A Prospective Cohort Study Re-examining Tissue Oximetry Monitoring in Microsurgical Breast Reconstruction

Darren L. Sultan, MD,[a,b] Elisa Atamian, MD,[a,b] Joseph Tarr, MD, PhD,[a,b] Randall Feingold, MD,[c] Armen K. Kasabian, MD,[a,b] Neil Tanna, MD, MBA,[a,b] Mark L. Smith, MD,[a,b] and Victor Moon, MD[a,b]

Background: The goal of inpatient monitoring after microsurgical breast reconstruction is to detect vascular compromise before flap loss. Near-infrared tissue oximetry (NITO) is commonly used for this purpose, but recent reports challenge its specificity and utility in current practice. Fifteen years after Keller published his initial study using this technology at our institution, we re-evaluate the role and limitations of this popular monitoring device.

Methods: A 1-year prospective study was performed for patients undergoing microsurgical breast reconstruction and monitored postoperatively using NITO. Alerts were evaluated, and clinical endpoints relating to an unplanned return to the operating room or flap loss were recorded.

Results: A total of 118 patients reconstructed with 225 flaps were included within the study. There were no cases of flap loss at the time of discharge. There were 71 alerts relating to a drop in oximetry saturation. Of these, 68 (95.8%) were deemed to be of no significance. In 3 cases (positive predictive value of 4.2%), the alert was significant, and there were concerning clinical signs apparent at that point. A sensor in an inframammary fold position was associated with nearly twice the average number of alerts as compared with areolar or periareolar positions ($P = 0.01$). In 4 patients (3.4%), a breast hematoma required operative evacuation, and these cases were detected by nursing clinical examination.

Conclusions: The monitoring of free flaps after breast reconstruction through tissue oximetry shows a poor positive predictive value for flap compromise and requires clinical corroboration of alerts but missed no pedicle-related adverse events. With a high sensitivity for pedicle-related issues, NITO may be helpful postoperatively, but the exact timeframe for use must be weighed at the institutional level.

Key Words: free flap, monitoring, near-infrared tissue oximetry, microsurgery

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As the availability of microsurgical breast reconstruction has grown and its popularity among patients has increased, so too has the importance of perioperative efficiency in ensuring cost-effective, reproducible, and high-quality outcomes. Enhanced recovery protocols have significantly improved pain management allowing patients to mobilize sooner and routinely leave the hospital within 2 days of having microsurgical reconstruction. Aside from pain control and patient mobilization, flap monitoring remains the other key concern in the perioperative period. Many protocols for monitoring flaps exist including the following: physical examination, pin-prick bleeding assessment, external Doppler examination, and implantable Doppler probes. The use of NITO for flap monitoring offers the potential benefit of continuous real-time readings using an external device that may identify preclinical evidence of flap compromise. In 2007, Keller[1,2] published his experience using a noninvasive near-infrared tissue oximeter monitor for postoperative flap monitoring. He found that the device detected impending flap compromise in 5 of 208 flaps before clinical signs being evident, and no flap was lost within the study period. Since that time, NITO has become a standard tool for microvascular flap monitoring at our institution and many others.

Subsequent studies have highlighted its utility in clinical practice, demonstrating a sensitivity and specificity of 100%.[3,4] They point out that there were no alarms raised in the absence of vascular crisis. However, more recent reports raise questions about the consistency of these outcomes. A retrospective study by Tran et al[5] found a false-positive rate with NITO between 84% and 100% depending on timing since the operation. Furthermore, with additional literature showing a marginal increase in effectiveness over clinical examination, NITO is determined to be cost-effective in only 13.5% of cases.[6] Fifteen years since Keller's original publication, our current study takes another look at our institutional experience with NITO to better understand its current role and limitations as a flap monitoring tool. We seek to clarify its predictive value and its performance in real-life clinical settings to draw conclusions regarding its future use.

METHODS

Data Collection

All patients undergoing free flap breast reconstruction at 1 of 2 academic hospitals (North Shore University Hospital or Long Island Jewish Medical Center) for a period of 1 year between June 2020 and June 2021 were initially included in the study. Any patient who by the discretion of the lead surgeon was not monitored postoperatively by NITO tissue oximetry was excluded. There were 3 such cases. A total of 118 patients were included in the study. Demographic factors related to patient health as well as details of the final operative reconstruction were recorded. The study parameters were reviewed and approved by the Northwell Health Institutional Review Board. A waiver of informed consent was also issued by the institutional review board. All study participants were included prospectively and were cared for in accordance with pre-established standard of care protocols in place at the hospitals.

In short, NITO monitoring was performed for all patients included in the study with the ViOptix system (ViOptix, Inc, Newark, CA). Sensors are placed at the conclusion of the operation, affixed with a transparent membrane dressing and maintained in place until at least postoperative day (POD) 2 or longer in cases where the patient is discharged at a later point. Monitoring occurs every hour for the first night, every 2 hours starting with the shift change the following morning and then every 4 hours on the subsequent morning. Nurses are instructed to monitor a flap by recording the tissue oximetry saturation, color, temperature, capillary refill, and turgor and to notify the covering physician for a change from the baseline. With respect to the tissue oximetry, nurses are instructed to alert for a drop of 10% in the saturation as compared with the postoperative baseline. The informed resident physician then comes to assess the patient by clinical examination and makes a determination regarding flap integrity. This determination is based on clinical examination including measures of color, temperature, capillary refill, and turgor in addition to adjunct methods such as handheld Doppler if a skin perforator is present within the monitoring skin

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From the [a]Division of Plastic and Reconstructive Surgery, Donald and Barbara Zucker School of Medicine at Hofstra/Northwell; [b]Division of Plastic and Reconstructive Surgery, Northwell Health; and [c]New York Breast Reconstruction and Aesthetic Plastic Surgery, Private Practice, Great Neck, NY
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Reprints: Darren Sultan, MD, Northwell Health, 600 Northern Blvd, Great Neck, NY 11021. E-mail: dsultan1@northwell.edu.

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island or skin scratch test. Attendings are notified based on resident assessment. All such alerts and their outcomes were recorded. Patients continued to be monitored until discharge, thereby allowing continued assessment of flaps for any changes after the initial alerts. Any adverse events defined by an unplanned return to the operating room or flap loss were additionally recorded. Alerts on the basis of loss of signal quality such as by loss of adequate contact of the sensor with the flap skin were excluded. As the goal of the study was to reassess an inpatient monitoring program, flap loss during the inpatient period only was recorded.

Data Analysis

Descriptive statistical analyses were used to draw conclusions and inform comparisons between patient groupings. For comparisons of the means between more than 2 cohorts, a single-factor analysis of variance test was used. For comparisons between 2 cohorts, a Student *t* test was used to compare means. For categorical comparisons, χ^2 analysis was performed. For the purpose of the abovementioned statistical tests, associated *P* values less than 0.05 were deemed significant. All statistical calculations were performed through Microsoft Excel, Version 2107.

RESULTS

From the period of June 2020 until June 2021, 118 patients with a total of 225 flaps were included in the study. One hundred one patients underwent bilateral reconstruction, and 17 underwent unilateral reconstruction. In 6 cases, 2 flaps were stacked to reconstruct a given breast. All surgeries were performed at 1 of 2 institutions under the auspices of Northwell Health. With the exception of 3 known cases excluded from analysis because the lead surgeon preferred to have the flaps monitored exclusively by handheld Doppler checks, the remainder of cases were monitored by NITO as well as by clinical criteria based on institution protocols discussed previously (these 3 cases were not included in the total of 118 patients). Patient demographics and clinical factors related to final operative reconstruction are summarized in Table 1. The overwhelming majority underwent reconstruction with deep inferior epigastric perforator (DIEP) flaps, with fewer than 10% of patients undergoing reconstruction with another flap type. In 5 cases (4.2%), more than one flap was used to reconstruct a single breast. Nearly three quarters had flaps monitored through a skin island taking the place of the previous nipple areolar complex. A smaller subset had nipple-sparing mastectomies and therefore had monitoring skin paddles in a periareolar or inframammary fold (IMF) position.

There were no cases of flap loss for the study cohort at the time of inpatient discharge from the hospital. There were 7 cases (5.9%) of unplanned returns to the operating room. These adverse events included 4 cases (3.4%) of breast hematomas and 1 (0.8%) abdominal hematoma where the alarm was raised initially based on clinical examination and where the NITO measurement at the time of the alert was unaffected. In 3 cases (2.5%), there was a concern for flap compromise as detected by a drop in the tissue oximetry saturation and where there was also a clinically apparent color change at the time of the alert. In 2 of those cases, a return to the operating room uncovered a potential risk to the flap pedicle. In the remaining case, the initial concern for the flap self-resolved before operative intervention. Details relating to these cases are summarized in Table 2.

The overwhelming majority of nursing alerts triggered by a drop in the tissue oximetry reading were of no clinical significance after further investigation. There were a total of 71 such alerts. As above, only 3 of these alerts (positive predictive value of 4.2%) were consistent with a potential flap compromise, and only 2 alerts (2.8%) resulted in intervention leading to flap salvage. In all cases of concern for the flap integrity, there were corresponding signs on examination to support the concern. There were no cases of a return to the operating room on the basis of NITO monitoring alone and no cases of flap salvage on the basis of NITO monitoring alone. In fact, in the 68 of 71 cases (95.8%) where there was an alert based on a drop in the tissue oximetry saturation, the notified physician determined that there was no concern for flap viability based on clinical examination and obviated the need for operative intervention. These patients continued to be monitored throughout their inpatient stay without concern for flap integrity.

TABLE 1. Patient Demographics

Age	52.5 (range, 32–72)
Body mass index	28.9 (range, 19.1–47.4)
History of hypertension	35 (29.7%)
History of diabetes	11 (9.3%)
Current smoker	6 (5.0%)
History of venous thromboembolism	0 (0.0%)
History of chest radiation	16 (13.6%)
Length of inpatient stay	2.8 days (range, 2–5)
Timing of reconstruction	
Immediate	102 (86.4%)
Delayed	15 (12.7%)
Immediate unilaterally/delayed unilaterally	1 (0.8%)
Laterality of reconstruction	
Unilateral	17 (14.4%)
Bilateral	101 (85.6%)
Flap type	
DIEP	210 (93.3%)
TUG	13 (5.8%)
msTRAM	1 (0.4%)
SIEA	1 (0.4%)
Flap external skin paddle location	
Areolar	164 (72.9%)
Periareolar	29 (12.9%)
IMF	32 (14.2%)

Patient demographics including relevant health concerns and factors related to final operative reconstruction.

msTRAM, muscle-sparing transverse rectus abdominis musculocutaneous; SIEA, superficial inferior epigastric artery; TUG, transverse upper gracilis.

There was no significant difference in patient age ($P = 0.56$) or BMI ($P = 0.30$) between those who had NITO-related alerts and those without. There was similarly no difference in the average number of alerts for those who underwent DIEP or transverse upper gracilis flap reconstruction ($P = 0.68$). There was no significant difference in hospital length of stay between patients with alerts and those without ($P = 0.43$). There was no significant association between NITO-related alerts and historical factors such as hypertension ($P = 0.81$), diabetes ($P = 0.89$), smoking status ($P = 0.33$), and chest radiation ($P = 0.54$). Immediate versus delayed reconstruction was similarly not associated with the presence or absence of alerts ($P = 0.98$). The single patient factor associated with a greater number of alerts was sensor location where patients with a sensor in an IMF location had a significantly increased number of alerts on average as compared with those with areolar or periareolar sensors ($P = 0.01$). The greatest number of alerts occurred in the first POD from the morning until the period ending 24 hours after surgery. This is also the time when patients begin to ambulate based on the Enhanced Recovery After Surgery protocol in place at these hospitals. The breakdown of the timing of these alerts and their significance is depicted in Figure 1.

DISCUSSION

Breast reconstruction after oncologic resection is a fundamental and restorative part of clinical management with beneficial effects

TABLE 2. Summary of Adverse Patient Outcomes and Detection

Clinical Summary	Detected by NITO	Detected by Clinical Examination
Patient with left breast hematoma requiring return to operating room on POD 0 and 750 mL of clot removed. No flap compromise resulted.	No	Yes
Patient had a significant drop in NITO saturation reading with simultaneous color change of the flap to a dark purple color unilaterally. Patient underwent urgent return to operating room on POD 0, and the pedicle was determined to be kinked. Flap was salvaged and additional outflow was established through an SIEV to IMV anastomosis by way of a vein graft.	**Yes**	**Yes**
Patient with a large right breast hematoma resulting in a rapid response team alert for abrupt hypotension on POD 1. NITO reading was unchanged. Patient was brought back to the operating room with removal of 1 liter of clot. No flap compromise resulted.	No	Yes
Patient with left breast hematoma requiring return to operating room on POD 0 with 600 mL of clot removed. No flap compromise resulted.	No	Yes
Patient with abdominal hematoma requiring return to operating room on POD 2. Breasts were unaffected.	No	Yes
Patient had new congestion unilaterally, loss of handheld Doppler signal and a NITO reading drop on POD 3 resulting in a return to the operating room. Only 100 mL of clot was found near the pedicle, but the pedicle was noted to have some blood flow. Flap bleeding was noted to improve after removal of the clot.	**Yes**	**Yes**
Patient had drop in NITO saturation reading as well as dark discoloration of the flap within first few hours postoperatively. Attending was notified and plan for return to operating room planned. Prior to taking the patient to the operating room, the flap color improved spontaneously, so no reoperation was performed. The patient was subsequently monitored without issue.	**Yes**	**Yes**
On the morning of POD 1, the patient was noted to have unilateral breast swelling with concern for a hematoma. The patient was taken to the operating room, but only a minimal amount of clot was found. The flap was unaffected.	No	Yes

Summary of adverse patient outcomes and those resulting in an unplanned reoperation. No cases resulted in flap loss. Events detected by NITO are highlighted in bold.
IMV, internal mammary vein; SIEV, superficial inferior epigastric vein.

related to mental health and a sense of a return to normalcy for many cancer patients.[7–10] In addition to psychological gains, patients undergoing breast reconstruction report improvements in several quality of life measures when surveyed by the validated BREAST-Q.[11] The specific method of reconstruction is based on discrete patient factors regarding anatomy, patient health and willingness to undergo more or less invasive procedures. Despite the increased complexity and upfront cost, free flap breast reconstruction is increasingly being offered as an option to women.[12] This choice is likely explained by the improved patient satisfaction with autologous reconstruction,[13,14] and information-seeking patients are more likely to choose DIEP flaps over implant-based reconstruction.[15]

In an era where there is a heightened focus on the determination of need for inpatient hospitalization, efforts to shorten or even obviate the requirement for admission have been redoubled. For those undergoing mastectomy alone or even with implant-based reconstruction, this is being offered more frequently as an outpatient procedure.[16] This development increases pressure to standardize postoperative protocols for

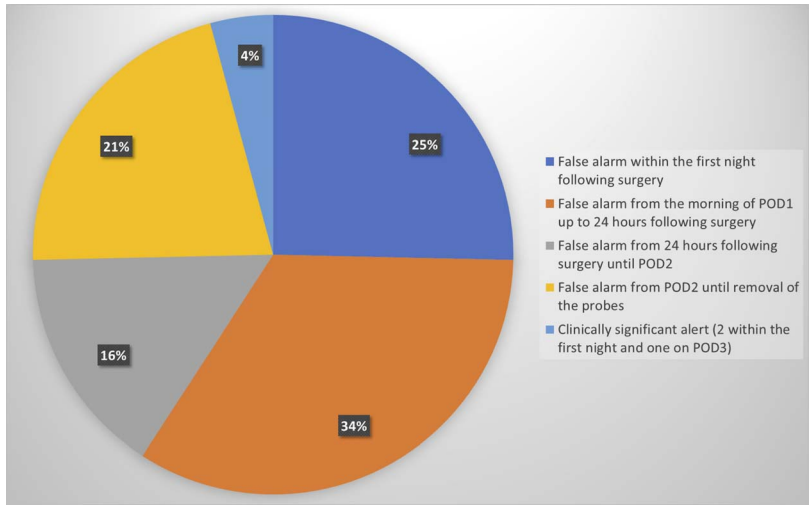

FIGURE 1. Timing of NITO-triggered alerts and their clinical significance. Summary of NITO-triggered alerts based on timing from surgery and their clinical significance. full color online

those undergoing autologous reconstruction to maintain a level of cost-effectiveness.[17] Several studies have helped to guide the development of an Enhanced Recovery After Surgery protocol with the purpose of streamlining the care of these patients. The use of regional blocks and multimodal pain therapy has been shown to decrease length of stay and can help reduce cost.[18–20]

Aside from pain control, an important determinant of length of stay is the need to monitor the viability of the free tissue transfer. In a cost-utility analysis by Jablonka et al,[21] the authors find that the incremental cost-effectiveness ratio of inpatient monitoring exceeds a predetermined willingness-to-pay threshold on POD 2. In effect then, the goal of inpatient monitoring is to capture any early threat to flap compromise in a timely manner to allow for possible salvage.

The goal of the study was to comprehensively re-evaluate the use of tissue oximetry in the postoperative monitoring of free flap breast reconstruction. In over a decade since early published reports on its usefulness in studies originating at our institution, there has been increasing evidence that the monitoring tool frequently raises alarms in the absence of true concern. There are a few factors that may account for this change. In high-volume centers where multiple cases of free flap breast reconstruction are done on a weekly basis even throughout a long stretch of the pandemic, care is streamlined such that the treatment team is well accustomed to all aspects of these patients' management. This volume-outcome relationship is true for many aspects of breast reconstruction and is an important driver of new trends where the complication rates are kept at a low level.[22–24] Nursing providers are familiar with the clinical examination of the free flaps. The residents and attendings are confident in their clinical assessments with adjunct measures through handheld Doppler checks where possible or skin scratch. Flap compromise is increasingly rare as a result of growing microsurgical expertise and institutional experience. Preoperative imaging is routinely used to guide informed dissection based on adequate perforators. Ultimately, flaps are rarely failing, and when they are, the clinical examination is often the determining factor for this assessment.

To highlight this shift, the study was designed to prospectively review the performance of inpatient NITO monitoring. Accordingly, with every alert for a drop in the saturation, the notified physician is left with the burden of determining flap viability in real time. This determination made again and again in the context of the study reflects the core purpose of the study regarding the utility of tissue oximetry monitoring. Although there is no preset algorithm for such an assessment, the use of the clinical examination in concert with the circumstances of the drop in the saturation is often helpful enough to guide further treatment. If the patient had just gotten up to use the bathroom causing an immediate bilateral drop in the saturation reading, that would be less likely to be of clinical significance as compared with a gradual drop in a flap turning purple. In cases of false alerts, time and effort are spent on the part of the notified physician to assure that there is indeed no concern for the flap viability. The patient is also needlessly made anxious when there is in reality no clinical concern.

Ultimately, the decision to ignore the alert in 68 of 71 cases is a useful takeaway. With such a low positive predictive value, the physician is forced to back up an actual concern for flap integrity based on the clinical examination. Accordingly, in this study, there were no operative explorations in the absence of clear concerns on clinical examination. Some level of clinical examination is needed regardless of other monitoring since in the case of breast hematomas, the NITO monitoring may not be affected even as 500 or 1000 mL of clot develops in the breast. The main benefit of NITO then is to direct the provider's attention to the clinical examination as it helped do in the 3 cases of concern for the flap. In these cases, it is not clear how long it would have taken for the nurse to alert the provider to the color change were it not for the NITO alarm. In a study by Koolen et al,[25] the authors find that with institutional experience with NITO monitoring, the salvage rate significantly increased beyond that of clinical monitoring alone. In our study as well, NITO monitoring helped direct important attention to the clinical examination and may very well have maintained the low flap loss for the cohort.

Near-infrared tissue oximetry monitoring is used widely in the United States, and there is a reason to believe that the experience presented in this article is not unique. In a recent retrospective review of cases from the group at the Indiana University School of Medicine, they find a similarly poor positive predictive value, leading to the recommendation to consider discontinuing monitoring after 24 hours.[5] In contrast to the latter study, alerts related to sensor contact or device malfunction were excluded from the current study. In addition, we provide a detailed review of cases with adverse events to further demonstrate the extent of the practical utility of NITO monitoring in real-time management decisions. This analysis helps uncover the redundancy as compared with clinical examination assessment discussed previously. Besides for NITO monitoring, other tools such as the implantable Doppler probe and microdialysis show statistically similar rates of flap salvage as compared with clinical examination in a matched cohort study.[26] In fact, the implantable probe and microdialysis resulted in needless operative explorations when falsely positive.[26]

With limited predictive value, perhaps the role of NITO monitoring should be reframed if it is to continue in its current form. Currently within the Northwell Health system, free flap breast reconstruction is conducted by the senior authors both at the tertiary hospital centers in the current study and in smaller community hospitals, as well. In the former case, residents are available for frequent flap monitoring, but in the latter cases, the nurses alone are often tasked with the burden of flap monitoring. Of the available options for inpatient monitoring, NITO offers a simple-to-use system whereby sensors are attached at the time of surgery, and the nurses need only to record the saturation reading at designated intervals. There is no need to find a signal with a Doppler probe or to draw conclusions regarding the pitch and quality of the sounds. While attendings may be alerted more frequently given the poor specificity of tissue oximetry, they will at least be reliably notified if there is a concern. Attendings in these situations also have the benefit of deciding for themselves whether the context of the saturation drop warrants an in-person assessment. At our institution, the monitors are connected to Wi-Fi allowing for remote access to the saturation data in real time. Finally, NITO is of value in situations where the skin paddle does not incorporate an underlying perforator to allow handheld Doppler checks and in darker-pigmented individuals where aspects of the clinical examination are less reliable. There were very few clinically meaningful alerts in the context of this study. However, it is unclear to what extent the clinical signs would have been missed by the nurse in the absence of NITO monitoring in those cases, and for this reason, in particular, NITO continues to be of some value given its high sensitivity.

Of all patient historical and operative factors recorded, only sensor location seemed to have an effect on the number of alerts. A sensor in an IMF position was associated with a greater number of alerts as compared with the number of alerts for other sensor locations. One explanation is that the flaps in this position are often small and in a dependent position and therefore subject to increased tissue edema or incisional drainage that may affect tissue oximetry measurements.

There are important limitations in the study. Providers had free license to evaluate the significance of NITO-triggered alerts in accordance with the established standard of care. There was no requirement for operative exploration based on a saturation threshold, and this may explain why there were no cases of needless operative exploration. In addition, the threshold of 10% for triggering an alert may be more conservative than for other institutions. This institutional policy is based on the understanding that with residents taking call from home overnight, they may need to be informed of a problem early on to give them time to return to the hospital before when the saturation has already dropped by 15% or 20%. Nevertheless, the findings from this article help support

more recent findings of questionable utility and thereby help overturn earlier assessments holding it in higher regard.[1–4] One area of possible interest is the theoretical association between a decrease in the tissue oximetry for a certain part of the flap and delayed fat necrosis as a result of partial flap compromise. While this was beyond the scope of the current study as it typically becomes apparent long after the initial hospitalization, it may be interesting to track this relationship in the future. It is unclear to what extent partial flap loss could be circumvented and the preparedness of providers to attempt salvage in such cases, but the ability to predict such an outcome may be an important first step.

In conclusion, we present findings from a prospective analysis of the utility of NITO monitoring for free flap breast reconstruction. We find that the monitoring program missed no pedicle-related adverse events at the tradeoff of frequent false alarms. We recommend that NITO-triggered alerts be corroborated based on additional clinical signs. The need to attend to false alerts must be weighed against the potential benefit of earlier notification in the rare event of flap compromise. The exact timeframe for use can be determined at the institutional level by weighing these pros and cons.

REFERENCES

1. Keller A. Noninvasive tissue oximetry for flap monitoring: an initial study. *J Reconstr Microsurg*. 2007;23:189–197.
2. Keller A. A new diagnostic algorithm for early prediction of vascular compromise in 208 microsurgical flaps using tissue oxygen saturation measurements. *Ann Plast Surg*. 2009;62:538–543.
3. Steele MH. Three-year experience using near infrared spectroscopy tissue oximetry monitoring of free tissue transfers. *Ann Plast Surg*. 2011;66:540–545.
4. Chen Y, Shen Z, Shao Z, et al. Free flap monitoring using near-infrared spectroscopy: a systemic review. *Ann Plast Surg*. 2016;76:590–597.
5. Tran PC, DeBrock W, Lester ME, et al. The false positive rate of transcutaneous tissue oximetry alarms in microvascular breast reconstruction rises after 24 hours. *J Reconstr Microsurg*. 2021;37:453–557.
6. Schoenbrunner A, Hackenberger PN, DeSanto M, et al. Cost-effectiveness of ViOptix versus clinical examination for flap monitoring of autologous free tissue breast reconstruction. *Plast Reconstr Surg*. 2021;148:185e–189e.
7. Rubino C, Figus A, Lorettu L, et al. Post-mastectomy reconstruction: a comparative analysis on psychosocial and psychopathological outcomes. *J Plast Reconstr Aesthet Surg*. 2007;60:509–518.
8. Mullan MH, Wilkins EG, Goldfarb S, et al. Prospective analysis of psychosocial outcomes after breast reconstruction: cross-cultural comparisons of 1-year postoperative results. *J Plast Reconstr Aesthet Surg*. 2007;60:503–508.
9. Denford S, Harcourt D, Rubin L, et al. Understanding normality: a qualitative analysis of breast cancer patients' concepts of normality after mastectomy and reconstructive surgery. *Psychooncology*. 2011;20:553–558.
10. Harcourt DM, Rumsey NJ, Ambler NR, et al. The psychological effect of mastectomy with or without breast reconstruction: a prospective, multicenter study. *Plast Reconstr Surg*. 2003;111:1060–1068.
11. Eltahir Y, Werners LLCH, Dreise MM, et al. Quality-of-life outcomes between mastectomy alone and breast reconstruction: comparison of patient-reported BREAST-Q, and other health-related quality-of-life measures. *Plast Reconstr Surg*. 2013;132:201e–209e.
12. Cai Y, Boas SR, Summerville L, et al. National trends in hospitalization charges for autologous free flap breast reconstruction. *Ann Plast Surg*. 2020;85(S1 Suppl 1):S135–S140.
13. Pirro O, Mestak O, Vindigni V, et al. Comparison of patient-reported outcomes after implant versus autologous tissue breast reconstruction using the BREAST-Q. *Plast Reconstr Surg Glob Open*. 2017;5:e1217.
14. Alderman AK, Wilkins EG, Lowery JC, et al. Determinants of patient satisfaction in postmastectomy breast reconstruction. *Plast Reconstr Surg*. 2000;106:769–776.
15. Gopie JP, Timman R, Hilhorst MT, et al. Information-seeking behaviour and coping style of women opting for either implant or DIEP-flap breast reconstruction. *J Plast Reconstr Aesthet Surg*. 2011;64:1167–1173.
16. Bian J, Krontiras H, Allison J. Outpatient mastectomy and breast reconstructive surgery. *Ann Surg Oncol*. 2008;15:1032–1039.
17. Grover R, Padula WV, Van Vliet M, et al. Comparing five alternative methods of breast reconstruction surgery: a cost-effectiveness analysis. *Plast Reconstr Surg*. 2013;132:709e–723e.
18. Jablonka EM, Lamelas AM, Kim JN, et al. Transversus abdominis plane blocks with single-dose liposomal bupivacaine in conjunction with a nonnarcotic pain regimen help reduce length of stay following abdominally based microsurgical breast reconstruction. *Plast Reconstr Surg*. 2017;140:240–251.
19. Batdorf NJ, Lemaine V, Lovely JK, et al. Enhanced recovery after surgery in microvascular breast reconstruction. *J Plast Reconstr Aesthet Surg*. 2015;68:395–402.
20. Rodnoi P, Teotia SS, Haddock NT. Economic impact of refinements in eras pathways in DIEP flap breast reconstruction. *J Reconstr Microsurg*. 2022;38:524–529.
21. Jablonka EM, Lamelas AM, Kanchwala SK, et al. A simplified cost-utility analysis of inpatient flap monitoring after microsurgical breast reconstruction and implications for hospital length of stay. *Plast Reconstr Surg*. 2019;144:540e–549e.
22. Tanna N, Clayton JL, Roostaeian J, et al. The volume-outcome relationship for immediate breast reconstruction. *Plast Reconstr Surg*. 2012;129:19–24.
23. Tanna N, Broer PN, Weichman KE, et al. Microsurgical breast reconstruction for nipple-sparing mastectomy. *Plast Reconstr Surg*. 2013;131:139e–147e.
24. Alba B, Schultz BD, Cohen D, et al. Risk-to-benefit relationship of contralateral prophylactic mastectomy: the argument for bilateral mastectomies with immediate reconstruction. *Plast Reconstr Surg*. 2019;144:1–9.
25. Koolen PGL, Vargas CR, Ho OA, et al. Does increased experience with tissue oximetry monitoring in microsurgical breast reconstruction lead to decreased flap loss? The learning effect. *Plast Reconstr Surg*. 2016;137:1093–1101.
26. Whitaker IS, Rozen WM, Chubb D, et al. Postoperative monitoring of free flaps in autologous breast reconstruction: a multicenter comparison of 398 flaps using clinical monitoring, microdialysis, and the implantable Doppler probe. *J Reconstr Microsurg*. 2010;26:409–416.