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Review article

Dynamic InfraRed Thermography (DIRT) in DIEP-flap breast reconstruction: A review of the literature

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ABSTRACT

In the industrialised world still 34% of the breast cancer patients are surgically treated by a mastectomy. Breast cancer patients in general have a good prognosis and a long-term survival. Therefore, it is important that the treatment doesn't focus only on survival but also on the quality of life. Breast reconstruction improves the quality of life. A breast reconstruction with an autologous free DIEP (Deep Inferior Epigastric artery Perforator) flap is one of the preferred options after mastectomy. A challenging step in this procedure is the selection of a suitable perforator that provides sufficient blood supply for the flap. Current techniques to locate the perforator vessels include handheld Doppler, colour Doppler ultrasound (CDU), Magnetic resonance angiography (MRA), computer tomographic angiography (CTA) and dynamic infrared thermography (DIRT). At present CTA is the golden standard and DIRT a new option. The objective of this article is to document whether DIRT can accurately map the position of the perforators and measure their influence on the perfusion of the flap in order to select the best perforators to improve the outcome of breast reconstructions with free DIEP flaps. A systematic review of the literature published between January 1998 and November 23th 2018 was conducted regarding the possible benefit of dynamic infrared thermography (DIRT) in DIEP-flap breast reconstructions.

The databases PubMed and Web of Science were used to search for qualified articles. Inclusion criteria were women who underwent a breast reconstruction by means of a DIEP flap where DIRT was used to analyse the blood supply of the flap.

The search yielded a total of fourteen suitable articles: six articles being descriptive clinical studies, three case reports, three expert opinions/Overview articles and two systematic reviews.

There are only a limited number of studies looking at the use of DIRT in breast reconstruction with DIEP-flaps. Adequate identification of the dominate vessel(s) in DIEP reconstruction is essential for a successful outcome. DIRT appears to be an ideal alternative technique for the identification of the dominant perforators of the flap. With the use of DIRT it is possible to identify the dominant vessel(s) preoperatively. The use of DIRT during the operation allows the tailoring of the surgery and postoperative use may identify vascularisation problems in an early stage.

Additional high-quality studies are needed, but DIRT seems to be a valuable investigation for the pre-, per- and postoperative phase of DIEP-flap reconstructions.

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Contents

Introduction

Breast cancer is the most frequent cancer among women. At present, breast cancer impacts 2.1 million women worldwide each year [1]. It is suspected that this figure will increase further to 3.0 million women in 2040 [1].

Breast cancer causes the highest number of cancer-related deaths among women. In 2018, it is estimated that approximately 627,000 women died from breast cancer – that is approximately 15% of all cancer deaths among women. While breast cancer rates are higher among women in more developed regions, rates are increasing in nearly every region globally [1].

Belgium has the highest incidence of breast cancer in women per capita (113.2/100,000) which totals to around 11,000 women each year [1]. One third (34%) of the breast cancer patients undergo uni- or bilateral mastectomy and 1 out of 7 undergo reconstruction surgery. Half of which performed with autologous tissue. Thirty two percent of the autologous tissue flaps are deep inferior epigastric perforator (DIEP)-flaps [1,2].

In a breast reconstruction with a DIEP flap, the skin and subcutaneous tissue from the patient's lower abdomen are used as a free flap to reconstruct the patient's breast. The flap receives its blood supply from the deep inferior epigastric artery and one or two concomitant veins through a perforator. The perforator is then anastomosed to the internal mammary artery and vein for an optimal blood supply of the reconstructed breast [3–6].

Selection of the best perforators is the key in this procedure. This will reduce operative time, lower complication rates and ensure an overall better result [7].

Current techniques to locate the perforator vessels include handheld Doppler, colour Doppler ultrasound (CDU), Magnetic resonance angiography (MRA), computer tomographic angiography (CTA) and dynamic infrared thermography (DIRT) [7–9]. The current golden standard for perforator selection is CTA on which the location and hemodynamic properties of the flap can be reviewed [4,7,8,10]. CTA is frequently used because it is non-invasive and has a high spatial resolution with visualisation of the intramuscular course of the vessels even as small as 0.3 mm. This technique however also has some clear disadvantages: use of intravenous (IV) contrast agents and radiation, high purchasing cost, not usable during surgery and it also does not provide physiological information on flow characteristics of perforators pre- and postoperatively.

An alternative might be DIRT (dynamic infrared thermography). DIRT uses an IR camera to measure the skin temperature based on heat emitted by tissues. This generates a color-coded map, which is a translation for the perfusion of the skin [7,11].

DIRT is a dynamic investigation technique; this means that the skin must undergo a thermal cold challenge. The DIRT measures the rate and patterns of rewarming after cooling. This technique allows to identify the most dominant perforators and the area they perfuse.

DIRT is less invasive than CTA because it doesn't use radiation nor contrast agents. It is a quick imaging technique that is available pre-, per- and post-operative. DIRT is relatively easy to interpret, and it has a low purchasing cost. On the other hand, DIRT only provides information on the physiology of the perforator and not on the morphology. This means that the surgeon must have a thorough knowledge of the vascular anatomy in order to interpret the results [11].

The objective of present systematic review is to document whether DIRT can accurately map the position of the perforators and measure their influence on the perfusion of the DIEP flap in order to improve the outcome of breast reconstructions with free DIEP flaps. Unlike the included reviews, our review focuses not only on the peroperative use of DIRT, but also on the pre-, per- and postoperative use of DIRT in breast reconstructions with DIEP flaps [19,20]. DIRT will be compared with (multidetector) CTA (MDCTA), MRA and handheld Doppler or Colour Doppler Ultrasound (CDU).

Method

Search and study collection

The databases that were consulted for this review were PubMed and Web of Science. The following search terms were used: [thermography AND (breast reconstruction OR mammoplasty)]. Articles that had been published between January 1998 and November 23th 2018 were included. The primary search provided 29 matches in PubMed and 32 in Web of Science. An extra search in Science Direct and the Cochrane Database delivered no new results. After evaluating the references of the eligible articles, 12 more studies were found. After duplicates were removed, 56 articles were taken into account.

Study selection

Three independent readers reviewed the selected articles. All articles of conflict were debated until mutual agreement was found. One article was immediately discarded based on the language (Russian). Additionally 40 articles were excluded on title and abstract.

The criteria used for the exclusion on title and abstract were:

- The article must contain the use of thermography.
- The included patients undergo breast reconstruction with DIEP-flap.
- The full text of the article is written in English or German.

If one of these criteria was not met, the study was excluded.

Fourteen studies measured up to all the criteria and were accepted for further analysis.

Study quality

Using the Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 v2.1 the qualified articles were assessed for their level of evidence by three independent reviewers (Table 5). Any disparity between them was discussed until both gave their consent.

Data selection

All the selected studies reported the advantages and disadvantages of different imaging methods for the selection of the dominant perforators for DIEP flap breast reconstructions. Present study reviewed the use of DIRT during breast reconstructions with DIEP flaps and compare the results with (multidetector) CTA (MDCTA), MRA and handheld Doppler or Colour Doppler Ultrasound (CDU).

The data we extracted from the selected studies are the number of participants, their mean age and mean BMI, imaging methods preoperatively, peroperatively and postoperatively performed with the accompanying results and the outcome of the surgery.

Results

The literature search, performed by previously defined search terms, identified 61 records. After adding 12 studies from references and removing all the duplicates 56 articles remained for screening. The titles and abstracts were examined and discussed until 14 articles remained for full text screening. Those studies could be included in the systematic review after full text reading. The process of data collection and selection is shown in Fig. 1: Prisma flow diagram showing the process of data collection, selection and organisation.

In total fourteen studies were included, with six articles being descriptive clinical studies [4,8,13–16], three case reports [12,17,18], three expert opinions/Overview articles [9–11] and two systematic review on intraoperative evaluation of perfusion in free flap surgery [19,20]. No published randomised controlled studies were found.

Nine studies described the use of DIRT for preoperative imaging [4,8–14,16], seven studies described the intraoperative use of DIRT [11,14,15,17–20] and two studies investigated the postoperative use of DIRT [11,14].

Several studies [4,8,11–13,18] concluded that DIRT is a promising technique for preoperative perforator mapping in DIEP-flap reconstructions, because DIRT can identify the location of the perforators and can give a qualitative assessment of the

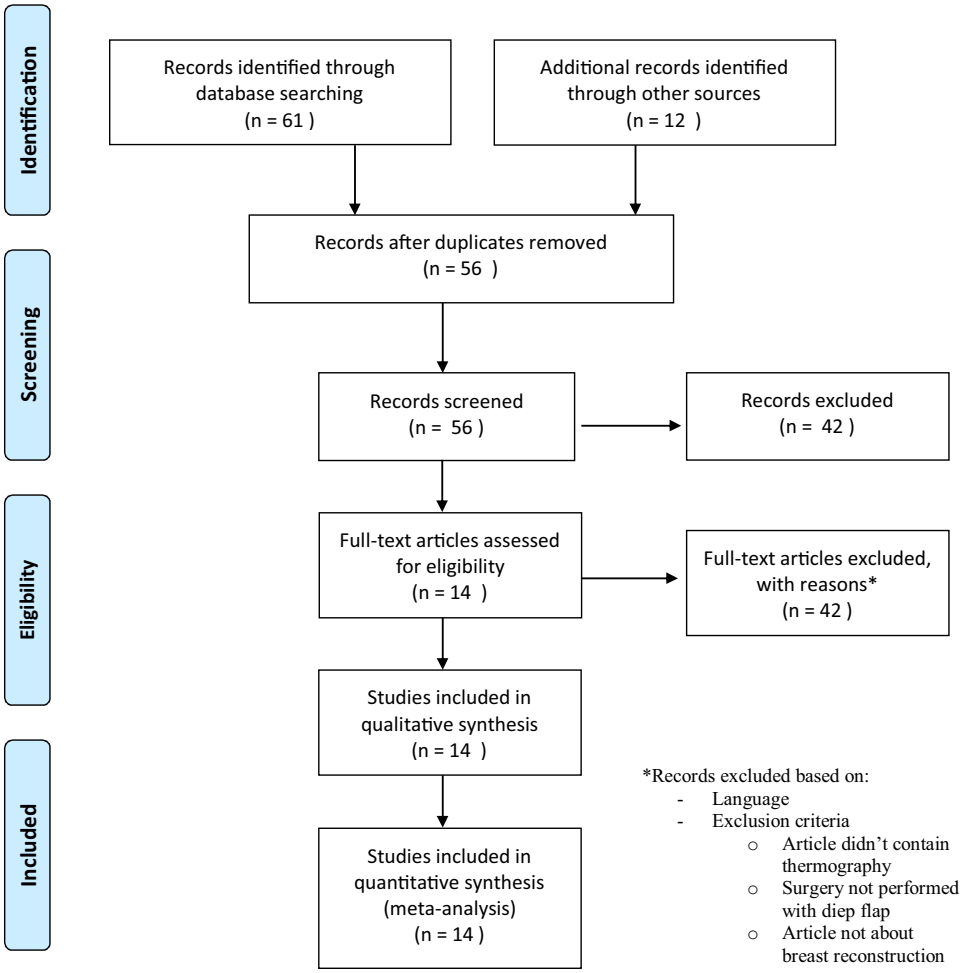

Fig. 1. Prisma 2009 flow diagram.
From the PRISMA group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analysis: the PRISMA statement. PLoS Med §(7): e1000097. Doi: https://doi.org/10.1371/journal.pmed1000097.

perforators. Although Muntean et al. [7] believe in their study on pigs that DIRT should be combined with CDU for an optimal result.

Smit et al. [19] concluded that fluorescence imaging and laser Doppler are the most suitable imaging techniques to measure free flap perfusion peroperatively, but did not comment on the outcome of the use of DIRT peroperatively. De Weerd et al. [15] found that DIRT could be a valuable method for intraoperative monitoring of free tissue transfer.

The collected data are summarized in Tables 1–7 (Table 1: overview of studies describing the advantages and disadvantages of DIRT; Table 2: overview of studies describing the advantages and disadvantages of (MD)CTA; Table 3: overview of studies describing

Table 1
Overview of studies describing the advantages and disadvantages of DIRT.

Study	DIRT: advantages	DIRT: disadvantages
De Weerd et al. [13]	Indirect information of the flow Easy to interpret Non-invasive No radiation No contrast agents Easy to execute	
Nahabedian et al. [9]	No radiation No contrast agents	Moderate accuracy No information on course or calibre of vessel
Tenorio et al. [8]	Investigate any tissue with outstanding precision Simple procedure Detects clinically significant vessels	Cold challenge is uncomfortable for the patient Artefact images (due to skin rash, subcutaneous injections . . .)
De Weerd et al. [11]	Non-invasive No radiation No contrast agents Easy to perform Relatively easy to interpret Able to detect reperfusion problems (torsion/ external compression) during surgery Immediate feedback	Does not show morphology of the perforators
Whitaker et al. [12]	Repeatable Pre-, intra- and postoperative Provides information regarding functional characteristics of individual vessels No radiation Non-invasive Single hospital visit Short procedure Immediate report Low cost Detects clinically significant vessels	Only detects vessels >1 mm diameter Temporal information
Lohman et al. [20]	Qualitative information	Subjective information
Weum et al. [4]	facilitates flap design	Cold challenges Time consuming No information about intramuscular course Detects only perforators that transport blood to the skin surface
Mohan et al. [10]	Non-invasive No contrast agents Low cost	Limited evidence Moderate and variable data 2D images Not widely available
Smit et al. [19]	Assessment of perfusion	Influence of internal and external factors
Steenackers et al. [18]	Fast and easy Real time image	Only the perforators going to the skin will be shown

Table 2
Overview of studies describing the advantages and disadvantages of (MD)CTA.

Study	(MD)CTA: advantages	(MD)CTA: disadvantages
De Weerd et al. [13]	Information on the diameter and location	Radiation Contrast agents
Nahabedian et al. [9]	Precise anatomic localization and intramuscular course Valuable in women who had prior abdominal surgery 3D images	IV contrast agents Radiation No information on the flow of the perforator
Tenorio et al. [8]	Global picture (trajectory can be obtained)	Radiation IV contrast agents High cost
De Weerd et al. [11]	High spatial and temporal resolution Precise description of origin, intramuscular course and point of fascia penetration	IV contrast agents Radiation High cost
Whitaker et al. [12]	Detects 100% of perforators Locates to <1 mm 3D images	Radiation IV contrast agents Delay between scan and report Static images High cost
Mohan et al. [10]	3D or 4D image Ultra high resolution Objective findings Detects vessels as small as 0.3 mm Easy interpretation Sensitivity and specificity close to 100% Visualisation of linking vessels, connection with adjacent perforator territories	Radiation Use of IV contrast agents with the risk of hypersensitivity or nephrotoxicity No physiological information on flow characteristics or assessment of perfusion High cost
Weum et al. [4]	Precise anatomical description of the origin of perforators, intramuscular course and point of fascia penetration Information on the continuity of the deep inferior epigastric system in patients that have been previously operated in that area	Often intra-operative changes necessary [18] Radiation Contrast agents Diameter is sum of artery and vein High cost Time consuming

Table 3
Overview of studies describing the advantages and disadvantages of MRA.

Study	MRA: advantages	MRA: disadvantages
Nahabedian et al. [9]	No radiation Greater contrast resolution than CTA so it can detect very small perforators Information on perforator location, size and distance from umbilicus 97% correlation between MRA and intraoperative findings	Contrast agents Lower spatial resolution than CTA Motion artefacts due to breath holding periods No information on flow
Tenorio et al. [8]	Global picture (trajectory can be obtained)	Use of contrast agents Expensive
Mohan et al. [10]	3D image No radiation High imaging quality and accurate localization of perforators High concordance with intraoperative findings Better delineation of intramuscular course	Longer scan time Need for MR contrast agent (but better safety-risk profile and lower hypersensitivity than CTA) Contraindications e.g. defibrillator, claustrophobia, metallic foreign objects . . . High cost Limitation for vessels <0.8mm Motion artefacts (long breath-hold periods) Availability and timing

Table 4
Overview of studies describing the advantages and disadvantages of Handheld Doppler/CDU.

Study	Handheld Doppler / CDU: advantages	Handheld Doppler / CDU: disadvantages
De Weerd et al. [13]		Many false positive results Definite learning curve
Tenorio et al. [8]	Can differentiate between artery and vein Not expensive Easy to use	Sensitivity and specificity not accurate enough Unreliable information about dominance of perforators No information about surface area or perfusion or size of vessel False positive locations (deep blood vessels that do not perfuse skin Examiner-dependent Time consuming Often uncomfortable for the patient Depends on patient's BMI
Nahabedian et al. [9]	Flow, direction and velocity easily determined Differentiate between vein and artery 96% effective perforator detection No radiation No contrast agents	No 3D image or architectural detail Moderate accuracy Many false positive results No information on calibre or course
Smit J et al. [19]	Non invasive Simple and consistent method	Only assessment of pedicle Movement artefact No assessment of perfusion area
Mohan et al. [10]	Less expensive No radiation or contrast agents	Significant inter-observer variability Long investigation (45-60 min) High false positive rates Difficulty in interpretation of findings Difficult reproducibility Patient body habitus dependent Only 2D images

the advantages and disadvantages of MRA; Table 4: overview of studies describing the advantages and disadvantages of Handheld Doppler/CDU; Table 5: overview of all included studies with their results and level of evidence; Table 6: summary of the advantages and disadvantages of DIRT; Table 7: summary of the advantages and disadvantages of (MD)CTA).

Discussion

Breast reconstruction after breast cancer with a free DIEP flap is one of the most preferred reconstructive techniques in Western Europe at the moment. Unlike breast reconstructions with the free transverse rectus abdominis myocutaneous flap, no muscle of fascia is harvested in breast reconstructions with the DIEP flap, in order to reduce the donor side morbidity [21]. In a free transverse rectus abdominis myocutaneous flap several perforators supply the flap, while a free DIEP flap is only supplied by 1 or 2 perforators. The selected perforator is crucial for flap survival as it is the only source of blood supply to the flap. Therefore adequate perforator selection is mandatory for this type of surgery. Perforator flap surgery requires dissection of small and fragile blood vessels. The pre-operative identification and mapping of the perforators is necessary to reduce complications and optimizes flap design, reduces operating times, lowers complication rates and provides and overall better result [22].

Currently, CTA is considered to be the golden standard for preoperative perforator selection [4,7,8,10]. CTA allows for precise anatomical description of the origin of the perforators, their intramuscular course and the point of fascia penetration. However, CTA has some clear disadvantages: the use of IV contrast agents, radiation exposure and the high purchasing cost [4,7–13,23]. Therefore, an alternative was sought. Dynamic infrared thermography (DIRT) is an attractive approach for perforator mapping in DIEP flaps with lesser disadvantages.

Itoh and Arai described for the first time in 1993 the use of dynamic infrared thermography (DIRT) for perforator mapping in DIEP flaps [24]. DIRT uses an IR camera to measure the skin temperature based on heat emitted by tissues. This generates a

Table 5
Overview of clinical studies and their results and level of evidence.

Study *Study Design and Level of evidence*[*]	Patient info	Preoperative investigations	Intraoperative investigations	Postoperative Investigations / outcome
De Weerd et al. [15] *Descriptive clinical study,IV*	10 patients Mean age: 49.5y (34-59) Mean BMI: 25.3 kg/m2 (20.2-30.5)	Handheld Doppler and DIRT	DIRT In all cases DIRT corresponded with Doppler DIRT detects perfusion problems	2 flaps failed: 1 due to intima lesion; 1 due to inadvertent damage
Kalra et al. [17] *Case report, IV*	2 patients Mean age: 41y		Objective measurement of perfusion of perforators with DIRT	
De Weerd et al. [14] *Descriptive clinical study, IV*	20 patients (16 DIEP, 4 SIEA) Mean age: 51y (34-65) Mean BMI: 27.0 kg/m2 (20.2-30.5)	Handheld Doppler and DIRT	End of operation: DIRT	Clinical assessment, handheld Doppler, DIRT on day 1,3 and 6 after surgery DIRT: pattern of general rewarming + pattern of rewarming with hotspots Day 1: hyperaemia All DIEP flaps survived, 5 partial flap loss (<5%) 1 SIEA flap did not survive
De Weerd et al. [13] *Descriptive clinical study, IV*	27 patients (23 DIEP) Mean age: 50y (34-65) Mean BMI: 26.2 kg/m2 (20.2-36.4)	DIRT and handheld Doppler (+ last 8 patients: additional CTA) Not all Doppler locations could be related to a hot spot Hot spots always slightly more lateral	In all DIEP flaps: selected hot spot = suitable perforator In all cases: DIRT correlated well with CTA and intraoperative findings	All flaps survived, 3 had minor partial flap loss (<5%)
Tenorio et al. [8] *Descriptive clinical study, IV*	10 patients	Handheld doppler and DIRT: 33% no match doppler: deep fascia level; DIRT: subcutaneous tissue No thermal challenge	All perforators confirmed during surgery	
Nahbedian [9] *Expert Opnion/ Overview, IV*		MRA, CTA, DIRT, Fluorescent Angio, Duplex and Color Duplex ultrasound		Near Infrared Spectroscopie (NIR)
De Weerd et Al. [11] *Expert Opinion/ Overview, IV*		DIRT	DIRT	DIRT
Whitaker et al. [12] *Case report, IV*	1 patient, 41y	CTA : one suitable single medial row perforator (2mm) DIRT: one hot spot	Confirmation perforator	No complications
Lohman et al. [20] *Systematic review and Meta-analysis, I*			DIRT; Indocyanine green angiography; Photospectrometry: potential benefit, but more studies needed	
Weum et al. [4] *Descriptive clinical study, IV*	25 patients Mean age: 57y (38-69) Mean BMI: 27.2 kg/m2 (21.6-32.4)	Doppler, CTA, DIRT DIRT		24/25 flaps survived, 1 flap: bleeding (diagnosed to late) In all cases: DIRT selected most suitable perforator
Mohan AT et al. [10] *Expert Opinion, Overview, IV*		CTA, MRA, DIRT, indocyanine green fluorescence angiography		
Walle et al. [16] *Descriptive clinical study,IV*	10 patients, (13 DIEP) Mean age: 55y Mean BMI: 26 kg/m2	CTA, DIRT	All perforators confirmed during surgery	
Steenackers G et al. [18] *Case report, IV*		CTA, DIRT	CTA, DIRT	
Smit JM et al. [19] *Systematic review and Meta-analysis, I*			Fluorescence imaging, laser Doppler, oxygen saturation, ultrasound, DIRT	

[*] Oxford Centre for Evidence-Based Medicine 2011.

color-coded map, which is a translation for the perfusion of the skin [7,11]. As the name implies, DIRT is a dynamic investigation technique. This is because the skin must undergo a thermal cold challenge first. DIRT measures the rate and pattern of rewarming after cooling. Our review showed that DIRT is a promising technique to support and even replace CTA because DIRT doesn't need IV contrast agents nor radiation. It is therefore a safe, repeatable and easy investigation. Together with the fact that it is a short investigation that requires only a single hospital visit, it results in a high patient compliance. In addition, this technique has

Table 6
Summary of the advantages and disadvantages of DIRT.

Advantages	Number of studies	According studies
Non-invasive	5	[9–13]
No contrast agents	5	[9–11,13,20]
No radiation	3	[11–13]
Low cost	3	[10,12,20]
Repeatable	1	[12]
Pre-, intra- and postoperative use	1	[12]
Information on flow and functional characteristics of the vessels (e.g. diameter)	4	[8,9,12,13]
Requires single hospital visit	1	[12]
Short procedure	2	[12,18]
Real-time and immediate report	3	[11,12,18]
Identifies clinically significant vessels	1	[12]
Simple investigation (easy to perform, easy to interpret)	5	[8,11,13,18,20]
Investigate any tissue with outstanding precision	1	[8]
Shows reperfusion problems during surgery	1	[11]

Disadvantages	Number of studies	According studies
No information on intramuscular course of the vessels	1	[4]
Detects only perforators that transport blood to the skin surface	2	[4,18]
Limited evidence (moderate and variable data)	3	[10,19,20]
2D images	1	[10]
Low availability	1	[10]
Detects only perforators with diameter >1 mm	1	[12]
Temporal information	1	[12]
No information on the morphology of the vessels	2	[9,11]
Cold challenge is uncomfortable for patient	2	[8,20]
Artefact images	2	[8,19]
Moderate accuracy	1	[9]

Table 7
Summary of the advantages and disadvantages of (MD)CTA.

Advantages	Number of studies	According studies
Precise anatomical description of the origin of perforators, intramuscular course and point of fascia penetration	4	[4,9,11,13]
Information on the continuity of the deep inferior epigastric system in patients that have been previously operated in that area	2	[4,9]
3D or 4D images	3	[9,10,12]
Objective findings	1	[10]
Detects vessels as small as 0,3 mm	2	[10,12]
High spatial and temporal resolution	2	[10,11]
Easy interpretation	1	[10]
Global picture	1	[8]
Detects close to 100% of perforators	2	[10,12]
Visualisation of linking vessels, connection with adjacent perforator territories	1	[10]

Disadvantages	Number of studies	According studies
Often fails to identify dominant perforator because the diameter is the sum of artery and vein	1	[4]
High cost	5	[4,8,10–12]
Radiation	7	[4,8–13]
IV contrast agents	7	[4,8–13]
No physiological information on flow characteristics or assessment of perfusion	2	[9,10]
Delay between scan and report	1	[12]
Static images	1	[12]
Time consuming investigation	1	[4]

a low cost, is easy to perform and easy to interpret for the surgeon. On the other hand, DIRT produces 2D images that only provide information on the physiology of the vessels and not on the morphology [7–13,18]. About the accuracy of this technique is not enough evidence yet [10].

When we study the results of the advantages and disadvantages of the different imaging methods, we can conclude that the golden standard CTA has a very high resolution to give a precise anatomical description of the origin of perforators, their intramuscular course and their point of fascia penetration (Tables 2 and 7). The 3D image makes it easy to interpret the results. Another advantage is that it can be used in women that have been previously operated in the abdominal area. Unfortunately, CTA is an expensive imaging technique that uses radiation and IV contrast agents. It also provides no physiological information of the perforators and often has a false positive result when not compared to another imaging method, because the diameter of a vessel is the sum of the artery and vein [4,7].

MRA is also a technique with need of IV contrast agents and a major limitation are the motion artefacts and the long breath-hold periods (Table 3). It has a slightly lower spatial resolution than CTA and provides no information on the flow of the perforators. It has however a greater contrast resolution than CTA and has a good correlation with intraoperative findings [8–10].

Doppler (Table 4) is a safe and cheap technique gives information on the course, diameter and blood flow characteristics of the perforator vessels and is able to differentiate between an artery and a vein, but is has to deal with a lower sensitivity and specificity, inter-observer variability and a high number of false positives [7–10,13,25]. Moreover it is a very time consuming examination.

This review revealed that DIRT has more to offer than only preoperatively perforator selection. It can also be used for the peroperative monitoring of the flap perfusion. Additionally it can be used for flap monitoring in order to detect early perfusion problems [11,14,15,18–20].

DIRT in the preoperative phase

When DIRT was tested preoperatively in clinical studies, in all cases DIRT selected the dominant perforator for the skin flap, which was confirmed during the surgery [4,7,8,12–17]. Hot spots that show rapid and progressive rewarming can be related to suitable perforators peroperatively. Rapid rewarming indicates that the perforator is capable of transport more blood to the skin, rapid progression of the hot spots suggests a better developed vascular network around the hotspot [11].

DIRT correlated well with CTA, but less with Doppler. This might be because Doppler measures vessels in the deep fascia level and DIRT measure vessels in the subcutaneous tissue level.

DIRT in the peroperative phase

DIRT during surgery was used in seven of the included articles [11,14,15,17–20]. DIRT in the intraoperative phase was able to detect successful arterial inflow in the flap, as well as partial and total obstruction of arterial inflow. DIRT can also measure the profound improvement in rate and pattern of rewarming after performing an extra venous anastomosis [11,15].). Kalra et al. confirmed during a pilot study on 2 patients that thermography was able to measure the strength of each perforator on the perfusion of the flap [17]. They did not include cooling of the flap.

DIRT is a valuable alternative of clinical examination to evaluate at any stage during surgery to check the perfusion of the flap. DIRT also allows for qualitative assessment of the perforators and facilitates flap design [20]. However further studies are needed to confirm and standardize these results.

DIRT in the postoperative phase

Monitoring of the DIEP flap postoperatively is mandatory to detect early signs of compromised perfusion. At present most surgeons rely on clinical observations to monitor flap perfusion. These clinical observations include skin color, turgor of the flap, capillary refill and skin temperature. In a clinical study with 20 free flaps during the first postoperative week after a free DIEP flap DIRT was used to examine the qualitative changes in perfusion of the flap [14]. The postoperative use of DIRT during the first postoperative week showed that the vascularization of the free DIEP flap is dynamic process. The monitoring postoperative is promising to detect perfusion problems in free DIEP flaps. However additional studies have to be performed to standardize the use of DIRT to detect perfusion problems in free flaps.

Limitations

Nearly all of the articles in this review are descriptive clinical studies [4,8,13–16], case reports [12,17,18], expert opinions/ Overview articles [9–11] and only two systematic reviews [19,20]. The level of evidence of these studies is low, which gives reason to believe there is more risk for bias. Also the included group of patients is rather limited with 27 patients included in the biggest series [13]. There were no published randomised trials on this topic. This limits the quality of evidence presented in this systematic review.

Conclusion

The level of evidence for DIRT is limited due to the lack of randomized controlled trials. The available data revealed that DIRT is already a valuable asset for preoperatively perforator selection: it is a harmless, low-cost and quick imaging tool that gives information on blood flow and functional characteristics of the vessels. Although it gives no information on the morphology of the vessels and only detects certain perforators (diameter >1 mm and those that transport blood to the skin surface), it is capable of identifying the vessels that are clinically significant. Moreover, it is easy to use and delivers easy-to-interpret results in real-time, which makes it useful for intraoperative flap monitoring as well.

The authors conclude that preliminary studies are promising on the use of DIRT in DIEP-flap breast reconstruction, but this information is not standardized yet and more studies are recommended. This means that there is still need for further investigations, not only for the pre-operative use of DIRT but also for the per- and postoperative use. Standardisation of the measurement methodology, measurement setup, processing of the images and cooling should be investigated in future clinical studies and even further investigations on animal models should be considered.

Although randomized studies are needed to provide definitive proof, the data in these studies suggest that the use of DIRT is an additional tool that improves the results of free flap breast reconstructions and on top of that the examination is cheap, not invasive and does not harm the patient.

Declaration of Competing Interest

The authors declare that there is no conflict of interest; there was no funding.

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