi-s)



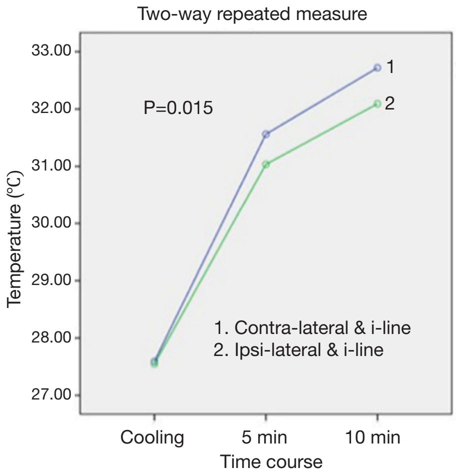




**Figure 5** These graphs are the results of analysis.

34.36±0.89, contra-superior (Cont-s) 34.78±0.70, contra-inferior (Cont-i) 34.50±0.91, *Figure 4*]. The inferior side was significantly cooler than the superior side, even in the healthy side of the breast mound. A comparison of the ipsilateral and contralateral sides revealed a significant difference between the inferior sides (P=0.0453), but not the superior sides (P=0.192).

Two-factor repeated measures ANOVA (within-subject factor and interaction) was performed to analyze the effect of measurement site (ipsilateral or contralateral side), as the independent factor, on rewarming patterns. This analysis was performed to determine relationships between the groups (ipsilateral or contralateral side) and over time, using F test. (The time course was as within-subject factors; immediately, 5, and 10 minutes after cooling: the groups, ipsilateral or contralateral side, were as between-subjects factors: Mauchly's test of sphericity, P=0.500). There was a significant correlation between the time course of rewarming patterns and the ipsilateral or contralateral inferior sites (time course × ipsilateral or contralateral side, df =2, MS =1.900, F=4.456, P=0.015, *Figure 5*). However, there was no significant difference in superior sites (df =2, MS =0.029, F=0.083, P=0.920).

## Discussion

As expected, the skin temperature on the inferior side of the reconstructed mound was cooler than on the healthy side; and, DIRT showed that blood perfusion was comparably poor on the inferior area of the AMS-reconstructed breast mound where the pectoralis muscle could not line the inside of the pocket. However, there have been no complications reported more than 2 months after surgery. Also, breast mounds reconstructed with AMS did not exhibit ischemic changes, and so far, there has been no need to halt reconstruction of a breast mound while using the AMS procedure. One concern of this study is whether poor perfusion of the skin flap, which was observed in the inferior area of breast mounds reconstructed with AMS, would be an indicator of poor prognosis. After the initial favorable time for infection, the breast mounds reconstructed with AMS appear completely complication free 1 year after the procedure was performed.

When comparing the AMS procedure with any other methods, in this regard, however, the overwhelming advantage offered by the AMS procedure should be considered. The design of a prospective study about the feasibility of the AMS procedure should assess not only the cosmetic results, but also categorize them in the immediate, and one-stage reconstruction surgery. In our experience, immediate, one-stage, and prosthesis-based breast reconstruction have been severely limited without using the AMS procedure, because we cannot employ AlloDerm. One-stage reconstruction using autologous tissue (e.g., LDF flap or DIEP flap) is a more invasive surgery and sacrifices the healthy donor site, and thus is an inappropriate comparison. A complete muscle pocket, built for implantation, using pectoralis major and serratus anterior muscles would be impossible for most breasts, especially large breasts with ptosis. We have achieved, on average, an implant volume to specimen weight ratio of 1.41. AMS resolved the imbalance between favorable implant volume and the scant muscles available around the breast. If the serratus anterior muscle was used instead of AMS, we occasionally selected two-stage reconstruction; once the tissue expander was inserted, the flap and muscle pocket were gradually expanded after the initial surgery. Then, the tissue expander was replaced with cohesive gel in the second surgery. Adjuvant radiotherapy is known to complicate the reconstruction process and increase the potential for other complications (15-17).

Given this perspective, if we wish to reconstruct a large breast immediately after surgery for breast cancer in one-stage, our options are extremely limited. The AMS procedure overcomes the limitation of insufficient muscle pocket size for favorable implants. During the first 2 months after reconstruction surgery, when breast mounds are most susceptible to bacterial infections, and for at least 1 year after reconstruction surgery, there have been no ischemic flap complications in breast mounds that we reconstructed with AMS. Based on these findings, we will continue to perform reconstruction using AMS methods. However, DIRT revealed apparently poor perfusion of the skin flap, in the inferior area, where the flap was not lined up with the muscle. In the long term, we should be able to acquire sufficient data regarding flap condition to determine the feasibility of this method.

Our examination has limitations. First, as described above, there was no evidence that poor perfusion in the lower area of AMS-reconstructed breast mounds, as observed during DIRT examination, was indicative of any major complications in the future. Second, we did not compare our DIRT data with data of conventional reconstruction procedures, e.g., latissimus dorsi muscle flap repair or covering the implant with a complete muscle pocket designed from both pectoralis major muscle and serratus anterior muscle.

## Conclusions

Blood perfusion was comparably insufficient in the inferior area of the reconstructed breast mound with AMS, where the muscle could not be used to line the inside of the envelope. However, there were no severe flap complications due to ischemia.

## Acknowledgements

None.

## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

*Ethical Statement:* We obtained informed consent by each patient and approved by the institutional ethics board of the Japanese Red-Cross Society of Himeji.

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