JPRAS Open 42 (2024) 113–132

Contents lists available at ScienceDirect

JPRAS Open

journal homepage: www.elsevier.com/locate/jpra

Review Article

Radiologic findings in women after Autologous Fat Transfer (AFT) based breast reconstruction: A Systematic Review

M.E.P. Rijkx[a,b,*], E. Bernardi[a,#], S.J. Schop[a,b,#], E.M. Heuts[c], M.B.I. Lobbes[d,e,f], J.E. Hommes[a,b], A. Piatkowski de Grzymala[a,b], T.J.A. van Nijnatten[d,f]

[a] *Department of Plastic-, Reconstructive-, and Hand Surgery, Maastricht University Medical Center, Maastricht, The Netherlands*
[b] *NUTRIM School of Nutrition and Translational Research in Metabolism, Maastricht University, Maastricht, The Netherlands*
[c] *Department of General Surgery, Maastricht University Medical Center, Maastricht, The Netherlands*
[d] *Department of Radiology, Department of Radiology and Nuclear Medicine, Maastricht University Medical Centre, Maastricht, The Netherlands*
[e] *Department of Radiology, Zuyderland Medical Center, Sittard-Geleen, The Netherlands*
[f] *GROW Research Institute for Oncology and Reproduction, Maastricht University, Maastricht, the Netherlands*

ARTICLE INFO

Article history:
Received 16 June 2024
Accepted 11 August 2024
Available online 20 August 2024

Keywords:
Breast reconstruction
Autologous Fat Transfer
Lipofilling
Breast Cancer
Breast Surgery
Radiology

ABSTRACT

Purpose: Autologous fat transfer (AFT) is increasingly used in breast reconstructive surgery. Due to post-surgical changes, in breast imaging after AFT, it can be challenging to differentiate between benign and suspicious findings. This systematic review aimed to present an overview of the literature on breast imaging after AFT-based breast reconstruction. The descriptive radiologic findings focus on different breast imaging modalities (i.e., mammography (MG), ultrasound (US), and breast magnetic resonance imaging (MRI)) to provide an overview of the most commonly reported benign and suspicious findings.

* Corresponding author: Maud Rijkx, M.D., Department of Plastic, Reconstructive and Hand surgery, Maastricht University Medical Center, P. Debyelaan 25, 6229 HX Maastricht, the Netherlands, Telephone: +31 43 387 7481, Fax: +31 43 387 5485.
E-mail address: maud.rijkx@mumc.nl (M.E.P. Rijkx).
# Shared 2nd authors. Equal contributors.

https://doi.org/10.1016/j.jpra.2024.08.002

Results: The literature search yielded 20 studies from 2006-2022 that reported AFT-based breast reconstructions and included the radiologic evaluation of the included breast imaging modalities. Only six of the 20 included studies provided qualitative descriptions of radiologic findings. Fat necrosis was most frequently reported. On MG, fat necrosis was described in a variety of stages such as oil cyst or cytosteatonecrosis with or without calcifications. On US, it was described as a nonvascular hypo- or anechoic mass, and on breast MRI, it was most frequently reported as hypointense homogenous architectural distortion. Additional biopsies to differentiate between benign and malignant findings after AFT-based breast reconstruction were reported in 13 of the 20 studies. Among all included studies in the current review, a total of 34 of 137 biopsies were considered malignant (24.8%).
Conclusion: Qualitative descriptions of the reported radiologic findings after AFT for breast reconstruction were limited. Additional biopsies can be considered to differentiate between benign and suspicious findings. More experience and research are necessary to improve the interpretation of breast imaging after AFT-based breast reconstructions.

Introduction

Autologous fat transfer (AFT) to the breast is increasingly employed due to its attractive qualities such as minimal invasiveness, high patient satisfaction, and natural appearance.[1-3] This technique is commonly used for the correction of breast abnormalities, for partial reconstruction after breast-conserving therapy (BCT), and for total breast reconstruction after mastectomy. The surgical procedure requires the harvest of autologous fat tissue via liposuction, followed by its reinjection into the chest region to reconstruct the breast.[4,5] To achieve the large autologous fat transfer volumes required for total breast reconstruction, an external breast expander device can be used.[3]

Despite its promising attributes, AFT-based breast reconstructions initially gave rise to oncological safety concerns. This concern was partially due to the harvested fat tissue containing adipose-derived stem cells, which were hypothesized to stimulate the proliferation of residual cancer cells. However, more and more studies report consistent results supporting the oncological safety and efficacy of AFT-based breast reconstructions.[6] The second aspect of oncological safety concern involves the detection of new/recurrent breast cancer using imaging.[7,8] This is due to the typical radiologic findings in AFT-based breast reconstructions that can potentially mimic breast cancer recurrence.

Imaging is used to rule out breast cancer recurrence after breast cancer treatment. Imaging can be considered in symptomatic women or during breast cancer screening or follow-up. It is currently unknown which imaging technique is most suitable for AFT-based breast reconstructions. An AFT-based reconstructed breast does not contain any foreign material or transferred blood vessels as in implant-based reconstruction or flap-based reconstruction, respectively.[9,10] AFT-based breast reconstructions could therefore be considered more structurally similar to breasts that have undergone BCT, which also only contain the breasts' native blood supply and no foreign material. In patients who have undergone BCT, mammography (MG) is generally the first step of follow-up.[11] Thus far, there is no available guideline specifically addressing the recommendation of radiologic follow-up in patients that underwent solely AFT for partial or total breast reconstruction.[11,12] In addition, no study has been performed to provide an overview of the radiologic findings in women after AFT-based breast reconstructions.

Through the compilation of the current literature's descriptions of the radiologic findings in AFT-based breast reconstructions, significant descriptive radiographic characteristics can be collected to help clinicians differentiate between benign and suspicious radiologic findings more easily. With this systematic review, we aimed to present an overview of the qualitative radiologic characteristics in AFT-based breast reconstructions.

Methods

Protocol and registration

This systematic review was performed according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement for reporting systematic reviews and meta-analyses of health care interventions.[6]

Eligibility criteria

Inclusion and exclusion criteria were outlined before data collection. All articles with original data concerning AFT in the human female breast for breast reconstruction were considered eligible if they provided information on the performed imaging modalities and their corresponding breast imaging findings. For this review, all surgical/technical methods of AFT were included. Articles were excluded if AFT was used on the breast only for cosmetic augmentations and/or if imaging was only reported for volumetric reasons. If a study incorporated a combination of eligible and ineligible participants, for example, when both breast augmentation and breast reconstruction occurred, the subgroup data of the eligible participants needed to be available to consider the study eligible for inclusion. Eligible imaging modalities included MG, ultrasound (US), and breast magnetic resonance imaging (MRI). Other imaging techniques, such as digital breast tomosynthesis (DBT) or contrast enhanced mammography (CEM), were not included in this review.

No restrictions on the publication date or follow-up duration were predefined. Reviews, technical descriptions, letters to the editor, and commentaries were excluded. In case-control studies, if the control participants did not receive the intervention (AFT to the breast), they were not included in the analysis.

Information sources

PubMed, EMBASE, the Cochrane Library, and CINAHL databases were searched to find eligible literature for this review. All database searches were completed on February 3, 2023.

Search strategy

The literature search was conducted using breast MeSH-terms in combination with "breast" or "mamma" as free search terms. These terms were search combined with all possible technical names of AFT such as lipofilling, liposculpturing, lipo-injection, lipoinjection, lipotransfer, lipo-transfer, lipo-modelling, lipomodeling, lipograft, lipo-graft, microlipoinjection, lipoaspirate, lipotransplant, micro lipofilling, micro-lipofilling, graft, transfer, inject, transplant, fat tissue, fatty tissue, adipose tissue, or autologous fat.

This broad predetermined search strategy was used to ensure all relevant articles were identified. Both randomized controlled trials (RCT) and non-randomized studies of interventions (NRSI) were included in the database searches with no language restrictions. For an overview of the specific search strategies per database, see Appendix A.

Study selection process

After search completion and deduplication, two reviewers (MR, EB) independently screened all studies for eligibility by using the predefined eligibility criteria. All studies were stored in the Endnote

Reference Management Tool. In case of uncertainty after the title or abstract screening, full-text analysis was performed before making the final decision. Any disagreements during this inclusion stage were resolved by discussion or after consulting a third independent researcher (SS) until consensus was reached. If data was missing or unsuitable, authors were contacted to request this information. If attempts to retrieve data were unsuccessful, the study was excluded.

Data collection

Two reviewers (MR, EB) independently performed the data collection with a predefined data extraction form.

This data extraction form included for each article:

- Publications details such as the first author's name and the publication date.
- Study details including study design, study period, and inclusion and exclusion criteria.
- Patient population characteristics.
- Details of the surgical intervention such as indication for the procedure, mean number of AFT sessions, volume injection formation, and the surgical details of the fat harvesting, fat processing, and fat reinjection technique.
- Details of the radiologic findings for each imaging modality such as the indication for imaging, the technical system information, the reported radiographic diagnosis, and their corresponding radiographic characteristics in combination with their BI-RADS classification.
- Details of the performed biopsies and their corresponding cyto- and histopathological results in case of breast cancer (recurrence) after AFT-based breast reconstructions.

The data extraction sheet was completed and saved in Excel® (Microsoft, Redmond, Washington, USA), pilot-tested, and refined for this systematic review. If necessary, authors were contacted for further information.

Data items

For the study characteristics, the study designs, the number of operated breasts, the number of participants per study, and their corresponding baseline characteristics, such as age, Body Mass Index (BMI), and the indication for AFT-based breast reconstructions, were reported. Total breast reconstruction (BR-T) included solely AFT as the reconstructive method after mastectomy. Partial breast reconstruction (BR-P) was defined as either AFT to the breast after breast-conserving surgery or AFT in conjunction with any other autologous or non-autologous based breast reconstructive method.

To present the radiologic results of the individual studies, the following sections were reported: indications for breast imaging, technical aspects of the used imaging modalities, radiographic characteristics of the benign findings, radiographic characteristics of the malignant findings, and the biopsy results.

For the indications of breast imaging, included studies were allocated to the standard imaging group when imaging for all participants took place at the same time after their last AFT procedure. Studies were allocated to the indication group when imaging was performed after the last AFT procedure based on the evaluation of the health care professional or the patient herself.

The technical aspects of all imaging modalities of the included studies were reported separately. The technical aspects of breast US consisted of vendor, type, frequency of the transducer in MHz, and the use of Doppler techniques. For breast MRI, this information included the field strength (1.5T or 3T), the MR sequences (T1-weighted [T1W], T2-weighted [T2W], diffusion-weighted imaging), and the administration of (intravenous) contrast. If any information was missing, data was considered not reported (NR).

The benign and malignant radiographic findings of the performed imaging modality were presented. Additional information on a given radiographic diagnosis was provided by reporting the BI-RADS classification, the time of imaging after the last AFT procedure, and the corresponding radiographic description.

All cytological and/or histopathological biopsy results were used for the assessment of breast cancer recurrence.

Risk of bias assessment

Assessment of the methodological quality of each study was assessed independently by two review authors (MR, EB), and a third author (SS) helped resolve any disagreements. All types of bias were evaluated and judged to be "low risk," "moderate risk" and "high risk".[7,8] For RCT, the risk of bias in each study was assessed with the RoB2: a revised Cochrane risk of bias tool for randomized trials.[14] For NRSI, the risk of bias in each study was assessed with the ROBINS-I tool.[15]

Results

Study selection

The electronic search yielded 4,304 potentially useful articles. After deduplication, 2,552 articles were evaluated for eligibility. In total, 1,145 articles were screened on title and abstract. All articles describing AFT as a breast reconstruction method were considered eligible, resulting in 113 eligible articles for full-text analysis. The articles excluded for being in a different language were published in Chinese, Spanish, and Hebrew. After full-text analysis, 25 articles were included in this systematic review. Of the included studies, five studies reported a combination of both breast reconstruction and breast augmentation. We contacted the corresponding authors by e-mail to request the results specific to their breast reconstruction groups. After sending two reminders, no authors responded, and therefore these studies were excluded. One of these studies had to be excluded due to incorrect contact details. For an overview, see Figure 1 for the flow diagram.

Study characteristics

Patient demographics

A total of 1,467 patients were included in the review. The number of participants per study ranged from one to 252 participants, with a mean age of 38.5 to 60 years and a mean BMI of 20.7 to 30.1 kg/m^2.

Indications for AFT in breast reconstruction

Of the 20 studies that used AFT-based breast reconstructions, 15 studies used AFT in partial breast reconstruction, three in total breast reconstruction, and two studies reported a combination of both reconstruction techniques.

Level of evidence

The included studies were mostly retrospective (n=11) and consisted of 11 case series, five retrospective cohort studies, one prospective cohort study, two matched cohort studies, and one case report. Publication dates ranged from 2006 to 2022. A detailed overview of all study characteristics can be found in Table 1.

Risk of bias within studies

A summary of the risk of bias, for each item from each study, is presented in Figure 2. Scores leading to overall biases were moderate or high for every study; we reported high risk of bias for six studies and moderate risk of bias for the other 14 studies. More detailed information and the foundation for the scores is provided in Appendix B.

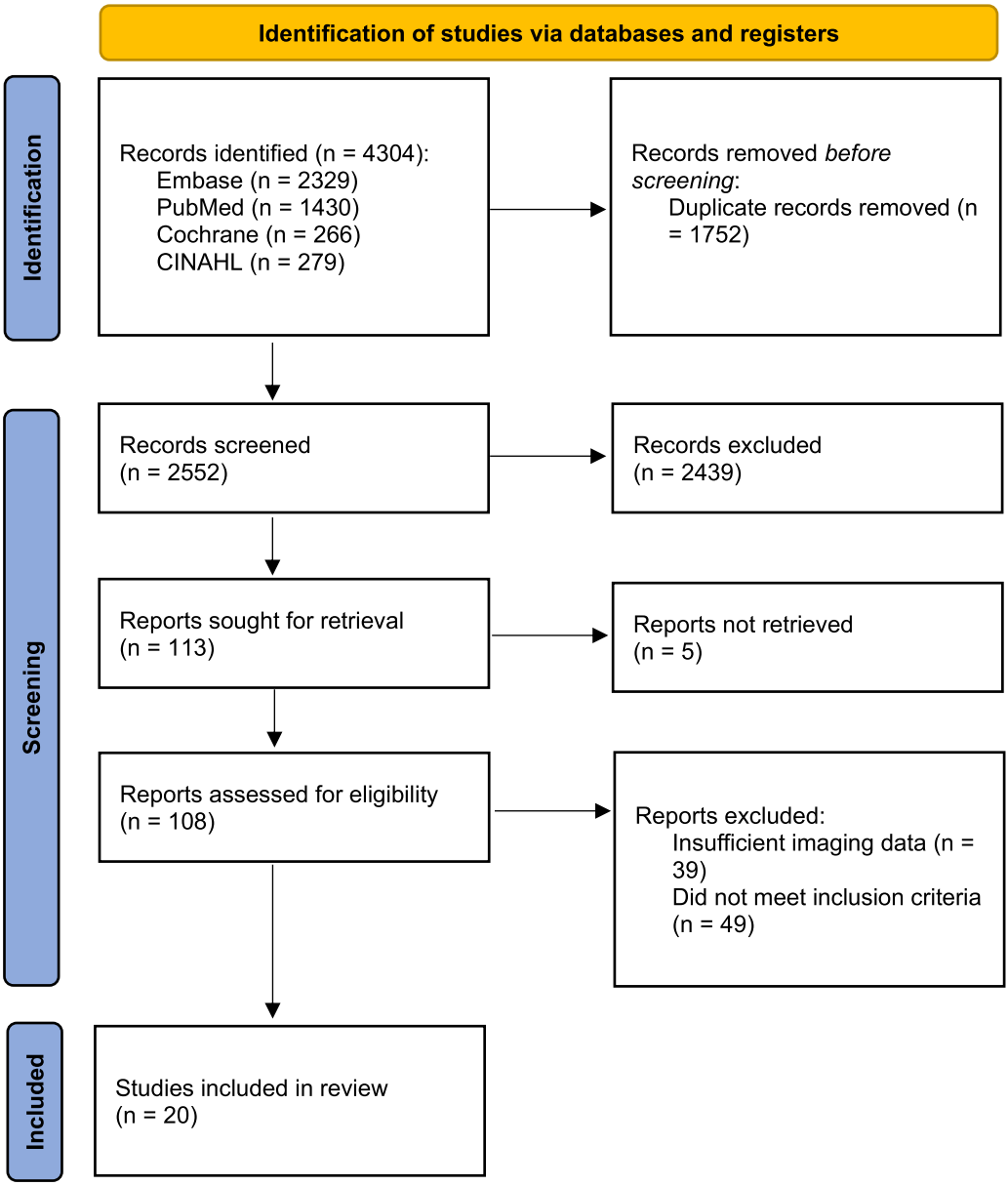

Figure 1. Flow-diagram of the search-strategy of this systematic review. Legend: n = number of studies, BR = breast reconstruction, BA = breast augmentation. *Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools. *From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

Table 1
General characteristics of all included studies.

Study Characteristics			Demographics					Level of evidence*
Study	Study Design	Country	No. AFT Patients	No. breasts	Mean Age ± SD (range)	Mean BMI ± SD (range)	Indication for AFT	
Ahmed, Y. S. (2022)[16]	P CS	Egypt	54	-	47.57 ± 9.26	30.1	BR- P	4
Brenelli F. (2014)[17]	P CS	Brazil	59	-	50 ± 8.5	-	BR-P	4
Cason, R. W. (2020)[18]	R CH	USA	93	-	48.7 ± 9.26	<25 kg/m^2: 30.1%. 25-30 kg/m^2: 39.8%. >30 kg/m^2: 30.1%	BR- P	3
Dile, P. (2021)[19]	R CS	France	252	297	*50 (29- 75)	*24 (18- 44)	BR- mix	4
Fracol, M. (2022)[20]	R CS	USA	- 30	775	49.1 ± 10.0 38.5	25.9 ± 5.3 27	BR- mix	3
Gosset J. (2008)[21]	R CS	France	42	-	50.7 (35-64)	-	BR-P	4
Hanson, S. E. (2020)[22]	R CH	USA	72	72	*51 (28-68)	*27.2 (18.5–39.4)	BR-P	3
Juhl A.A. (2018)[23]	P CH	Denmark	42	-	53.6 ± 9.4 (33-75)	25.7 ± 3.7	BR-P	2b
Kaoutzanis C. (2016)[24]	R CS	USA	108	167	48 (22-71)	25.7 (19.5-38.1)	BR-P	4
Mann R.A. (2018)[25]	R CS	USA	37	-	54.4 (41-74)	27.6 (20.5-37.5)	BR-P	4
Missana M.C. (2007)[26]	R CS	France	69	74	51 (21-73)	-	BR-P	4
Parikh R.P. (2012)[27]	R CS	USA	37	69	53 (40-71)	27.4 (19.6-42.1)	BR-P	4
Pierrefeu-Lagrange A.C. (2006)[28]	P CS	France	30	34	51	-	BR-P	4
Pinell-White X.A. (2015)[29]	MCH	USA	46	51	49.6 (32-68)	-	BR-P	2b
Pulagam S.R. (2006)[30]	CR	USA	1	1	54 (46-62)	-	BR-P	4
Quan, Y. (2022)[31]	R CH	China	45	52	44.1 ± 8.95 43.5 ± 8.86	20.7 ± 3.13 21.1 ± 2.98	BR-T	4
Sayyed, A. A. (2022)[32]	R CH	USA	155	228 129 ABR 99 IBR	60.0 ± 10.3	-	BR-P	-
Sorotos, M. (2022)[33]	P MCH	Italy	79	117	48 (39.5–49) 42 (39–47) 42 (36–48)	22.9 (21.2–23.5) 23 (21.1–23.8) 23.1 (21.2–24.1)	BR-T	2
Valmadrid, A. C. (2020)[34]	R CH	USA	186	319	53.1 (45.7–59.3) 51.3 (42.7–58.7)	28.4 (24.8–32.4) 27.4 (23.3–32.5)	BR-P	3
Zhang, X. (2021)[35]	P CS	China	30	-	42.7	22.8	BR-T	-

Legend: ABR = autologous breast reconstruction; BMI = body mass index, BR-P = partial breast reconstruction, BR-T = total breast reconstruction, BR-mix = combination of partial and total breast reconstruction, IBR = implant-based breast reconstruction, P = prospective, R = retrospective, CS = case series, CH = cohort study, MCH = multi cohort study.

* Level of evidence is based on Melnyk & Fineout-Overholt 2023.[36]

Figure 2. summary of the risk of bias assessment.

Table 2
indication, timing, modalities of imaging performed after AFT-based breast reconstruction.

Study	Indication for breast imaging	Imaging modalities performed			Timing of the imaging
		MG	US	MRI	
Ahmed, Y. S. (2022)[16]	COMB	√			STD: 12M, 24M after final AFT procedure
			√		
Brenelli F. (2014)[17]	COMB	√			STD: Every year
			√		
Cason, R. W. (2020)[18]	IND	√	√	√	
Dile, P. (2021)[19]	IND	√	√	√	
Fracol, M. (2022)[20]	IND	√	√	√	
Gosset J. (2008)[21]	STD	√	√	√	12M after final AFT procedure
Hanson, S. E. (2020)[22]	COMB	√	√		NR
Juhl A.A. (2018)[23]	NR	√	√		NR
Kaoutzanis C. (2016)[24]	IND	√	√	√	
Mann R.A. (2018)[25]	COMB	√	√	√	STD: NR
Missana M.C. (2007)[26]	STD			√	3M after final AFT procedure
Parikh R.P. (2012)[27]	IND		√		
Pierrefeu-Lagrange A.C. (2006)[28]	NR	√	√	√	NR
Pinell-White X.A. (2015)[29]	NR	√	√	√	NR
Pulagam S.R. (2006)[30]	IND	√	√		8Y after final AFT procedure
Quan, Y. (2022)[31]	STD			√	3M, 6M after final AFT procedure
Sayyed, A. A. (2022)[32]	IND	√	√	√	NR
Sorotos, M. (2022)[33]	STD		√		Every 6M
Valmadrid, A. C. (2020)[34]	IND	√	√	√	
Zhang, X. (2021)[35]	STD		√	√	At least 6M after final procedure

Legend: AFT = autologous fat transfer, STD = standardized imaging follow-up, IND = imaging performed on indication, COMB = combination of standardized imaging follow-up combined with imaging performed on indication, M = months, Y = years, NR = not reported.

Radiographic results of individual studies

Indications for breast imaging after AFT

The majority of the studies (n=17) reported their indication for performing breast imaging. Five studies performed standardized follow-up imaging after performing AFT-based breast reconstruction. Two studies performed standardized follow-up and reported additional imaging after finding a palpable nodule.[16,25] Eight studies performed imaging solely on the indication, commonly after finding a palpable nodule in the reconstructed breast. Most studies performed a combination of MG, US, and MRI (n=10). For an overview of the indications for breast imaging and the timing of the performed imaging per study, see Table 2.

Technical aspects

Most studies did not report the technical details of the imaging modalities used (n=14). For MG, the acquisition of all mammograms was performed in craniocaudal and oblique directions. In addition, one study (Juhl et al.[23]) also performed separate lateral projections. For the studies that reported US details (n=3), only the vendor was reported, without additional information.

Of the studies that reported MRI details (n=4), all used 1.5T systems. The MR sequences of the images were T1W, T2W, and reported before and after gadolinium injection. For an overview of the reported technical details per included study, see Appendix C.

Radiographic characteristics of benign findings

Mammographic (MG) characteristics. Calcifications related to fat necrosis were the most reported mammographic finding. They were described as round, regular calcifications with a clear center and

<2 mm in diameter. In addition, fat necrosis was also described as a complex cyst or as partially calcified fat necrosis. One study (Gosset et al.[21]) reported oil cysts on MG and described it as greasy and small with a fine dense border associated with wall calcifications. For an overview of all MG characteristics per study, see Table 3.

Ultrasound (US) characteristics. From the seven studies that reported their benign US findings, the most common finding was fat necrosis. Fat necrosis mostly presented as a hypo- or anechoic mass without vascularity. The typical appearance of oil cysts was an anechoic cystic mass with posterior enhancement. For an overview of all US characteristics per study, see Table 4.

MRI-characteristics. In the four studies that reported benign MRI-findings, the most common finding was fat necrosis. Oil cysts were commonly described as hypointense homogeneous areas on T1W images with fat suppression and were described as not visible on T2W images. Fat necrosis was described as a circumscribed area with the center of the area displaying a slight hypersignal intensity on T2W images. For an overview of all MRI findings per study, see Table 5.

Breast biopsies

Overall, 137 biopsies were reported. Thirty-four of these biopsies were considered malignant (24.8%) according to pathology results. No studies reported qualitative radiologic descriptions of malignancies using mammographic or MRI data. Two studies provided ultrasonographic radiologic characteristics.[20,27] Breast malignancies were described as either hypoechoic or as a complex echogenicity and were often vascularized.

Discussion

This systematic review incorporated data from 20 studies with 1,467 patients reporting imaging after AFT-based breast reconstruction performed in the period 2006-2022. The qualitative descriptions of the reported radiologic findings after AFT-based breast reconstructions among the included studies were limited. Nevertheless, we recognized some potential radiographic patterns within the different imaging modalities for AFT-based partial breast reconstruction. Fat necrosis was the most common benign finding on US and MRI after AFT and was described in multiple stages. On MG, fat necrosis was described in a variety of stages such as oil cyst or cytosteatonecrosis with or without calcifications. On US, fat necrosis presented as hypo- or anechoic masses without vascularity. On MRI, fat necrosis was typically described as hypointense homogeneous images on T1W sequences but was not visible on T2W sequences. The only radiologic pattern that could be recognized for malignancy was reported on US, in which breast cancer recurrence was described as a hypoechoic or complex echogenicity often with vascularization. In the examined literature, an average of 18% of radiologic findings required biopsy. The criteria used to decide what findings required biopsy could not be determined. While much more knowledge and clinical practice is needed, the learning curve of differentiating between benign and malignant radiologic findings can be overcome.

The indications to perform breast imaging after AFT-based breast reconstructions varied among the studies but were mainly performed in symptomatic women. Based on the included studies, most women did not undergo standard radiologic follow-up after AFT-based breast reconstruction. The only study that performed standardized imaging for follow-up in this review used MG, US, and MRI. Future studies are necessary to determine if AFT can be treated as any other reconstruction method and only requires imaging upon indication in the case of mastectomy. Future studies are also needed to determine the additional value of other imaging modalities, such as CEM and DBT. Only MG, US, and MRI were included in this review, because they are the most commonly used breast imaging modalities.[37,38]

Among the included studies, there was a frequent lack of descriptive radiologic characteristics of the benign findings. Instead, studies often emphasized the quantification of findings, which severely limited the radiologic characteristics that could be identified. Approximately three of four biopsies were benign (75.2%), suggesting that radiologic lesions requiring a biopsy were frequently benign. In future studies, sharing both quantitative radiologic diagnoses and the qualitative radiologic details

Table 3
Mammographic characteristics after AFT for breast reconstruction.

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-classification score (N)	Radiologic finding (N)	(N)	Radiographic description	(N)
Ahmed, Y. S. (2022)[16]	45	12, 24M after last AFT procedure	MG, US	NR	Oil cysts (5)	5	NR	NR
					Macrocalcifications (10)	10		
Brenelli F. (2014)[17]	59	6M, after final AFT procedure	MG, US	NR	Suspicious lesions (6)	6	NR	NR
					Oil cysts (3)	3		
					Irregular lump (3)	3		
					Macrocalcificiations (6)	6		
					Microcalcifications	3		
Fracol, M. (2022)[20]	29	NR	MG, US, MRI	NR	No mammographic correlation	21	Normal mammographic findings not further specified	19/21
					Indeterminate features		NR	2/21
Gosset J. (2008)[21]	21	12M	MG, US, MRI	*BIRADS 2	Microcalcifications	13	Round, regular with a light center, and <2 mm, isolated or associated with small clear images. There were calcified foci corresponding to cystosteatonecrosis	4/13
				NR	macrocalficiations		NR	3/13
				*BIRADS 2	Oil cysts		Greasy, regular small, surrounded images with a fine regular dense border associated with wall calcifications and corresponding to oil cysts	5/13
				NR	Opacity with calcifications		Heterogeneous opacity of 33 mm with microcalcifications in the form of an image containing thick-walled cubicles	1/13

(*continued on next page*)

Table 3 (*continued*)

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-classification score (N)	Radiologic finding (N)	(N)	Radiographic description	(N)
Mann R.A. (2018)[25]	37	NR	MG, US, MRI	NR	Non-suspicious findings (20): scarring, fat necrosis, and oil cysts	23	NR	20/23
					Suspicious lesions (3): ruptured apocrine cyst, lipoma, and fat necrosis		NR	3/23
Pierrefeu-Lagrange A.C. (2006)[28]	30	NR	MG, US, MRI	*BIRADS 1	Normal examinations	24	NR	NR
				*BIRADS 2	microcalcifications	4	Regular round calcifications with a clear center, very small in size < 2mm corresponding to calcified cystosteatonecrosis	
				*BIRADS 2	Fat necrosis	7	Oil cysts: small fat images surrounded by a fine regular dense border sometimes associated with wall calcifications	6/7
							Cystosteatonecrosis: 30mm image of a complex cyst	1/7
				*BIRADS 4	Opacity	1	Slightly blurred contour, <6 mm, corresponding with a benign gigantocellular granuloma	1/1
Pinell-White X.A. (2015)[29]	46	NR	MG, US, MRI	NR	Abnormal MG findings	6	NR	NR
Pulagam S.R. (2006)[30]	1	NR	MG, US	NR	Fat necrosis	1	Partially calcified fat necrosis	1/1

Legend: AFT = autologous fat transfer, NR = not reported, Y = years, M = months, MG = mammography, US = ultrasound, MRI = Magnetic Resonance Imaging. BIRADS = Breast Imaging Reporting & Data system (BI-RADS).

Table 4
ultrasound characteristics after AFT for breast reconstruction.

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-score (N)	Radiologic finding (N)	(N)	Radiographic description	(N)
Fracol, M. (2022)[20]	62	NR	MG, US, MRI	NR	Fat necrosis	74	Anechoic	7
							Hypoechoic	23
							Hyperechoic	3
							Mixed echogenicity	12
							Circumscribed	27
							Irregular	0
							Vascular	0
							Largest dimension > 0.8 cm	21
					Fat necrosis (oil cyst)	21	Anechoic	18
							Hypoechoic	2
							Hyperechoic	0
							Mixed echogenicity	0
							Circumscribed	17
							Irregular	0
							Vascular	0
							Largest dimension > 0.8 cm	9
					Benign lesion	34	Anechoic	0
							Hypoechoic	11
							Hyperechoic	0
							Mixed echogenicity	8
							Circumscribed	8
							Irregular	1
							Vascular	1
							Largest dimension > 0.8 cm	21
					Indeterminate	11	Anechoic	0
							Hypoechoic	9
							Hyperechoic	0
							Mixed echogenicity	1
							Circumscribed	7
							Irregular	2
							Vascular	0
							Largest dimension > 0.8 cm	1

(*continued on next page*)

Table 4 (*continued*)

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-score (N)	Radiologic finding (N)	(N)	Radiographic description	(N)
					Concerning for malignancy	10	Anechoic	0
							Hypoechoic	8
							Hyperechoic	0
							Mixed echogenicity	1
							Circumscribed	1
							Irregular	1
							Vascular	2
							Largest dimension > 0.8 cm	8
Gosset J. (2008)[21]	21	12M	MG, US, MRI	NR	Fat necrosis (oil cyst)	17	Simple cysts with posterior enhancement between 5-20mm	12
					Fat necrosis (cystosteatonecrosis)		Mixed images, oval shaped with liquid and pseudosolid components between 20-35mm.	4
					Nodules		Circums cribed regular oval image of 74mm (fibro-adipose tissue)	1

(*continued on next page*)

Table 4 (*continued*)

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-score (N)		Radiologic finding (N)	(N)	Radiographic description	(N)
Parikh R.P. (2012)[27]	37	Median 9 months	US	*BIRADS 2 *BIRADS 3 *BIRADS 4	32 12 22	Palpable nodule on physical examination	66	Solid hypoechoic avascular mass	15
								Solid avascular mass, isoechoic	1
								Solid hyperechoic mass with or without vascularity	2
								Solid mass complex with or without vascularity	7
								Typical cystic appearance/anechoic mass with posterior acoustic enhancement without vascularity	27
								Cystic mass with internal echoes without vascularity	10
								Negative ultrasound findings	4

(*continued on next page*)

Table 4 (*continued*)

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-score (N)	Radiologic finding (N)	(N)	Radiographic description	(N)
Pierrefeu-Lagrange A.C. (2006)[28]	30	NR	MG, US, MRI	NR	Normal examinations	20	Hypoechoic fat lobules	20
					Fat necrosis (oil cysts)	12	Simple cystic images with a small posterior enhancement with a size of 5-20mm	11
							Mixed image with an oval shape with regular outline with liquid and pseudosolid components	1
					Solid images	2	Hypechoic image, slightly irregular in contour (epithelioid and gigantocellular granuloma)	1
							Homogeneous oval hyperechoic image (cystosteatonecrosis)	1
Pinell-White X.A. (2015)[29]	64	NR	MG, US, MRI	NR	Abnormal imaging	11	NR	NR
Pulagam S.R. (2006)[30]	1	8Y after last AFT procedure	MG, US	NR	Fat necrosis	1	Hypoechoic mass	1
Sorotos, M. (2022)[33]	79	Every 6M after last AFT procedure	US	NR	Fat necrosis (oil cysts)	2	NR	NR

Legend: AFT = autologous fat transfer, NR = not reported, Y = years, M = months, MG = mammography, US = ultrasound, MRI = Magnetic Resonance Imaging. BIRADS = Breast Imaging Reporting & Data system (BI-RADS).

Table 5
MRI characteristics after AFT for breast reconstruction.

Study	N of images performed	Timing of the benign occurrence (months)	Imaging modality performed	BIRADS-classification score (N)	Radiologic finding (N)	(N)	Radiographic description	(N)
Gosset J. (2008)[21]	21	12M	MG, US, MRI	NR	Fat necrosis (oil cysts)	6	Small oil cysts: Regular, homogeneous hyposignal in T1w with fat suppression. Not visible in T2W images.	5/6
							Large oil cyst 35mm	1/6
					Fat necrosis (cytosteatonecrosis)	3	NR	NR
					Normal findings	9	It is impossible to distinguish transferred fat tissue from normal breast fat.	9/9
Missana M.C. (2007)[26]	69	3M	MRI	NR	Fat necrosis	5	Circumscribed hypointense area with a hyperintense rim can be seen on T1W sequences with fat suppression. The center of the nodule was usually iso- or hypointense.	5/5
Pierrefeu-Lagrange A.C. (2006)[28]	30	NR	MG, US, MRI	NR	Normal findings	24	Fat appears in T2W images as homogeneous hypersignal. On T1W images, the fat is homogeneous hypointense with fat suppression.	24/24
					Fat necrosis	9	Oil cysts: Many small, circumscribed images regular with homogeneous hypo signal on T1W images with fat suppression. Not visible on T2W images and between 5-20mm.	7/9
							Cytosteatonecrosis: Both lesions show characteristics of hypointense T1W images with fat suppression surrounded by a hyperintense border. On T2W images the center of the nodule is in slight hypersignal and is circumscribed.	2/9
					Nodule	1	Small nodule less (< 1cm) shows a hypo signal on T2W image (benign gigantocellular granuloma)	1/1
Pinell-White X.A. (2015)[29]	46	NR	MG, US, MRI	NR	Abnormal findings	11	NR	NR

Legend: NR = not reported, Y = years, M = months, MG = mammography, US = ultrasound, MRI = Magnetic Resonance Imaging. BIRADS = Breast Imaging Reporting & Data system (BI-RADS).

of the benign and malignant findings is recommended to augment radiologic knowledge. With more comprehensive information available, clinicians can improve their ability to differentiate radiologic findings, and the number of (unnecessary) biopsies can decrease.

It is important to acknowledge that the recurrence rates described in this review are not indicative of the recurrence rates after AFT for breast reconstruction due to selection bias. The 2.0% of local breast cancer recurrence observed here (30 out of 1,467 patients) should not be interpreted as a valid measurement of cancer recurrence after AFT for breast reconstruction.

It should be mentioned that the results of this review are based on a moderate level of evidence as the studies were mostly case-cohort studies including from 1 to 250 participants. Across the included studies, there was a variety of fat processing and injection techniques used. It was decided not to exclude studies based on surgical intervention details or whether partial or total reconstruction was performed to avoid reducing the already limited number of studies available. It was also decided not to separate the radiologic findings based on whether only AFT or AFT in conjunction with another reconstructive method was performed. AFT was often combined with various types of autologous flap reconstructions, and the literature based on AFT as a total breast reconstruction was very limited. We know that AFT combined with other types of reconstruction is different from AFT as a total breast reconstruction method. The radiologic appearance can therefore also be different. However, the goal of this systematic review was to give an overview of all the qualitative radiologic findings after AFT and to learn from this. The effect of the amount of fat injected, number of procedures, fat processing technique, and total versus partial reconstruction on imaging findings could be investigated in future studies when more radiologic data on AFT-based breast reconstructions is available.

It should also be considered that multiple studies were included in which radiologic imaging occurred before 2010. Over the last decade, radiologic techniques have improved and provide much higher resolution images.[39] The lower quality of images could have contributed to limiting the descriptions and evaluations of the radiologic images. If repeated in new studies with contemporary radiologic techniques, the reported findings could provide more thorough details on the radiologic characteristics expected with each imaging modality. Given the long inclusion period, there have also been changes in BI-RADS regulations so the radiologic evaluations reported by older studies do not match what would be reported for the same data today. For example, a distinction is no longer made between micro- and macrocalcifications, but rather the morphology is leading (heterogeneous, amorphous, fine pleiomorphic, linear, etc.).[40]

This study had some limitations that influenced the interpretation of this review. One limitation was the exclusion of imaging modalities such as DBT and CEM and the inclusion of all different surgical intervention types. Even though this was done intentionally, it is possible that relevant imaging characteristics were missed. Another limitation is the possible under-reporting of biopsies. If a study reported no biopsy results, it was assumed that no biopsies were performed. However, it is possible that in these studies, biopsies were performed but were not published if the performance and results of biopsies were not designated as reported outcomes.

Conclusion

Qualitative descriptions of the reported radiologic findings after AFT for breast reconstruction were limited. Additional biopsies should be considered to differentiate between benign and suspicious findings. More experience and research are necessary to improve the interpretation of breast imaging after AFT-based breast reconstructions.

Declarations

Funding:

None.

Conflicts of interest:

None declared.

Ethical approval:

Not required.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi: 10.1016/j.jpra.2024.08.002.

References

1. Sakai S, et al. Complications and Surgical Treatment of Breast Augmentation Using Autologous Fat Transfer and Fillers. *Plastic and Reconstructive Surgery - Global Open*. 2021;9(8):e3734.
2. Hivernaud V, et al. Autologous Fat Grafting in the Breast: Critical Points and Technique Improvements. *Aesthetic Plastic Surgery*. 2015;39(4):547–561.
3. Piatkowski AA, et al. Effect of Total Breast Reconstruction With Autologous Fat Transfer Using an Expansion Device vs Implants on Quality of Life Among Patients With Breast Cancer: A Randomized Clinical Trial. *JAMA Surgery*. 2023;158(5):456–464.
4. Tian D, et al. The Prognosis Outcomes of Autologous Fat Transfer for Breast Reconstruction After Breast Cancer Surgery: A Systematic Review and Meta-Analysis of Cohort Studies. *Gland surgery*. 2022;11(7):1180–1191.
5. Schop S, et al. BREAST Trial Study Protocol: Evaluation of a Non-invasive Technique for Breast Reconstruction in a Multicentre, Randomised Controlled Trial. *BMJ Open*. 2021;11(9):e051413.
6. Krastev TK, et al. Meta-analysis of the Oncological Safety of Autologous Fat Transfer After Breast Cancer. *British Journal of Surgery*. 2018;105(9):1082–1097.
7. Goncalves R, et al. The Oncological Aafety of Autologous Fat Grafting: a Systematic Review and Meta-analysis. *BMC Cancer*. 2022(1):22.
8. Noor L, et al. Imaging Changes After Breast Reconstruction with Fat Grafting - Retrospective Study of 90 Breast Cancer. *Pakistan Journal of Medical Sciences*. 2016(1):32.
9. Patel NG, Ramakrishnan V. Microsurgical Tissue Transfer in Breast Reconstruction. *Clinics in Plastic Surgery*. 2020;47(4):595–609.
10. Prasad K, et al. Cosmetic reconstruction in Breast Cancer Patients: Opportunities for Nanocomposite Materials. *Acta Biomaterialia*. 2019;86:41–65.
11. Imaging Expert Panel on Breast, et al. ACR Appropriateness Criteria® Imaging After Breast Surgery. *Journal of the American College of Radiology*. 2022;19(11S):S341–S356.
12. Expert Panel on Breast ImagingACR Appropriateness Criteria® Imaging After Mastectomy and Breast Reconstruction. *Journal of the American College of Radiology*. 2020;17(11S):S403–S414.
13. Coleman SR, Saboeiro AP. Fat Grafting to the Breast Revisited: Safety and Efficacy. *Plastic and Reconstructive Surgery*. 2007;119(3):775–785 discussion 786.
14. Sterne JAC, et al. RoB 2: A Revised Tool For Assessing Risk of Bias in Randomised Trials. *BMJ*. 2019;366(1):l4898.
15. Sterne JAC, et al. Robins-I: A Tool for Assessing Risk of Bias in Non-randomised Studies of Interventions. *BMJ*. 2016;355(355):i4919.
16. Ahmed YS, et al. Immediate Lipo-Filling as a Novel Technique for Volume Replacement in Oncoplastic Breast Conservative Surgery. *Aesthetic Plastic Surgery*. 2022;46(4):1612–1621.
17. Brenelli F, et al. Oncological Safety of Autologous Fat Grafting After Breast Conservative Treatment: A Prospective Evaluation. *Breast Journal*. 2014;20(2):159–165.
18. Cason RW, et al. The Influence of Fat Grafting on Breast Imaging After Postmastectomy Reconstruction: A Matched Cohort Analysis. *Plastic and Reconstructive Surgery*. 2020;146(6):1227–1236.
19. Dilé P, et al. Palpable Nodules After Autologous Fat Grafting in Breast Cancer Patients: Incidence and Impact on Follow-up. *Aesthetic Plastic Surgery*. 2023;47(2):503–511.
20. Fracol M, et al. The Palpable Nodule After Autologous Fat Grafting: Distinguishing Benign Versus Malignant Lesions in Breast Reconstruction. *Plastic and Reconstructive Surgery*. 2022;150:20S–29S.
21. Gosset J, et al. Aspects Radiologiques des Seins Traités par Lipomodelage Après Séquelles du Traitement Conservateur du Cancer du Sein. *Annales de Chirurgie Plastique Esthétique*. 2008;53(2):178–189.
22. Hanson SE, et al. Oncologic Safety and Surveillance of Autologous Fat Grafting Following Breast Conservation Therapy. *Plastic and Reconstructive Surgery*. 2020;146(2):215–225.
23. Juhl AA, Redsted S, Damsgaard TEngberg. Autologous Fat Grafting after Breast Conserving Surgery: Breast Imaging Changes and Patient-Reported Outcome. *Journal of Plastic, Reconstructive and Aesthetic Surgery*. 2018;71(11):1570–1576.
24. Kaoutzanis C, et al. Autologous Fat Grafting After Breast Reconstruction in Postmastectomy Patients: Complications, Biopsy Rates, and Locoregional Cancer Recurrence Rates. *Annals of Plastic Surgery*. 2016;76(3):270–275.
25. Mann RA, et al. Autologous Fat Grafting to Lumpectomy Defects: Complications, Imaging, and Biopsy Rates. *Journal of Surgical Research*. 2018;231:316–322.
26. Missana MC, et al. Autologous Fat Transfer in Reconstructive Breast Surgery: Indications, Technique and Results. *European Journal of Surgical Oncology (EJSO)*. 2007;33(6):685–690.

27. Parikh RP, et al. Differentiating Fat Necrosis From Recurrent Malignancy in Fat-Grafted Breasts: An Imaging Classification System to Guide Management. *Plastic and Reconstructive Surgery*. 2012;130(4):761–772.
28. Pierrefeu-Lagrange AC, et al. Évaluation Radiologique des Seins Reconstruits Ayant Bénéficié d'un Lipomodelage. *Annales de Chirurgie Plastique Esthétique*. 2006;51(1):18–28.
29. Pinell-White XA, et al. Radiographic Implications of Fat Grafting to the Reconstructed Breast. *The Breast Journal*. 2015;21(5):520–525.
30. Pulagam SR, Poulton T, Mamounas EP. Long-Term Clinical and Radiologic Results With Autologous Fat Transplantation for Breast Augmentation: Case Reports and Review of the Literature. *The Breast Journal*. 2006;12(1):63–65.
31. Quan Y, et al. Condensing of Low-Density Fat by Mechanical Process Improves Fat Retention and Reduces Oil Cyst Formation in Breast Reconstruction. *Aesthetic Plastic Surgery*. 2023;47(1):387–396.
32. Sayyed AA, et al. Review of Autologous Fat Grafting in Postmastectomy Reconstruction Patients: Nonroutine Diagnostics and Oncologic Safety. *Plastic and Reconstructive Surgery – Global Open*. 2022;10(10):e4579.
33. Sorotos M, et al. Long-Term Clinical and Aesthetic Results of a Systematic Fat Transfer Protocol for Total Breast Reconstruction After Nipple-Sparing Mastectomy. *Plastic & Reconstructive Surgery*. 2022;150(1):5–15.
34. Valmadrid AC, et al. Comparison of Telfa Rolling and a Closed Washing System for Autologous Fat Processing Techniques in Postmastectomy Breast Reconstruction. *Plastic and Reconstructive Surgery*. 2020;146(3):486–497.
35. Zhang X, et al. Total Breast Reconstruction Using Large-Volume Condensed and Viable Fat Grafting After Mastectomy. *Journal of Plastic Reconstructive and Aesthetic Surgery*. 2021;74(5):966–973.
36. Melnyk BM, Fineout-Overholt E. *Evidence-based practice in nursing & healthcare: A Guide to Best Practice*. Fifth edition. Philadelphia: Wolters Kluwer; 2023 Evidence-based practice in nursing and healthcare.
37. Aristokli N, et al. Comparison of the Diagnostic Performance of Magnetic Resonance Imaging (MRI), Ultrasound and Mammography for Detection of Breast Cancer Based on Tumor Type, Breast Density and Patient's History: A Review. *Radiography*. 2022;28(3):848–856.
38. Lee CH, et al. Breast Cancer Screening With Imaging: Recommendations From the Society of Breast Imaging and the ACR on the Use of Mammography, Breast MRI, Breast Ultrasound, and Other Technologies for the Detection of Clinically Occult Breast Cancer. *Journal of the American College of Radiology*. 2010;7(1):18–27.
39. Feinberg DA, et al. Next-generation MRI scanner designed for Ultra-High-Resolution Human Brain Imaging at 7 Tesla. *Nature Methods*. 2023;20(12):2048–2057.
40. Spak DA, et al. BI-RADS ® Fifth edition: A Summary of Changes. *Diagnostic and Interventional Imaging*. 2017;98(3):179–190.