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ARTICLE

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Assessment of local tissue water in breasts following breast reconstruction with an expander prosthesis or DIEP flap

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ABSTRACT

The role of breast oedema in breast reconstruction is unknown. Therefore, our aim was to investigate local tissue water (LTW) and breast oedema-related symptoms in breasts reconstructed with either an expander prosthesis (EP) or with a deep inferior epigastric perforator (DIEP) flap at a minimum of one year postoperatively. Sixty-eight patients randomised to breast reconstruction with an EP or DIEP flap completed follow-up. Objective evaluation was performed at a mean of 25 (standard deviation, SD 9.5) months following breast reconstruction, and included measurements of breast volume and LTW with the MoistureMeterD® instrument. The patients completed the BREAST-Q questionnaire pre- and postoperatively. No significant differences in LTW were found when comparing EP and DIEP flap reconstructed breasts. The reconstructed breasts had an increase in LTW compared with the non-operated contralateral breasts. The BREAST-Q responses related to breast oedema symptoms were overall low and the median responses ranged from 1 to 2. A score of 1 indicated that symptoms were experienced 'None of the time'. Our findings indicate that mastectomy followed by breast reconstruction inflicts damage on the lymphatic system, shown as an increase in LTW. However, no breast oedema-related symptoms were reported in the BREAST-Q questionnaire, and therefore, we consider our objective results to be below a potential threshold for symptomatic breast oedema. A threshold for clinical indication of breast oedema remains to be defined.

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Background

Breast surgery procedures give rise to temporary or persistent oedema in the skin and underlying tissue. Damage to the lymphatic vascular system during breast cancer surgery may lead to arm lymphoedema, a well-documented condition associated with impaired wound healing, risk of infection and a negative impact on patient-reported quality of life (QOL) [1–4]. Similarly, breast oedema following breast surgery causes local discomfort and pain and an overall worsened QOL [5,6]. In comparison, however, breast oedema has received little focus in literature [7].

Previous studies have mainly focused on breast oedema as a result of breast-conservation surgery (BCS) and treatment [3,5,6,8,9]. Risk factors for the development of breast oedema were found to encompass axillary lymph node dissection, sentinel lymph node biopsy and high body mass index (BMI) [6,9]. Radiation therapy (RT) also increased the risk [3,6,10].

Several methods have been used to investigate breast oedema. Subjective evaluation with clinical examination and self-reported questionnaires, as well as a number of objective approaches have been studied in the past [3,5,6,8,11,12]. The objective methods used were high-frequency ultrasound, bioelectrical impedance analysis, and tissue dielectric constant (TDC) measurements [3,8,12]. The MoistureMeterD® (MoistureMeterD®, Delfin Technologies Ltd, Kuopio, Finland) is a device measuring TDC and has been validated for assessment of oedema in biological tissues and is suitable for early detection of lymphoedema [13–15]. However, no standardised methods for measurement or a definition of breast oedema have yet been agreed [7,16].

Breast reconstruction is an established procedure facilitating higher QOL for breast cancer survivors [17]. Nonetheless, a breast reconstruction involves tissues already traumatised by previous cancer surgery. Hypothetically, a breast reconstruction would inflict additional damage to the breast's lymphatic circulation, resulting in postoperative oedema. Breast oedema in breast reconstruction has previously been assessed by Greenhowe *et al.* using the MoistureMeterD® Compact [12]. The authors reported increased tissue water content in autologous immediate reconstructed breasts up to three months postoperatively [12]. Based on our literature search, this is the only report published on breast oedema from the perspective of breast reconstructions. Consequently, breast oedema in relation to breast reconstruction methods and prevalence over time is unknown.

The aim of this randomised study was therefore to objectively investigate local tissue water (LTW) in breasts reconstructed with either an expander prosthesis (EP) or a deep inferior epigastric perforator (DIEP) flap, and compare with the contralateral breasts.

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Another aim was to compare the results with specific BREAST-Q questions corresponding to breast oedema-related symptoms.

Material and methods

Study design

Between 2012 and 2018, 135 patients with unilateral mastectomy and no previous RT were refereed to our clinic for delayed breast reconstruction. All eligible patients were asked to participate in the study and randomised to breast reconstruction with either an EP or DIEP flap. At that time, participating in the study was the only way for these patients to be reconstructed with a DIEP flap. According to the national guidelines, DIEP flap breast reconstruction was offered only to patients with previous RT to the breast. After exclusion, 73 patients remained. Of these, 29 were reconstructed with an EP and 44 with a DIEP flap. The study details are described in our previously published study [18]. Written informed consent was collected from all patients prior to breast reconstruction surgery. Patient data and dates for follow-up were collected from study protocols and medical journals. The collected data were transferred to a document and coded before analysis to ensure confidentiality.

Patients included in the study were reconstructed with either an EP or a DIEP flap. An EP is a silicon implant with an inner fillable lumen connected to a subcutaneously placed detachable port. The EP is filled with saline *via* the port lumen. The EP used in this study was a Siltex Mentor® Contour Profile Becker-35, Cohesive II (Johnson & Johnson Medical Ltd, New Brunswick, New Jersey 08933, USA) and in all cases it was placed in the submuscular position. A DIEP flap surgery is a more extensive breast reconstruction method and includes transferring of autologous tissue from the abdomen to the chest as well as use of a microsurgical technique.

Patients and contralateral surgery

This study was approved by the Regional Ethical Review Board in Lund (ref no. 2012/187). Written informed consent was collected from all participating patients. The procedures were in accordance with the Declaration of Helsinki of 1964 and its most recent revision in 2013.

Sixty-eight of 73 patients completed follow-up at the outpatient clinic, 27 patients were reconstructed with EP and 41 with DIEP flaps. Of the five remaining patients, two were waiting for a nipple reconstruction. One patient was waiting for a second opinion, one patient cancelled her appointment several times, and TDC assessment was not completed in one patient. The mean age at breast reconstruction was 54 (standard deviation, SD 9.4) years. A mean of 25 (SD 9.5) months passed between the breast reconstruction and the follow-up (Table 1).

Of the 68 participating patients, 31 underwent symmetrising contralateral surgery. Twenty-four were reduction mammaplasties and seven were mastopexies. In the EP group, 15 patients had contralateral breast surgery, of which nine were reductions and six mastopexies. Of the 41 patients reconstructed with DIEP flaps, 16 had contralateral breast surgery and all but one was reductions. Contralateral surgery was performed at a mean of 18 (SD 8.1) months prior to follow-up. One patient had a contralateral breast reduction mammaplasty prior to the breast reconstruction. One patient had a breast augmentation two years after a mastopexy in the contralateral breast. The implant used was a Mentor® Siltex Round, Moderate Profile, Cohesive I (Johnson & Johnson Medical Ltd, New Brunswick, New Jersey 08933, USA).

Table 1. Patient characteristics, treatment factors and times to follow-up listed for all patients ($n = 68$) and by breast reconstruction method (EP $n = 27$ and DIEP flap $n = 41$).

	All patients	EP	DIEP flap	p Value[a]
Mean ± SD (range)				
Age (years)	54 ± 9.4	56 ± 9.0	53 ± 9.5	0.26
BMI (kg/m^2)	26 ± 3.8	25 ± 2.9	26 ± 2.7	0.37
Volume breast (ml)				
RB	474 ± 180	414 ± 139	514 ± 195	**0.02**
CB	489 ± 186	448 ± 163	517 ± 196	0.14
Arm lymphoedema	7 (10.3%)	1 (3.7%)	6 (14.6%)	0.23[c]
Treatment factors				
Chemotherapy	39 (57.4%)	13 (48.1%)	26 (63.4%)	0.21[b]
Endocrine therapy	47 (69.1%)	19 (70.4%)	28 (68.3%)	0.86[b]
Immune therapy	11(16.2%)	4 (14.8%)	7 (17.1%)	0.81[b]
Axillary operation				
ALND	16 (23.5%)	3 (11.1%)	13 (31.7%)	0.06[a]
SLNB	51 (75%)	23 (85.2%)	28 (68.3%)	
No	1 (1.5%)	1 (3.7%)	0	
Time to follow-up (months)				
Breast reconstruction to follow-up	25 ± 9.5 (11–56)	25 ± 10 (12–56)	25 ± 9.3 (11–50)	0.95
Contralateral surgery to follow-up	18 ± 8.1 (2–36)	15 ± 5.0 (4–25)	21 ± 9.5 (2–36)	0.06
Breast reconstruction to completed BREAST-Q	25 ± 10 (8–55)	26 ± 11 (11–55)	24 ± 9.3 (8–50)	0.42

[a]Student's *t*-test.
[b]Chi^2-test.
[c]Fisher's exact test.
SD: Standard deviation; BMI: Body mass index; EP: Expander prosthesis; DIEP: Deep inferior epigastric perforator; RB: Reconstructed breast; CB: Contralateral breast; ALND: Axillary lymph node dissection; SLNB: Sentinel lymph node biopsy.
p Values < 0.05 were considered significant and is in bold.

Between breast reconstruction surgery and follow-up, six patients reconstructed with an EP had a prosthesis exchange. Of the new breast prostheses inserted, one was a Mentor® Siltex Round, Moderate Plus Profile, Cohesive I (Johnson & Johnson Medical Ltd, New Brunswick, New Jersey 08933, USA), three were Mentor® CPG 312, Moderate Plus Profile, Cohesive III (Johnson & Johnson Medical Ltd, New Brunswick, New Jersey 08933, USA) and two were Mentor® CPG 313, High Projection, Cohesive III (Johnson & Johnson Medical Ltd, New Brunswick, New Jersey 08933, USA).

Objective examinations

All examinations were performed at the plastic surgery outpatient clinic. Before examination, nipple reconstruction and tattoo on the reconstructed breast had to be completed. One of two registered nurses performed the measurements according to a study-specific protocol (Supplementary Appendix). Breast volumes were assessed with plastic breast cups, with the patient in the sitting position [19]. TDC measurements were taken with the patient in the supine position. The breasts were divided into quadrants (medial upper, medial lower, lateral lower, lateral upper). In each quadrant, a point of measurement was marked at a distance of 3–5 cm from the areola border. If there was no areola, an estimation was made. Each point was measured three times using the MoistureMeterD® device and then averaged as recommended by a previous study [14]. The M25 probe was selected, providing a measurement depth of 5 mm.

TDC methodology

The MoistureMeterD® is a non-invasive and water-specific instrument. Placed on the skin surface, the coaxial probe transmits an

ultra-high-frequency electromagnetic wave of 300 MHz to the subcutaneous fat. Data received from the electromagnetic energy reflected back, generates the TDC, which is directly proportional to the tissue water content [13].

Four probes are accessible to the instrument, each measuring different depths of the tissue. With an increasing depth, the TDC values will be lower as a result of less water content in the deeper more fat-rich tissues [20].

BREAST-Q

Prior to the breast reconstruction and at the follow-up, all patients were instructed to complete the BREAST-Q Reconstruction Preoperative and Postoperative Module Version 1.0. The BREAST-Q questionnaire, designed to investigate patient satisfaction and QOL, consists of QOL domains (Psychosocial Well-being, Sexual Well-being and Physical Well-being) and Satisfaction domains (Satisfaction with Breasts, Satisfaction with Nipples, Satisfaction with Abdomen, Satisfaction with Outcome and Satisfaction with Care) [21]. In the Physical Well-being domain, there are seven questions that correspond to self-reported symptoms experienced by patients with breast oedema [5,6]. These questions are the same in the preoperative (labelled 3.i, 3.j, 3.k, 3.l, 3.m, 3.o and 3.p) and postoperative questionnaire (labelled 6.i, 6.j, 6.k, 6.l, 6.m, 6.o and 6.p) and were selected for analysis. The response options were 'None of the time' (1), 'A little of the time' (2), 'Some of the time' (3), 'Most of the time from' (4) and 'All of the time' (5). The mean time between breast reconstruction and completed BREAST-Q was 25 (SD 10) months (Table 1). Two patients in the DIEP flap group did not complete the preoperative questionnaire. In the DIEP flap group, one patient did not return the postoperative questionnaire and eight did not respond to the questions evaluated in this study. In the EP group, two patients did not respond to these questions.

Statistical analysis

Data was presented as mean and SD for parametric data and as median and quartiles (1q, 3q) for non-parametric data. Non-paired data were calculated with the Student's t-test or Mann–Whitney U-test, and for paired data the Paired t-test or Wilcoxon signed-ranks test were used. Ordinal data was tested with the Chi^2-test or Fisher's exact test. *P*-values below 0.05 were considered to indicate a significant difference. Statistical Package for Social Sciences version 26 (IBM Corp. Armonk, NY: IBM Corp. Released 2019) was used for statistical analysis.

Results

Patient characteristics and follow-up

A description of the patients and time between breast surgery and follow-up are given in Table 1. Age, BMI, treatment factors and follow-up times were comparable between the EP and DIEP flap groups. The reconstructed breasts were significantly larger in the DIEP flap group compared with the EP group.

TDC in breast reconstructions

Table 2 presents TDC measurements in breasts reconstructed with EP and DIEP flaps. No differences were found between the groups in any quadrant when tested for absolute values and ratios ($p_{absolute}$=0.78, p_{ratio}=0.26). Separated into groups by contralateral surgery, no significant differences in ratios between EP and DIEP flap breasts were observed ($p = 0.19$, 0.87, respectively). No significant differences were found between the TDC ratios or the absolute TDC values of the reconstructed breast when separating the patients into groups by chemotherapy, endocrine and immune therapy, type of axillary operation and presence of arm lymphoedema.

TDC in patients with non-operated contralateral breast

Comparisons of absolute TDC values in the group of patients with non-operated contralateral breasts are displayed in Table 3. Reconstructed breasts had significantly higher TDC values in all quadrants compared with the contralateral breasts ($p < 0.01$). On further separation of the patients using the reconstruction method, the EP group had significantly higher TDC values in all quadrants but the lateral upper quadrant. Similarly, DIEP flaps had significantly higher TDC values in all quadrants but the medial upper quadrant.

TDC in patients with operated contralateral breast

Absolute TDC values, presented as quadrant means in Tables 4 and 5, were significantly higher in all reconstructed breasts, apart from the medial upper quadrant compared with all operated contralateral breasts ($p < 0.01$). Divided into groups by type of contralateral surgery, the differences in TDC values were more pronounced in relation to contralateral breast reductions. The mean TDC values were comparable between the EP reconstructed breasts and the corresponding operated contralateral breasts. However, when comparing DIEP flap with the corresponding

Table 2. Comparisons of absolute TDC values and ratios in breasts reconstructed with EP or DIEP flaps, among all patients and in groups by prevalence of contralateral surgery.

	Absolute values			*Ratios (reconstructed/contralateral breast)*		
	EP	DIEP flap	*p* Value[a]	EP	DIEP flap	*p* Value[a]
TDC Median (1q, 3q)						
All reconstructed breasts $n = 68$	27	41		27	41	
Mean value quadrants	29.3 (25.5, 31.3)	28.6 (26.0, 31.4)	0.78	1.13 (1.06, 1.19)	1.09 (1.03, 1.15)	0.26
Patients with non-operated contralateral breasts $n = 37$	12	25		12	25	
Mean value quadrants	29.5 (27.4, 32.9)	28.7 (27.4, 30.7)	0.43	1.16 (1.04, 1.27)	1.07 (1.07, 1.16)	0.19
Patients with contralateral surgery $n = 31$ (reduction/mastopexy)	15 (9/6[b])	16 (15/1)		15 (9/6[b])	16 (15/1)	
Mean value quadrants	27.4 (23.7, 31.2)	27.8 (25.6, 43.2)	0.24	1.09 (1.09, 1.17)	1.11 (1.11, 1.14)	0.87

[a]Mann–Whitney U-test.
[b]One patient had a breast augmentation two years after mastopexy in the contralateral breast.
TDC: Tissue dialectic constant; 1q: Lower quartile; 3q: Upper quartile; EP: Expander prosthesis; DIEP: Deep inferior epigastric perforator.

Table 3. Comparisons of absolute TDC values in reconstructed breasts and non-operated contralateral breasts.

	Reconstructed breast	Non-operated contralateral breast	*p* Value[a]
TDC Median (1q, 3q)			
EP and DIEP flap, *n*			37
Mean value quadrants	28.9 (27.5, 30.8)	26.5 (25.1, 28.4)	**<0.01**
EP, n			12
Mean value quadrants	29.5 (27.4, 32.9)	26.4 (25.1, 28.9)	**<0.01**
DIEP flap, n			25
Mean value quadrants	28.7 (27.4, 30.7)	26.5 (25.1, 28.2)	**<0.01**

[a]Wilcoxon signed-rank test.
TDC: Tissue dialectic constant; 1q: Lower quartile; 3q: Upper quartile; EP: Expander prosthesis; DIEP: Deep inferior epigastric perforator.
p-values < 0.05 were considered significant and are in bold.

Table 4. Comparisons of absolute TDC values in reconstructed breasts and operated contralateral breasts.

	Reconstructed breast	Operated contralateral breast	*p* Value[a]
TDC Median (1q, 3q)			
EP and DIEP flap, n			31
Mean value quadrants	27.4 (24.8, 31.9)	25.9 (23.4, 29.3)	**<0.01**
EP, n			15[b]
Mean value quadrants	27.4 (23.7, 31.2)	25.6 (23.4, 27.7)	0.06
DIEP flap, n			16
Mean value quadrants	27.8 (25.6, 34.2)	26.7 (22.9, 29.6)	**<0.01**

[a]Wilcoxon signed-rank test.
[b]One patient had a breast augmentation two years after mastopexy in the contralateral breast.
Abbreviations: TDC: Tissue dialectic constant; 1q: Lower quartile; 3q: Upper quartile; EP: Expander prosthesis; DIEP: Deep inferior epigastric perforator.
p-values <0.05 were considered significant and are in bold.

Table 5. Comparisons of absolute TDC values in reconstructed breasts and contralateral breasts after reduction mammaplasty or mastopexy.

	Reconstructed breast	Reduction mammaplasty	*p* Value[a]	Reconstructed breast	Mastopexy	*p* Value[a]
TDC Median (1q, 3q)						
EP and DIEP flap, n			24			7
Mean value quadrants	27.8 (25.6, 33.0)	26.1 (23.4, 29.2)	**<0.01**	24.8 (20.4, 31.5)	25.5 (18.3, 30.0)	0.24
EP, n			9			6[b]
Mean value quadrants	27.4 (24.6, 30.6)	25.9 (23.7, 27.1)	0.14	27.3 (20.0, 32.3)	25.6 (19.9, 30.8)	0.25
DIEP flap, n			15			1
Mean value quadrants	28.2 (25.7, 34.3)	27.5 (22.7, 29.6)	**<0.01**	24.8 (24.8, 24.8)	24.8 (24.8, 24.8)	

[a]Wilcoxon signed-rank test.
[b]One patient had a breast augmentation two years after mastopexy in the contralateral breast.
Abbreviations: TDC: Tissue dialectic constant; 1q: Lower quartile; 3q: Upper quartile; EP: Expander prosthesis; DIEP: Deep inferior epigastric perforator.
p-values <0.05 were considered significant and are bolded.

operated contralateral breasts, significantly higher TDC values were seen in all quadrants but the medial lower.

BREAST-Q

The BREAST-Q questions analysed are presented in Table 6. The question 3/6.k '*Nagging feeling in your breast area*' received a significantly higher score postoperatively in the DIEP flap group. The remaining questions were comparable. The median pre- and postoperative responses ranged from 1 to 2 in both groups.

Discussion

To our knowledge, this is the first report investigating LTW in delayed breast reconstruction. No significant differences were observed comparing the two breast reconstruction methods regarding LTW or breast oedema-related symptoms assessed with the BREAST-Q questionnaire. However, reconstructed breasts had a higher amount of LTW compared with breasts that had not been exposed to previous surgery. Our findings indicate that reconstructed breasts have a remaining increase in LTW at a mean of two years postoperatively compared with non-operated breasts.

Breast oedema is a condition related to breast cancer treatment and has received little focus in the past, especially in terms of breast reconstruction. One could presume DIEP flap reconstructed breasts to have an increase in LTW during the initial postoperative period. Tissue injury initiates an acute inflammatory response, subsequently leading to the transfer of intravascular fluids to the interstitial space [22,23]. The inflammatory response will be higher the more extensive the surgery, and thus, the response will be greater in a DIEP flap breast reconstruction than in EP [24] . In addition, transferring of a DIEP flap includes separation of the flap from its adjacent tissues, inevitably damaging the lymphatic circulation. An imbalance between excess interstitial fluids and an impaired lymphatic drainage will result in tissue oedema [25]. The hypothesis is supported by Greenhowe *et al.*, who report an increased tissue water content in autologous breast reconstruction during the first three months following surgery compared with the contralateral breasts [12]. Although a difference in LTW might have been present at an earlier stage also in this study, our results indicate that LTW in EP and DIEP flaps are comparable in the longer-term perspective.

Table 6. Comparison of pre- and postoperative BREAST-Q responses regarding questions comprising breast oedema-related symptoms for all patients ($n = 68$) and by breast reconstruction method (EP $n = 27$ and DIEP flap $n = 41$).

	All patients			EP			DIEP flap		
Median (1q, 3q)	Preop	Postop	*p* Value[a]	Preop	Postop	*p* Value[a]	Preop	Postop	*p* Value[a]
Question 3/6.i "Tightness in your breast area?"	1 (1, 2)	2 (1, 2)	0.83	2 (1, 3)	2 (1, 2)	0.81	1 (1, 2)	1 (1, 2)	0.45
Question 3/6.j "Pulling in your breast area?"	2 (1, 2)	1 (1, 2)	0.12	2 (1, 3)	2 (1, 2)	0.08	2 (1, 2)	1 (1, 2)	0.46
Question 3/6.k "Nagging feeling in your breast area?"	1 (1, 1)	1 (1, 2)	**0.04**	1 (1, 2)	1 (1, 2)	0.74	1 (1, 1)	1 (1, 2)	**0.01**
Question 3/6.l "Tenderness in your breast area?"	1 (1, 2)	1 (1, 2)	0.56	1 (1, 2)	1 (1, 2)	0.87	1 (1, 2)	1 (1, 2)	0.21
Question 3/6.m "Sharp pains in your breast area?"	1 (1, 1)	1 (1, 1)	0.25	1 (1, 1)	1 (1, 1)	0.91	1 (1, 1)	1 (1, 1)	0.10
Question 3/6.o "Aching feeling in your breast area?"	1 (1, 1)	1 (1, 1)	0.93	1 (1, 2)	1 (1, 1)	0.36	1 (1, 1)	1 (1, 1)	0.10
Question 3/6.p "Throbbing feeling in your breast area?"	1 (1, 1)	1 (1, 1)	0.21	1 (1, 1)	1 (1, 1)	0.23	1 (1, 1)	1 (1, 1)	0.52

The questions belong to the BREAST-Q Reconstruction Preoperative (question 3) and Postoperative (question 6) Module Version 1.0 and are preceded by 'In the past two weeks, how often have you experienced:' The response options range from 1–5 where 1 corresponds to 'None of the time' and 5 to 'All of the time'.
[a]Wilcoxon signed-rank test.
1q: Lower quartile; 3q: Upper quartile; EP: Expander prosthesis; DIEP: Deep inferior epigastric perforator.
p-values <0.05 were considered significant and are bolded.

In order to relate our objective findings with the patients' perceptions, we selected BREAST-Q questions corresponding to breast oedema-related symptoms. Pain, heaviness, swelling and tensed skin in the breast have previously been reported in the literature [5,6,26]. The patients in this study did not report any breast oedema-related symptoms pre- or postoperatively, as indicated by the median BREAST-Q responses ranging from 1 to 2. However, the BREAST-Q questionnaire was not created for analysis of separate questions [27]. The questions we selected have not been validated for breast oedema assessment. Fortunately, a patient-reported questionnaire for breast oedema was recently presented and validated in a study by Verbelen *et al.* [26]. The questionnaire focuses on patients following BCS, similar to most studies published on breast oedema [5,6,26]. A breast oedema-specific questionnaire may be useful in future studies for assessing breasts following both breast reconstruction and BCS.

In this study, operated breasts had higher LTW compared with non-operated breasts. Similar findings have been presented previously in both short-term and long-term assessments [12,28–30]. The aforementioned study by Greenhowe *et al.*, reported increased tissue water content in the operated breasts during the three first postoperative months [12]. Two other studies investigated the lymphatic function following breast surgery with lymphoscintigraphy [28,29]. Perbeck *et al.* found a higher radiotracer clearance in breasts operated for benign tumours compared with healthy breasts two to five years postoperatively. The high clearance rate was initially interpreted as increased lymph flow, a theory that was later questioned and instead proposed to be a result of dermal backflow [28,31]. Similarly, a higher radiotracer clearance was found postoperatively in breasts that had undergone reduction mammaplasty compared with preoperatively [29]. Both studies indicated a worsened lymphatic function in breasts following surgery. Moreover, they suggested the lack of clinical findings of breast oedema to be due to a residual reserve capacity for the lymphatic circulation [28,29]. In this study, without any reported breast oedema-related symptoms, we propose that the lymphatic reserve capacity in the reconstructed breasts has not yet been exceeded. Subsequently, our objective TDC results are considered to fall below a potential symptomatic threshold for breast oedema.

Currently, no diagnostic threshold for breast cancer-related breast oedema is in place. In an attempt to create a diagnosis threshold for breast cancer-related arm lymphoedema, Mayrovitz *et al.* assessed TDC in the ventral forearms [15]. They suggested a TDC ratio above 1.20 to indicate subclinical lymphoedema. To increase the sensitivity, a threshold ratio of 1.165 was also discussed [15]. In our study, the EP/non-operated contralateral breast ratio comes very close to the subclinical oedema threshold (TDC ratio = 1.16), although no symptoms of oedema were reported. However, breast oedema ratios may be different and not comparable with that of the forearms. This hypothesis was strengthened by Mayrovitz et al. in a more recent study suggesting different TDC thresholds for different anatomical locations [32]. Further investigations are warranted.

There are some limitations of this study. Due to the absence of a clear definition of breast oedema, multiple assessment methods have been used in previous studies, thus limiting the interpretation of our objective findings [7]. Also, this study has a wide follow-up interval between breast reconstruction and objective examination, potentially affecting the results. In a future study, it would be of interest to establish a TDC ratio threshold for breast oedema diagnosis. In the presence of such a threshold, TDC measurements could be performed to assess breast oedema routinely at an out-patient clinic. Moreover, a translation of the Dutch breast oedema questionnaire could enable the use of a validated patient-reported diagnostic tool [26].

A strength of this study was its randomised prospective study design. To optimise the conditions for reliable data collection, all measurements were taken by one of two nurses. The MoistureMeterD® Compact was recently reported to be a reliable tool with high intra- and inter-rater reliabilities [33].

Conclusion

In conclusion, there were no differences in LTW between the EP and the DIEP flap breast reconstructions. However, the significant increase in LTW in reconstructed breasts compared with non-operated contralateral breasts indicates lymphatic damage measurable up to a mean of two years after surgery. However, the patients did not report any breast oedema-related symptoms, suggesting our objective findings fall below a potential symptomatic breast oedema threshold. Establishing a diagnostic breast oedema threshold for TDC ratios is warranted and could be the

aim of a future study. Finally, the use of a breast oedema-specific questionnaire would be of value in the future.

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