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Original Article

Using ICG to Streamline Perforator Selection in DIEP Flap Reconstruction: Retrospective cohort study of outcomes in our first one hundred flaps ☆

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ABSTRACT

The use of indocyanine green in conjunction with near infra-red fluoroscopy as an adjunct to the clinical assessment of tissue perfusion is now well established.[1-3] Its intraoperative use in breast reconstruction with deep inferior epigastric (DIEP) flaps has been described since 2009.[4-6] Fat necrosis is commonly encountered in the recovery period. This study reports on our step-by-step practical technique of using indocyanine green (ICG) to streamline perforator choice intraoperatively during DIEP flap raising for breast reconstruction and our rates of fat necrosis (8%) and flap survival (100%) within the first 100 flaps in our regional reconstruction unit. We discuss the benefits and pitfalls of using ICG fluoroscopy at various stages of breast reconstruction with free DIEP flaps. This study has been reported using the STROBE guidelines.

☆ Work partly presented at the BAPRAS Celtic Meeting in October 2023

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Introduction

Indocyanine green (ICG) is a water soluble substance with a 3 to 5 minute half-life that binds to plasma proteins and is excreted in the bile. When excited using an 805 nm laser, it emits fluorescence which can be detected using a camera device. In 1969, it was approved by the Federal Drug Agency for use in humans. When injected intravascularly, it can be used to visualize real time perfusion. Reported intraoperative uses include the demonstration of tissue perfusion in mastectomy skin flaps,[7] in free flaps pre- (6) (5) and post-anastomosis,[4] and in tissues after traumatic injury.[8] Its use in breast reconstruction in general was described by Johnston.[9] When injected interstitially, it is used to identify sentinel lymph nodes in breast and melanoma surgery and in lymphangiography.[1]

ICG angiography has been used to detect areas of hypo-perfusion in deep inferior epigastric perforator (DIEP) flap breast reconstruction surgery since 2009 when Hembd reported its use after microvascular anastomosis and demonstrated a reduction in fat necrosis within his cohort.[4] In our patient cohort, ICGa was used prior to subfascial flap raising so that adequate tissue volume perfusion on the chosen perforator could be confirmed prior to flap raising. This saved time, confirmed an adequate perforator, which usually allows a single perforator to be used, and reduced the risk of subsequent fat necrosis.

Our cohort included patients receiving chemotherapy or radiotherapy, bilateral and irradiated flaps and those who are expected to undergo radiotherapy. The routine integration of ICG into DIEP flap reconstruction improves confidence and rapid decision making in perforator choice and bespoke flap design with confirmed perfusion of the chosen area of the flap.

Fat necrosis was diagnosed if a lump or abnormality in a reconstructed breast was detected by the patient or clinician on follow-up examination and subsequently diagnosed using ultrasound and cytology as fat necrosis.

Our objectives were to communicate the specific methods of choosing perforator and tissue and report the favorable outcomes from our first 100 flaps, comparing them to UK wide outcome data in regards to the overall outcomes and to other internationally-reported outcomes in regards to fat necrosis as we believe that our techniques help to achieve favorable outcomes for our patients.

Methods

Patients considering free flap breast reconstruction are referred to our reconstructive team by the breast surgeons who are based in the same unit in Belfast. Every referred patient requesting possible reconstruction is counseled as to the various reconstructive options. If they choose to consider free DIEP reconstruction, they undergo a preoperative computer tomography angiography of the abdomen from the symphysis pubis to the mid liver using Siemens SOMOTOM Definition AS 64 Slice Scanner. Narrow 0.8 mm slices in axial, coronal, and sagittal slices allow the intramuscular course of the vessels to be evaluated. Perforators are chosen based on their position in the abdominal wall, vessel caliber, and intramuscular course through the rectus muscle.

From this visual information, we can choose perforators that are identified on computed tomography angiography as being in a beneficial position to help with the provision of adequate tissue, have a good vessel caliber, and a visible and ideally short passage through the rectus muscle. We choose our preferred “primary” perforator and 1 to 2 secondary or “lifeboat” perforators for each flap. These are isolated ready for use in case of a complication when raising the primary perforator.

The patient visits the clinic on the preop day and the abdominal wall is examined using a Doppler probe to mark the position of the primary and “lifeboat” perforator on the abdominal wall surface. Other standard preop markings are performed simultaneously. The patient is provided with a low molecular weight heparin injection vial to administer to themselves at home the night before surgery and is then admitted early on the morning of surgery.

Intraoperatively, all perforators are raised to the level of the fascia. In bilateral cases, the flap tissue is divided vertically down the midline. The secondary perforators are clamped and the cessation of perfusion across the clamps is checked using a Doppler probe.

The anesthetist administers 3 ml of ICG dye (2.5 mg/ml) followed by a 10 ml normal saline flush intravenously. This enters the circulation and perfusion of the abdominal skin is observed via the SPY-

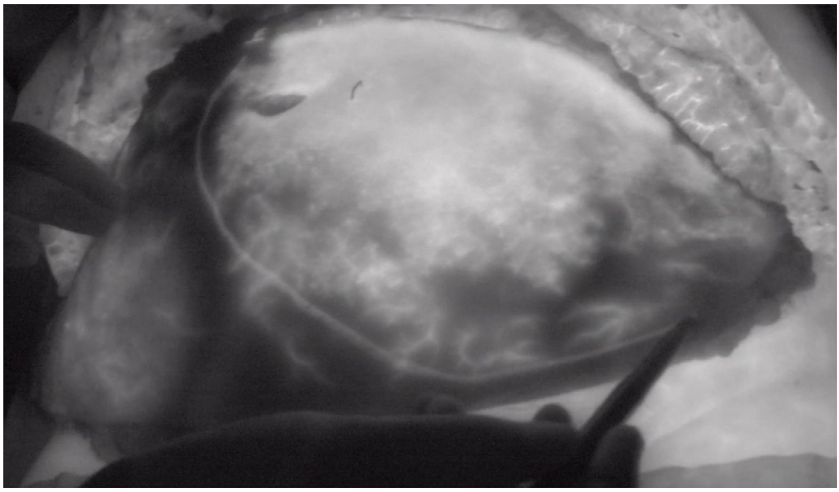

Figure 1. Marking of perfused areas of flap after intravenous administration of indocyanine green.

PHI infrared camera (Stryker). It takes approximately 30 s before the injected ICG fluorescence can be observed on the screen (video 1). The perfused area of the flap is infused with the ICG dye and glows green on fluoroscopy. When the area of the perfused flap appears to be stable the team marks the area of tissue supplied (Figure 1). This usually takes 2 min, but if the perfusion is poor, the team may wait another minute. If the perfused area is considered insufficient, the clamp is removed from one of the adjacent perforating vessels and the area of tissue supplied is re-assessed. Poorly supplied areas of the flap are marked for later removal and if sufficient tissue is supplied, the flap is then raised on the one chosen vessel. If sufficient, both perforators would then be included in the raise either on a single or bi-pedicled raise. We have not experienced a case as yet where 2 perforators have not been sufficient. We then perform fluoroscopy examination on the mastectomy flaps if present, to assess their perfusion. If any skin is inadequate, it can be removed at this point prior to de-epithelialization of the flap. This ICG-A evaluation takes approximately 3 min in total.

Our only exclusion criteria to performing DIEP were a Body Mass Index of >40 kg/m^2, inadequacy of available abdominal skin and fat, patient-reported ongoing smoking, or inadequate vessels on abdominal computed tomography angiography examination. The last reason is very rarely encountered as the narrow 0.8 mm slice protocol detects an adequate vessel in nearly every case. At the end of the procedure, the operative data are recorded immediately in the UK national flap registry and the operation note is generated from this input.

After the operation, patients are moved initially to recovery and then to a general ward under the care of a nursing team trained in flap monitoring and patient care post free flap reconstruction. Drains are removed when they collect less than 50 ml in 24 h and patients are discharged generally on day 2 or 3, once they are mobilizing freely and are comfortable.

All patients are reviewed at week one, week 2 and week 4 after discharge by one of the 2 consultants in the team and have open access to breast care nurse advice for 5 years. Patient-reported outcome measures are sent to patients at 3 and 6 months as per the UK flap registry protocol. Patients are entered into a self-directed aftercare program, and any palpable/symptomatic masses were examined using ultrasound examination with or without cytology as required. All patients underwent mammogram at 12 months post-reconstruction.

Data were recovered from patients notes and from the UK flap registry and a database was constructed. Fat necrosis data were obtained from the patients' paper and electronic records. Any imaging or cytology or histopathology recorded postoperatively was reviewed. It was not possible to always determine the perforator used nor flap weight in a flap raise retrospectively if this was not mentioned

in the operation note. We decided to report on our first 100 cases simply as a review of our outcomes after the milestone 100th case in our fledging unit.

Results

Our first 100 flaps were performed in 86 patients. All were women in the age range 33-70 years (mean, 48.1 years). The average Body Mass Index was 27.2 kg/m^2 (range, 19.2 to 38.9 kg/m^2). Fourteen patients underwent bilateral free flap reconstructions and 43 had contralateral aesthetic procedures. Twenty-seven patients had preop chemotherapy and 17 had preop radiotherapy. Seventeen went on to have postop radiation. Overall, 75% of the patient were in the tumor immediate category and 17 were delayed. These demographics are shown in comparison to the UK flap registry demographics[10] in charts 1-4.

In only 4 cases was more than one perforator used and only in 2 of these cases were bi-pedicled flaps used. Eight flaps had 2 venous anastomoses performed.

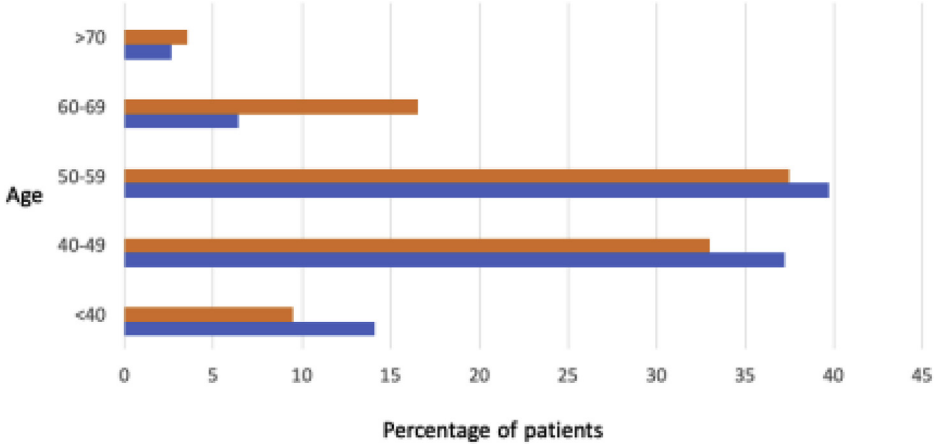

Chart 1. Comparison of ages between our patient cohort (blue) and the BAPRAS National Registry (orange).

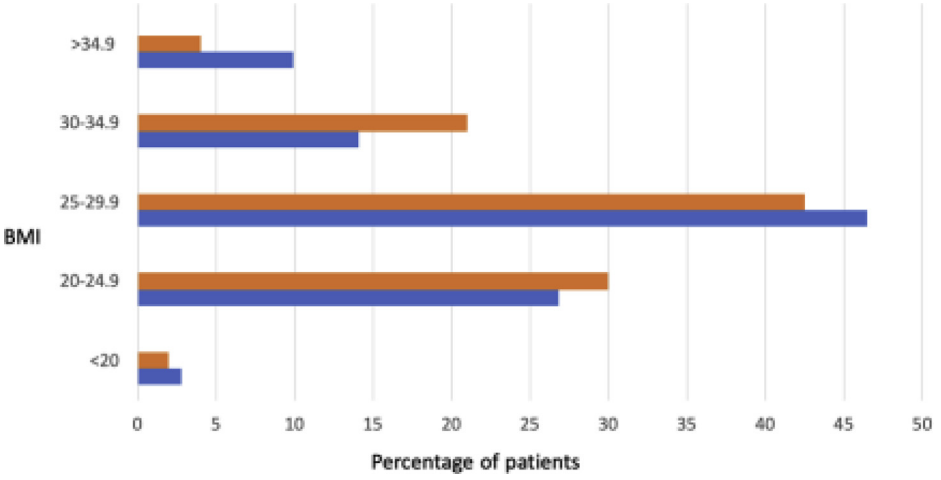

Chart 2. Comparison of Body Mass Index in our study cohort (blue) and BAPRAS National flap registry (orange).

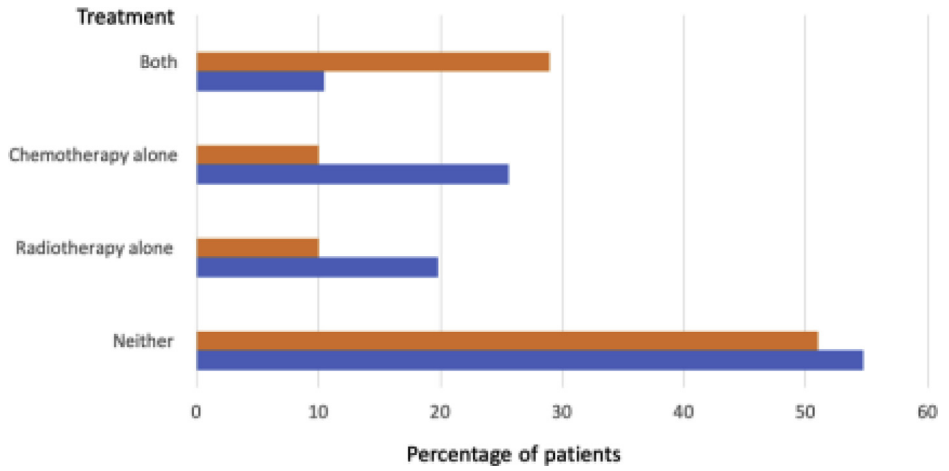

Chart 3. Comparison of preoperative procedures in our study (blue) and patients in the National BAPRAS flap registry.

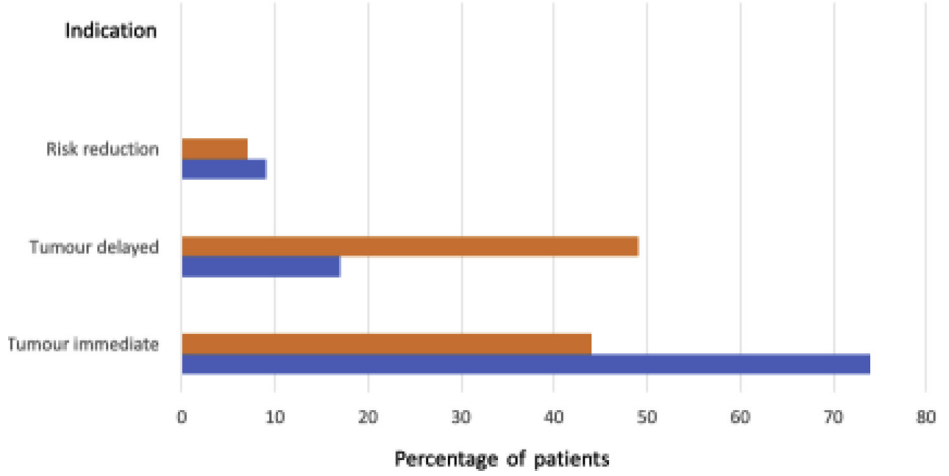

Chart 4. Comparison of Clinical indication for surgery between our patient cohort (blue) and National flap registry patients (orange).

Twenty-six flaps were raised on lateral perforators and 41 on medial row perforators. The operative information was not available on the other cases.

The mean transferred flap weight was 617 g (range, 240-1319 g). The mean ischemia time was 66.6 min (range, 39-245 min). The mean ischemia time was 66.6 min in all flaps and 71 min in those with fat necrosis.

Four patients had an early unplanned return to theater for flap salvage. In 2 of these cases, hematoma was evacuated. No revision of the micro-anastomosis was necessary in either case. In 2 cases, the vein was occluded; once due to a kink in the vessel and in the second due to the split pectoralis major muscle closing over the vessel. All the attempts at salvage were successful; therefore, our flap success rate was 100%. Our mean length of stay postop was 2.7 days (range, 2-5 days) which compares well with the UK flap registry mean of 4.7 days in 2019.

Patients were reviewed by a surgeon from the operating team at 6 weeks, 3 months, 6 months, 12 months, and 2 years. Ten patients on follow-up had a clinically detected palpable lump which

was subsequently confirmed by ultrasound examination with or without aspiration to confirm the diagnosis of fat necrosis in all cases. The size of the cystic areas, where noted, ranged from 5 to 45 mm in greatest diameter and between 5 to 22 mm in narrowest reported diameter. No patient received a therapeutic aspiration and none received or requested surgery.

Discussion

Fat necrosis rates after DIEP reconstruction have been reported in the literature are between 12.0% and 45.0%. Factors that impact the reported rates of necrosis include perforator row,[11] ischemic time,[12] flap weight, and perforator number and type.[13,14] The reporting of fat necrosis is hindered by the lack of an internationally accepted definition.[15,16] Wagner[16] helpfully created a grading system for fat necrosis in breasts reconstructed with autologous tissue. It mirrors the Baker's grading system for capsular contracture:

Grade I: Radiological evidence alone
Grade II: Clinically palpable
Grade III: Visible and palpable mass
Grade IV: Symptomatic

According to this grading system all of our patients with fat necrosis were Wagner's grade II. The average involved area on imaging was 2.25 cm^2. Five patients underwent aspiration and none of them required further surgery.

Lee et al. found in their 10-year follow-up study that the size of fat necrosis areas in irradiated breasts decreased by half 2 years after their first detection and that 60% of the areas with fat necrosis resolved during their 10-year follow-up period with no treatment.[17] Therefore, we believe that fat necrosis in non-irradiated breasts should resolve more quickly. The minimum diameter of areas of fat necrosis in our 10 patients, in whom it was detected, was $\leq$13 mm. Once the diagnosis is confirmed it is likely that these areas will be of no clinical or cosmetic concern.

Kroll et al.[18] found the incidence of fat necrosis to be higher in DIEPs when compared to free TRAM flaps but only when >70% of the flap was required and when no perforators were available. We place deep anchoring polydiaxone sutures (PDS) for flap stabilization. These may contribute to small areas of fat necrosis. Six patients had fat necrosis with a diameters $\leq$1.3 cm. It may be that the PDS anchoring sutures caused these small foci.

The mean weight of our flaps in patients with fat necrosis was 674 g (range, 294-892 g). Mulvey et al. reported that higher flap weights carried a risk factor for developing fat necrosis; 49% of their flaps weighing >1000 g raised on single perforators[13] developed fat necrosis.

Even with ICG use, fat necrosis rates between 14.4%[4] and 20%[19] are reported. Medial perforating vessels are considered to have a wider perfusion zone that lateral perforators[20] and yet lateral perforators have been reported as leading to less fat necrosis when used. Using only 1 or 2 perforators is known to lead to higher rates of fat necrosis[20] but this is not supported in other studies and is also not the finding in our experience.

Rates of fat necrosis in patient cohorts have been shown to decrease with ICG use before anastomosis from 59.6 to 29.2%[21] and Hembd reported a decrease in fat necrosis rates with ICG use post anastomosis[4] in single pedicle DIEPs.

We prefer to check the flap perfusion prior to raising the flap for several reasons which are as follows:

1. Before spending the time in raising our first choice of primary pedicle, we can ensure that it will provide us with tissue that is sufficiently perfused to recreate the breast.
2. The surgical plan to include another pedicle can be made early.
3. The area of tissue that is to be used based on perfusion can be chosen at an early stage and the flap can be reduced in size and de-epithelialized prior to transfer. This can help during anastomosis by having a smaller flap. In our experience, this aids a safer inset and less chance of injury to the anastomosed vessels during de-epithelization after microvascular anastomosis.

Hembd's data on reduction of fat necrosis with the use of intraoperative post-anastomotic ICG supports the use of ICG in checking tissue perfusion of a flap through the perforator vessel. We believe that we can achieve the same check pre-anastomosis. Our current rates of fat necrosis (8%) are comparable to that of Hembd's cohort (8.5%).

These data were gathered from the first 100 flaps performed in our fledging breast reconstruction unit. The benefit of this is that it provides some evidence on the use of microsurgery out-with a main plastic surgery unit and within a breast unit. We hope to publish more on these experiences in a further paper.

Conflicts of Interest

None

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Ethical approval

Not required.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi: 10.1016/j.jpra.2025.02.016.

References

1. Burnier P, Niddam J, Bosc R, Hersant B, Meningaud JP. Indocyanine green applications in plastic surgery: A review of the literature. *J Plast Reconstr Aesthet Surg.* 2017;70(6):814–827.
2. Nguyen CL, Barry N, Lindsay A, Seah JL, Easwaralingam N, Pulitano C, et al. Indocyanine green angiography in breast reconstruction surgery: A systematic review of cost-analysis studies. *J Plast Reconstr Aesthet Surg.* 2021;74(11):3196–3211.
3. Nguyen CL, Dayaratna N, Comerford AP, Tam SKM, Paredes SR, Easwaralingam N, et al. Cost-effectiveness of indocyanine green angiography in postmastectomy breast reconstruction. *J Plast Reconstr Aesthet Surg.* 2022;75(9):3014–3021.
4. Hembd AS, Yan J, Zhu H, Haddock NT, Teotia SS. Intraoperative assessment of DIEP flap breast reconstruction using indocyanine green angiography: Reduction of fat necrosis, resection volumes, and postoperative surveillance. *Plast Reconstr Surg.* 2020;146(1):1e–10e.
5. Newman MI, Samson MC. The application of laser-assisted indocyanine green fluorescent dye angiography in microsurgical breast reconstruction. *J Reconstr Microsurg.* 2009;25(1):21–26.
6. Griffiths M, Chae MP, Rozen WM. Indocyanine green-based fluorescent angiography in breast reconstruction. *Gland Surg.* 2016;5(2):133–149.
7. Mirhaidari SJ, Beddell GM, Orlando MV, Parker MG, Pedersen JC, Wagner DS. A prospective study of immediate breast reconstruction with laser-assisted indocyanine green angiography. *Plast Reconstr Surg Glob Open.* 2018;6(9):e1774.
8. Vasella M, Guidi M, Waldner M, Calcagni M, Giovanoli P, Frueh FS. Fluorescence angiography-assisted debridement of critically perfused glabrous skin in degloving foot injuries: Two case reports. *Medicine (Baltimore).* 2021;100(22):e26235.
9. Johnson AC, Colakoglu S, Chong TW, Mathes DW. Indocyanine green angiography in breast reconstruction: Utility, limitations, and search for standardization. *Plast Reconstr Surg Glob Open.* 2020;8(3):e2694.
10. Hazari A, Ho M, Cole R, Fowler C, Schache A. First UK National Flap Registry Report 2019. Report. 2019.
11. Kamali P, Lee M, Becherer BE, Wu W, Curiel D, Tran BNN, et al. Medial row perforators are associated with higher rates of fat necrosis in bilateral DIEP flap breast reconstruction. *Plast Reconstr Surg.* 2017;140(1):19–24.
12. Lee KT, Lee JE, Nam SJ, Mun GH. Ischaemic time and fat necrosis in breast reconstruction with a free deep inferior epigastric perforator flap. *J Plast Reconstr Aesthet Surg.* 2013;66(2):174–181.
13. Mulvey CL, Cooney CM, Daily FF, Colantuoni E, Ogbuago OU, Cooney DS, et al. Increased flap weight and decreased perforator number predict fat necrosis in DIEP breast reconstruction. *Plast Reconstr Surg Glob Open.* 2013;1(2):1–7.
14. Li Y, Long X. Optimizing perforator selection: A multivariable analysis of predictors for fat necrosis and abdominal morbidity in DIEP flap breast reconstruction. *Plast Reconstr Surg.* 2019;143(6) 1307e-8e.

15. Russo AL, Taghian AG. Fat necrosis of the breast in the accelerated partial breast irradiation era: the need for a universal grading system. *Breast Cancer Res Treat*. 2013;140(1):1–11.
16. Wagner IJ, Tong WM, Halvorson EG. A classification system for fat necrosis in autologous breast reconstruction. *Ann Plast Surg*. 2013;70(5):553–556.
17. Lee J, Park HY, Kim WW, Lee JJ, Keum HJ, Yang JD, et al. Natural course of fat necrosis after breast reconstruction: a 10-year follow-up study. *BMC Cancer*. 2021;21(1):166.
18. Kroll SS. Fat necrosis in free transverse rectus abdominis myocutaneous and deep inferior epigastric perforator flaps. *Plast Reconstr Surg*. 2000;106(3):576–583.
19. Malagón-López P, Vilà J, Carrasco-Lopez C, Garcia-Senosiain O, Priego D, Julian Ibanez JF, et al. Intraoperative indocyanine green angiography for fat necrosis reduction in the deep inferior epigastric perforator (DIEP) flap. *Aesthet Surg J*. 2019;39(4):NP45–NP54.
20. Bhullar H, Hunter-Smith DJ, Rozen WM. Fat necrosis after DIEP flap breast reconstruction: A review of perfusion-related causes. *Aesthetic Plast Surg*. 2020;44(5):1454–1461.
21. Malagón-López P, Carrasco-López C, García-Senosiain O, Vilà J, Del-Río M, Priego D, et al. When to assess the DIEP flap perfusion by intraoperative indocyanine green angiography in breast reconstruction? *Breast*. 2019;47:102–108.