



# Pure hemi-periareolar incision versus conventional lateral radial incision mastectomy and direct-to-implant breast reconstructions: comparison of indocyanine green angiographic perfusion and necrosis of the nipple

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**Background:** This study evaluated the feasibility of direct-to-implant breast reconstruction after nipple-sparing mastectomy using pure hemi-periareolar incision without extension and with the aid of indocyanine green angiographic evaluation on the mastectomy skin flap.

**Methods:** Patients who underwent immediate direct-to-implant breast reconstruction from December 2018 to February 2020 were included. After nipple-sparing mastectomy, indocyanine green angiographic evaluation of perfusion to nipple-areola complex was performed by video recording with a near infrared camera, and nipple perfusion time and perfusion pattern were analyzed. Patients were divided into a pure hemi-periareolar incision group and conventional lateral radial incision groups to compare nipple perfusion and surgical outcomes.

**Results:** A total of 61 breasts in 56 patients were included. Pure hemi-periareolar incision was used in 41 breasts, and conventional lateral radial incisions were used in 20 breasts. Nipple perfusion time was significantly increased in the pure hemi-periareolar incision group ( $79.6 \pm 65.8$  vs.  $43.2 \pm 49.8$  seconds,  $P=0.031$ ). While minor nipple-areola complex necrosis was significantly increased in the pure hemi-periareolar incision group (19.5% versus 0%;  $P=0.044$ ), major nipple-areola complex necrosis (2.4% versus 5.0%;  $P>0.999$ ) was not significantly different between the two groups. The rates of nipple-areola complex necrosis were 0%, 16.7%, and 63.6% in rapid, delayed, and no perfusion groups, respectively ( $P<0.001$ ). No nipple perfusion pattern was a significant predictor for nipple-areola complex necrosis in univariable and multivariable analyses ( $P<0.001$ ). There was no case of reconstruction failure.

**Conclusions:** Immediate direct-to-implant breast reconstruction after nipple-sparing mastectomy using pure hemi-periareolar incision can be safely performed using indocyanine green angiographic evaluation on the mastectomy skin flap.

**Keywords:** Direct-to-implant breast reconstruction; nipple-sparing mastectomy; indocyanine green; nipple-areola complex necrosis; mastectomy skin flap

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## Introduction

Freeman introduced immediate breast reconstruction after mastectomy with preservation of the nipple-areola complex (NAC) in 1962 in a case series of reconstructions after subcutaneous mastectomies for benign breast disease (1). Historically, subcutaneous mastectomy often left significant breast tissue within the skin flaps and at the base of the NAC. This concept was not ideal for prophylaxis or breast cancer treatment and had questionable oncologic safety (2). In the 1990s and 2000s, nipple-sparing mastectomy (NSM) and immediate breast reconstruction was gradually introduced. This method gained popularity for both therapeutic and prophylactic indications based on oncologic and surgical safety evidence and superior cosmetic outcomes (2-5). Preservation of the NAC in NSM indicates that this procedure is both the most conservative mastectomy method and also the most aesthetically appealing as it ensures a natural-appearing nipple (6).

Several different incision types have been suggested for NSM (e.g., inframammary fold, radial, periareolar, transareolar, reduction/mastopexy). Among them, periareolar incision provides advantages of a well-hidden incision scar within the periphery of the NAC and central access to all breast quadrants during mastectomy (7). Furthermore, postoperative NAC malpositioning can be minimized, unlike with radial incisions. Despite these advantages, some surgeons are reluctant to choose periareolar incision, mainly due to the potential high rate of postoperative nipple necrosis (8,9).

Studies have shown that intraoperative use of indocyanine green (ICG) angiography identifies areas of decreased perfusion and predicts mastectomy skin flap necrosis (10-14). Recently, Bilezikian *et al.* reported that prepectoral direct-to-implant (DTI) reconstruction can be safely performed in postmastectomy patients using ICG angiography and extended use of acellular dermal matrix (15). In this study, we present initial results of DTI breast reconstructions with acellular dermal matrix after NSM using pure hemi-periareolar incision with intraoperative ICG angiography. The secondary objective was to identify predictors for NAC necrosis by analyzing ICG angiographic perfusion images of the NAC. We present the following article in accordance with the STROBE reporting checklist (available at <http://dx.doi.org/10.21037/gs-20-506>).

## Methods

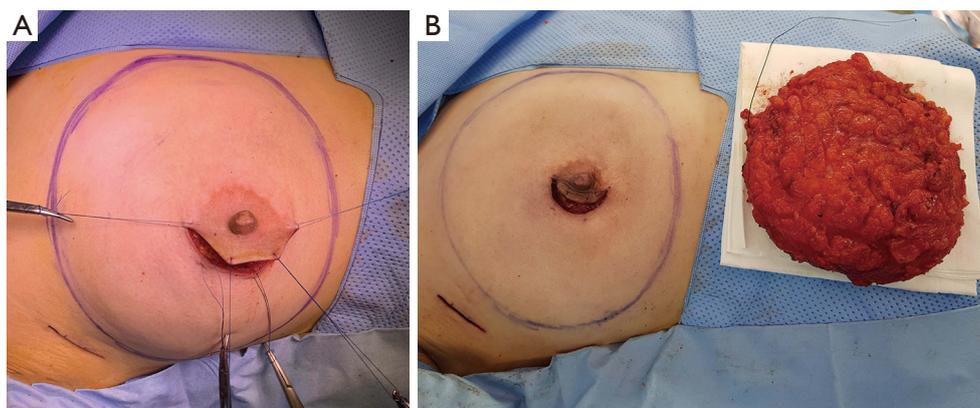
### *Patient cohort*

Prospectively recorded data from consecutive patients who underwent immediate DTI reconstruction with an acellular dermal matrix after NSM at our institution between December 2018 and February 2020 were retrospectively reviewed. The study was approved by the Institutional Review Board of Ewha Womans University Mokdong Hospital (IRB No. 2020-03-028) and performed in accordance with the principles of the Declaration of Helsinki (as revised in 2013). Individual consent for this retrospective analysis was waived. Patients who were followed up for at least 1 month postoperatively were included. Patients who had a previous breast procedure, including breast conserving surgery for previous malignancy, augmentation mammoplasty, mastopexy, and reduction mammoplasty, and a history of radiation therapy were excluded from this study. Three experienced oncologic surgeons with over 10 years of experience performed mastectomy, and the senior author (KJW) performed reconstructions.

### *Surgical technique*

The method of skin incision for mastectomy was selected based on surgeon preference, breast size, areola size, and tumor location. Three skin incision methods were used, including pure hemi-periareolar incision, lateral radial incision, and lateral radial incision with periareolar extension. Mastectomy using pure hemi-periareolar incision was performed using a semicircular incision along the NAC and no extensions, as previously described (*Figure 1*) (16). Indications for pure hemi-periareolar incisions include mastectomy candidates without nipple-areolar complex invasion (17).

Electrocautery dissection was used for all mastectomy procedures, and endoscopic devices were not used. The extent of dissection for mastectomy did not exceed the inframammary fold inferiorly, and sizable intercostal perforators at the 2nd or 3rd intercostal spaces were preserved medially to minimize necrosis of the mastectomy skin flap. After mastectomy, a breast sizer of similar size to the mastectomy specimen was temporarily placed in the mastectomy pocket. While the temporary sizer was



**Figure 1** Nipple-sparing mastectomy using pure hemi-periareolar incision. (A) A semicircular incision along the nipple-areolar complex was made. (B) Photograph taken after completion of nipple sparing mastectomy with pure hemi-periareolar incision.

in place, nipple perfusion was evaluated using a near-infrared camera (Moment K; IANC&S, Seoul, Korea). After administering 12.5 mg of ICG (25 mg ICG mixed with 5 mL normal saline, Dongindang Pharm., Siheung, Korea) followed by a 10 mL saline flush, video recordings were obtained from when fluorescence was started to visualize the mastectomy skin flap. Recordings continued for 180 seconds. DTI reconstruction proceeded if any fluorescence was observed in the lateral half of the areola (at least 50% of areola) by ICG angiography. In patients who could not afford a large acellular dermal matrix, had a thin mastectomy skin flap which can cause significant rippling, or had decreased areolar perfusion by ICG angiography, the implant was placed in the subpectoral space. An acellular dermal matrix (human cadaveric) was used for inferior and lateral support and implant coverage. Otherwise, implants were completely wrapped with the 16 cm × 16 cm or 18 cm × 18 cm acellular dermal matrix (human cadaveric), and the wrapped implant was placed in pre-pectoral spaces without suture fixation. Two closed suction drains were placed in the subpectoral and prepectoral spaces for subpectoral reconstruction and in the upper and lower pole of the prepectoral spaces for prepectoral reconstruction. Partial trimming of the areola for a width of 1 to 5 millimeters was determined by ICG angiographic findings, and mastectomy skin flaps with a width of 1 millimeter were performed in a routine manner to avoid compromised skin margins. Drains were removed when the drainage amount was less than 30 mL over 24 hours for two consecutive days. Prophylactic antibiotics were administered until drain removal.

### *Data collection*

Patients were divided into two cohorts of pure hemi-periareolar incision and conventional lateral radial incision groups. Clinical characteristics, operative characteristics, and surgical outcomes were compared between the two groups. The primary outcome was development of NAC necrosis, including major and minor necrosis. Major necrosis was defined as full-thickness necrosis requiring surgical intervention. Minor necrosis was defined as partial-thickness necrosis treated with conservative management. Other postoperative complications, including seroma, hematoma, and infection, were also assessed.

ICG angiographic findings were reviewed with video clips to identify clinically relevant variables of NAC necrosis. Nipple perfusion time was defined as the time interval between visualizing fluorescence on the mastectomy skin flap and nipple and measured. Nipple perfusion time was recorded as 180 seconds when the nipple was not visualized for 180 seconds. Patients were divided into three groups: rapid perfusion, delayed perfusion, and no perfusion. Rapid perfusion was defined as nipple perfusion time less than the median value of overall patients. Delayed perfusion was defined as nipple perfusion time equal to or more than the median value, but less than 180 seconds. No perfusion was defined as when the nipple was not visualized for 180 seconds.

### *Statistical analysis*

Mean and standard deviation were used to summarize continuous variables, and frequency and proportion were

used to demonstrate categorical variables. Clinical and operative variables were compared between groups using two-sample *t*-test or Mann-Whitney U test for continuous variables and Fisher's exact test and linear-by-linear association test for categorical variables. The selection of statistic test was based on the results of normality test. Binary logistic regression analysis was performed to analyze the effect of each clinical variable on binary outcomes. Variables with  $P < 0.20$  in univariable analysis were entered into a multivariate analysis. Multivariate analysis was performed using stepwise logistic regression, and adjusted odd ratios were reported with 95% confidence intervals. Statistical significance was determined by  $P < 0.05$ . All analyses were performed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA).

## Results

Among 60 patients who underwent DTI breast reconstructions after NSM in the study period, 56 met the inclusion criteria and were included in this study. Two patients were excluded due to previous augmentation mammoplasty, and the remaining 2 patients had a history of breast conserving surgery. The 56 patients with an average age of 46.8 years old (range, 32 to 64 years) had 61 DTI breast reconstructions following NSM using pure hemi-periareolar incision ( $n=41$ ) or conventional lateral radial incisions ( $n=20$ ), including radial incision ( $n=15$ ) and lateral radial incision with periareolar extension ( $n=5$ ). The average body mass index was  $22.3 \text{ kg/m}^2$  (range, 17.7 to 27.2), and implant volume was 296.5 mL (range, 150 to 550 mL). There were no significant differences between the pure hemi-periareolar incision group and the conventional lateral radial incision group in age, body mass index, hypertension, diabetes, smoking history, previous chemotherapy, mastectomy specimen weight, implant volume and position, sternal notch to nipple distance, and surgery duration. Sentinel lymph node biopsy was performed more often in the pure hemi-periareolar incision group than in the conventional lateral radial incision group (78.0% versus 35.0%), and axillary lymph node dissection was performed more in the conventional lateral radial incision group than in the pure hemi-periareolar incision group (14.0% versus 60.0%). Differences in lymph node management between the two groups were significant ( $P=0.001$ ). Duration of drain use was significantly decreased in the pure hemi-periareolar incision group compared to the conventional lateral radial incision group (9.9 versus 12.1 days;  $P=0.007$ )

(Table 1).

The complication profiles of the pure hemi-periareolar incision group and conventional lateral radial incision group are summarized in Table 2. Development of NAC necrosis was more common in the pure hemi-periareolar incision group than in the conventional lateral radial incision group, but the difference was not statistically significant (22.0% versus 5.0%, respectively;  $P=0.144$ ). Among NAC necrosis components, minor necrosis was significantly increased in the pure hemi-periareolar incision group compared to the conventional lateral radial incision group (19.5% versus 0%, respectively;  $P=0.044$ ), while major necrosis was not significantly different between the two groups (2.4% versus 5.0%, respectively;  $P > 0.999$ ). There were no significant differences between the two groups in incidence of seroma, hematoma, and infection ( $P > 0.999$ ). Overall complication rate was also not significantly different between the two groups (22.0% versus 5.0%, respectively;  $P=0.144$ ). No reconstruction failure was observed in either group ( $P > 0.999$ ).

Evaluation of ICG angiographic variables showed that median nipple perfusion time was 36.0 seconds. This was used as a reference point to divide rapid perfusion and delayed perfusion groups (Video 1). The mean nipple perfusion time was significantly increased in the pure hemi-periareolar incision group compared to the conventional lateral radial incision group (79.6 versus 43.2 seconds;  $P=0.031$ ), but the nipple perfusion pattern was not significantly different between the two groups ( $P=0.226$ ; Table 3). Subgroup analysis was then performed to evaluate the association between ICG angiographic variables and NAC necrosis in the pure hemi-periareolar incision group. Patients were divided into two groups, the NAC necrosis group ( $n=9$ ) and no necrosis group ( $n=32$ ). Nipple perfusion time was significantly higher in the NAC necrosis group than in the no necrosis group (166.0 versus 55.3 seconds;  $P < 0.001$ ; Figure 2). The rapid, delayed, and no perfusion groups showed 0% (0/17 breasts), 22.2% (2/15 breasts), and 77.8% (7/9 breasts) incidence rates of NAC necrosis, respectively. Differences in the NAC necrosis rate among the three perfusion patterns were statistically significant ( $P < 0.001$ ; Figure 3).

In univariable analysis, nipple perfusion time (OR 1.027; 95% CI: 1.013–1.042;  $P < 0.001$ ) and nipple perfusion pattern (OR 5.236; 95% CI: 2.244–12.217;  $P < 0.001$ ) were significantly associated with the development of NAC necrosis (Table 4). In multivariable analysis, nipple perfusion pattern was the only predictor for NAC necrosis

**Table 1** Clinical and surgical characteristics

	Overall patients (%)	Pure hemi-periareolar incision (%)	Conventional lateral radial incision (%)	P
No. of patients	56	36	20	
No. of breasts	61	41	20	
Mean age $\pm$ SD, yr	46.8 $\pm$ 8.2	46.9 $\pm$ 7.4	46.6 $\pm$ 9.8	0.779
Mean BMI $\pm$ SD, kg/m <sup>2</sup>	22.3 $\pm$ 2.6	22.4 $\pm$ 2.8	22.1 $\pm$ 2.2	0.775
Hypertension	5 (8.9)	4 (11.1)	1 (5.0)	>0.999
Diabetes	3 (5.4)	2 (5.6)	1 (5.0)	>0.999
Smoking history	3 (5.4)	2 (5.6)	1 (5.0)	>0.999
Previous chemotherapy	9 (16.1)	6 (16.7)	3 (15.0)	>0.999
Mastectomy weight $\pm$ SD, g	248.1 $\pm$ 133.9	242.5 $\pm$ 135.7	259.5 $\pm$ 132.7	0.490
Implant volume $\pm$ SD, mL	296.5 $\pm$ 98.0	297.9 $\pm$ 99.7	293.5 $\pm$ 96.7	>0.999
Implant position				0.283
Prepectoral	31 (50.8)	23 (56.1)	8 (40.0)	
Subpectoral	30 (49.2)	18 (43.9)	12 (60.0)	
Sternal notch to nipple distance <sup>†</sup>	22.0 $\pm$ 2.4	22.0 $\pm$ 2.2	22.0 $\pm$ 2.8	0.661
Axillary lymph node management				0.001*
None	4 (6.6)	3 (7.3)	1 (5.0)	
SLNB	39 (63.9)	32 (78.0)	7 (35.0)	
ALND	18 (29.5)	6 (14.6)	12 (60.0)	
Duration of drain insertion $\pm$ SD, day	10.6 $\pm$ 2.9	9.9 $\pm$ 2.4	12.1 $\pm$ 3.3	0.007*

SD, standard deviation; BMI, body mass index; SLNB, sentinel lymph node biopsy; ALND, axillary lymph node dissection. \*Statistically significant; <sup>†</sup>Sternal notch to nipple distance was measured using Crisalix 3D Surface Imager (Crisalix, S.A., Lausanne, Switzerland).

**Table 2** Comparison of complication profiles between pure hemi-periareolar incision and conventional lateral radial incision groups

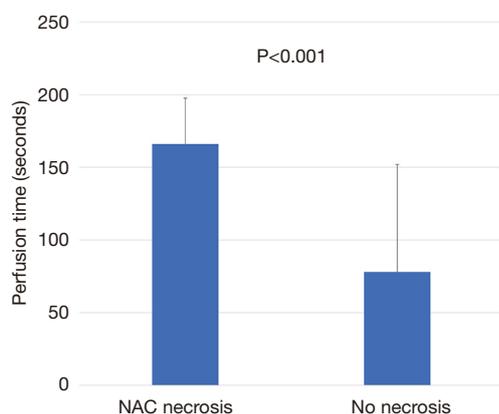
Complications	Overall (n=61)	Pure hemi-periareolar incision (n=41)	Conventional lateral radial incision (n=20)	P
NAC necrosis, n (%)	10 (16.4)	9 (22.0)	1 (5.0)	0.144
Minor necrosis	8 (13.1)	8 (19.5)	0	0.044*
Major necrosis	2 (3.3)	1 (2.4)	1 (5.0)	>0.999
Seroma, n (%)	2 (3.3)	1 (2.4)	0	>0.999
Hematoma, n (%)	1 (1.6)	1 (2.4)	0	>0.999
Infection, n (%)	1 (1.6)	1 (2.4)	0	>0.999
Overall complication, n (%)	10 (16.4)	9 (22.0)	1 (5.0)	0.144
Reconstruction failure	0	0	0	>0.999

NAC, nipple-areola complex. \*Statistically significant.

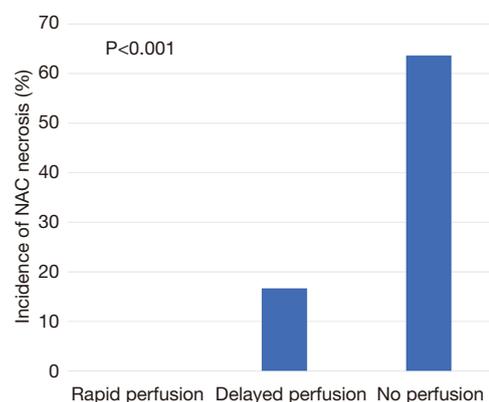
**Table 3** Comparison of indocyanine green angiographic variables between pure hemi-periareolar incision and conventional lateral radial incision groups

Complications	Overall (n=61)	Pure hemi-periareolar incision (n=41)	Conventional lateral radial incision (n=20)	P
Nipple perfusion time $\pm$ SD, seconds	67.6 $\pm$ 63.0	79.6 $\pm$ 65.8	43.2 $\pm$ 49.8	0.031*
Nipple perfusion pattern, n (%)				0.226
Rapid perfusion	30 (49.2)	17 (41.5)	13 (65.0)	
Delayed perfusion	20 (32.8)	15 (36.6)	5 (25.0)	
No perfusion	11 (18.0)	9 (22.0)	2 (10.0)	

SD, standard deviation. \*Statistically significant.



**Figure 2** Nipple perfusion time was compared between NAC necrosis group (n=9) and no necrosis group (n=32) in subgroup analysis of patients with pure hemi-periareolar incision. NAC necrosis group showed significantly increased perfusion time compared to no necrosis group (P<0.001). NAC, nipple-areola complex.



**Figure 3** In analysis of perfusion pattern, significant differences in incidence of NAC necrosis were observed among rapid, delayed, and no perfusion groups (0/17, 2/15, and 7/9 breasts, respectively; P<0.001). NAC, nipple-areola complex.

with statistical significance (Table 5). The odds of NAC necrosis in the no perfusion group was 5.2 times that in the other perfusion pattern group. Figures 4,5 show example preoperative and postoperative photographs of patients undergoing DTI reconstructions after mastectomy using pure hemi-periareolar incisions.

## Discussion

We demonstrated the surgical outcomes of DTI breast reconstructions after NSM using pure hemi-periareolar incision without extension. Complications of the mastectomy skin flap were minimized with intraoperative evaluation of mastectomy skin flap circulation by ICG

angiography. In the pure hemi-periareolar incision group, full-thickness necrosis of the NAC was observed in only 2.4% of cases (1/41 cases) and all 8 cases of minor necrosis (19.5%) healed spontaneously with conservative management. By using pure hemi-periareolar incisions, each procedure achieved dual aims of extirpative surgery and breast reconstruction. All four quadrants of the breast and axillary lymph nodes were adequately accessed when performing extirpative procedures for breast cancer because of central access provided by the incision. For breast reconstruction, visible scar was minimized and nipple malpositioning could be prevented, which can result from scar contracture in radial incisions.

Several incision methods have been suggested for NSM, including radial, inframammary fold, periareolar, transareolar, and reduction/mastopexy incisions. The inframammary fold incision is currently gaining popularity

**Table 4** Univariable analysis of clinical and indocyanine green angiographic variables for nipple-areola complex necrosis

Variables	Unadjusted OR (95% CI)	P
Age	1.068 (0.980–1.164)	0.132
BMI	0.973 (0.749–1.264)	0.836
Hypertension	1.306 (0.130–13.080)	0.821
Diabetes	2.722 (0.223–33.279)	0.433
Smoking history	NA <sup>†</sup>	NA <sup>†</sup>
Previous chemotherapy	0.597 (0.066–5.387)	0.646
Incision type		
Conventional lateral radial incisions	Ref.	Ref.
Pure hemi-periareolar incision	5.344 (0.627–45.535)	0.125
Mastectomy weight	1.002 (0.997–1.006)	0.515
Implant volume	1.001 (0.995–1.008)	0.682
Implant position		
Prepectoral	Ref.	Ref.
Subpectoral	1.687 (0.425–6.704)	0.457
Sternal notch to nipple distance‡	1.010 (0.762–1.339)	0.946
Surgery duration ± SD, min		
Axillary lymph node management		
None	Ref.	Ref.
SLNB	0.656 (0.059–7.280)	0.732
ALND	0.375 (0.025–5.572)	0.476
Duration of drain insertion ± SD, day	1.011 (0.798–1.282)	0.925
Nipple perfusion time	1.027 (1.013–1.042)	<0.001 <sup>†</sup>
Nipple perfusion pattern		
Perfusion (including rapid and delayed perfusion)	Ref.	Ref.
No perfusion	5.236 (2.244–12.217)	<0.001 <sup>†</sup>

OR, odds ratio; CI, confidence interval; BMI, body mass index; SD, standard deviation; SLNB, sentinel lymph node biopsy; ALND, axillary lymph node dissection. \*Statistically significant; <sup>†</sup>Not available according to the lack of events in the nipple-areola complex necrosis group; <sup>‡</sup>Sternal notch to nipple distance was measured using Crisalix 3D Surface Imager (Crisalix, S.A., Lausanne, Switzerland).

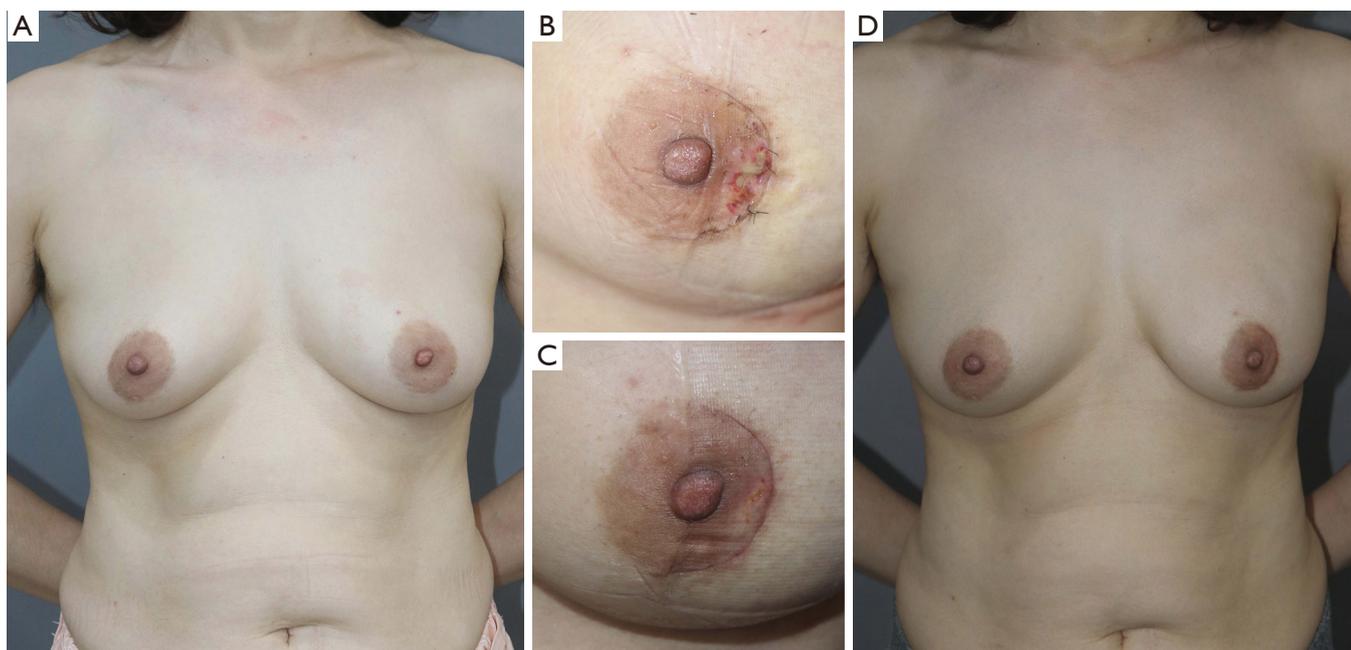
for several advantages, including direct visualization and tailoring of the inframammary fold, less tension on incision edges with retraction, and acceptable incision scar (9). However, adequate access to the upper breast pole is more challenging via inframammary incision, and long incision is usually required for oncologic resection (9,18). Furthermore, a separate axillary incision for axillary lymph node dissection along with the long inframammary fold incision may cause perfusion-related complications in the inferior mastectomy

skin flap and NAC (19,20). Conversely, periareolar incisions provide central access to all breast quadrants during mastectomy and, when necessary, to the axilla for sentinel lymph node biopsy and axillary dissections (17). Furthermore, the scar can be well-hidden within the periphery of the areola because of different color and texture of the areola and surrounding skin. However, the main disadvantage of the periareolar incision is the high rate of nipple-areola necrosis, which ranged from 9%

**Table 5** Multivariable analysis of clinical and indocyanine green angiographic variables for nipple-areola complex necrosis

	Adjusted OR (95% CI)	P
Age	–	–
Incision type		
Conventional lateral radial incisions	Ref.	Ref.
Pure hemi-periareolar incision	–	–
Nipple perfusion pattern		
Perfusion (including rapid and delayed perfusion)	Ref.	Ref.
No perfusion	5.236 (2.244–12.217)	<0.001*

OR, odds ratio; CI, confidence interval. \*Statistically significant.

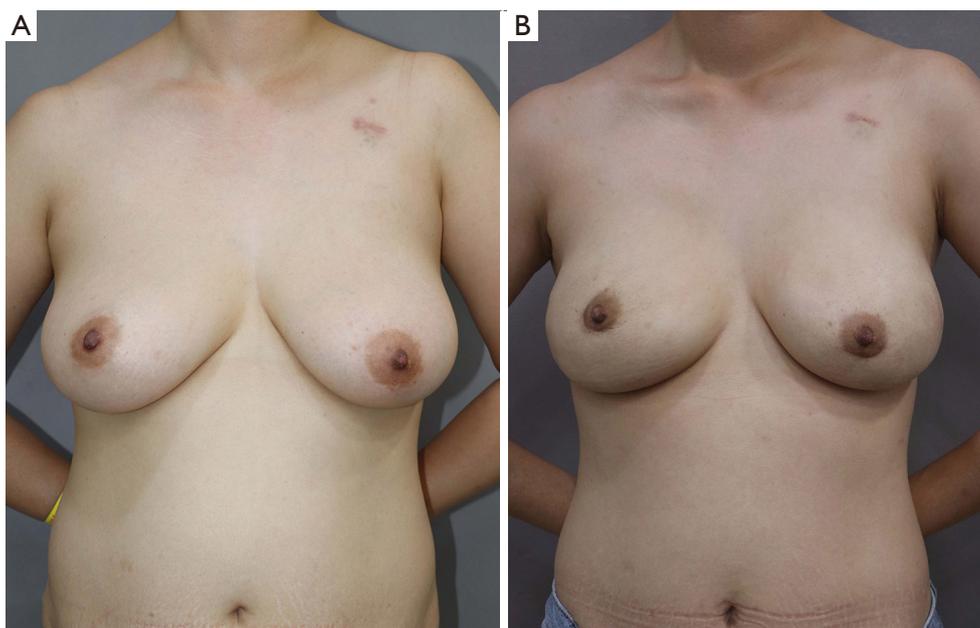


**Figure 4** A 48-year-old woman underwent prepectoral direct-to-implant breast reconstruction after nipple-sparing mastectomy with pure hemi-periareolar incision on her left breast. (A) Preoperative view. (B) 2-week postoperative view. Partial-thickness necrosis developed on lateral areola. (C) 4-week postoperative view. Partial-thickness necrosis completely healed with conservative management. (D) 4-month postoperative view.

to 29% in a meta-analysis (9). To minimize the risk of nipple-areola necrosis after mastectomy using peri-areolar incision, intraoperative assessment of ICG angiography was performed to aid decision making for reconstruction. This included whether to proceed with the reconstructive procedure, determination of surgical plane for implant placement, and amount of partial trimming for circulation-compromised areolar skin.

Several studies have been conducted using ICG

angiography to objectively evaluate perfusion of the mastectomy skin flap to predict skin flap necrosis (10-12, 21-25). All studies have evaluated perfusion of mastectomy skin flaps using fluorescence intensity. Gorai *et al.* also assessed time and rate of increase to reach maximum perfusion (24). Although fluorescence intensity has been demonstrated as a useful predictor for postoperative mastectomy skin flap necrosis, several potential drawbacks should be considered. The absolute values of fluorescence



**Figure 5** A 37-year-old woman underwent subpectoral direct-to-implant breast reconstruction after nipple-sparing mastectomy using pure hemi-periareolar incision on bilateral breasts. (A) Preoperative view. (B) 6-month postoperative view.

considered to be predictive for necrosis vary greatly among studies. These values can be influenced by measurement tools and surrounding circumstances, such as ambient lighting in the operation theater (26). There are generalization issues for fluorescence intensity because intensities obtained by various fluorescence imaging systems have different values and cannot be compared with each other without additional correlation study (23).

Conversely, time-related variables, such as perfusion time, rate of increase, and perfusion velocity, have rarely been investigated. Erni *et al.* observed significant reduction in the perfusion velocity of microcirculation of the ischemic flap at 1 hour after surgery using an extended flap model in the experimental setting (27). In a retrospective study of ICG angiographic evaluation of the mastectomy skin flap after immediate tissue expander reconstruction, Gorai *et al.* showed that the rate of increase to reach maximum perfusion is a more sensitive parameter than fluorescence intensity (24). In this study, we demonstrated that perfusion time was significantly increased in the NAC necrosis group compared to the no necrosis group, and the rates of NAC necrosis were significantly different between the three groups with different perfusion velocity, including rapid, delayed, and no perfusion. Time-related measurements have several advantages. These measurements can be easily applied

to clinical settings, and the results can be compared to measurements of another instrument without a correlation process. Time-related measurements do not require a reference value, whereas fluorescence intensity does usually require a reference value. In addition, the reference value is variable and unpredictable in circulatory compromised mastectomy skin flaps (21). Finally, the measurements do not require special equipment or software to quantify fluorescence and only require an ICG camera. We believe that time-related measurements, such as perfusion time, rate of increase, and perfusion velocity, are suitable indicators for perfusion of mastectomy skin flap and NAC.

We suggest several strategies regarding the use of intraoperative ICG angiography to minimize the risk of NAC necrosis in DTI breast reconstruction after NSM using pure hemi-periareolar incision. DTI can be safely performed in patients with 50% or more of NAC visualized by ICG angiography after mastectomy. When perfusion was confirmed to cross the nipple, total nipple necrosis did not occur, even with no perfusion pattern of the nipple. Alternatively, staged expander/implant reconstruction should be considered with cases in which less than half of the NAC is visualized. Among patients with 50% or more of the NAC visualized by ICG angiography, prepectoral reconstruction can be safely performed in patients with

rapid perfusion pattern. Prepectoral reconstruction can be performed for patients with delayed or no perfusion patterns, but meticulous efforts are required to minimize skin tension and maintain perfusion of the mastectomy skin flap. For breasts with no perfusion pattern of the nipple, NAC necrosis was more than 5 times more likely than in breasts with rapid or delayed perfusion patterns. Subpectoral reconstruction can be considered with no nipple perfusion pattern to avoid direct exposure of the implant in cases of possible major NAC necrosis. When significantly reduced or no perfusion areas were found in the areolar margin of the incision, trimming of the areolar margin by 1 to 5 mm may facilitate wound healing.

The current study had several limitations. Other variables that may affect outcomes were possibly omitted due to the retrospective study design. For example, core temperature of patients and environment temperature were not measured when performing ICG angiography, but these temperatures could affect peripheral circulation and measurements of ICG angiography. Breast measurements such as sternal notch to nipple distance and degree of ptosis could also be associated with NAC necrosis because NAC perfusion after NSM is dependent only on the skin flap perfusion and a greater distance from the chest wall to the nipple could increase NAC necrosis (28-30). According to the result of this study, sternal notch to nipple distance was not a significant predictor for NAC necrosis. However, the result needs further validation because sternal notch to nipple distance was obtained retrospectively using an automated 3D program in a relatively small number of study population in this study. The small number of cases included in this study is another limitation. Major NAC necrosis was not significantly different between the pure hemi-periareolar incision and conventional lateral radial incision groups, but only 1 patient in each group developed major necrosis. Further larger studies are warranted to confirm that DTI reconstruction after mastectomy using pure hemi-periareolar incision is feasible for breast reconstruction. Finally, the study population was limited to Asian women. Relatively low BMI and low mastectomy specimen weight might be associated with favorable outcomes. We believe that pure hemi-periareolar incision is feasible for large breasts (up to 738 g in this series) as well, but further studies in patients with relatively large breasts are necessary.

## Conclusions

DTI breast reconstruction after NSM using pure hemi-

periareolar incision can be safely performed with intraoperative evaluation of the mastectomy skin flap by ICG angiography. Nipple perfusion time and patterns suggested in this study may be useful predictors for NAC necrosis.

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