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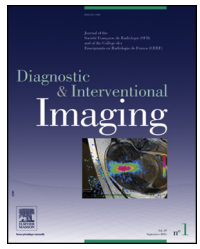

REVIEW / *Breast imaging*

MRI vacuum-assisted breast biopsies

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KEYWORDS
Breast cancer;
Vacuum biopsies;
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Targeted ultrasound;
Second look examination

Abstract The indications, technique, results and limitations of MRI vacuum-assisted breast biopsies are discussed from a review of the literature. This was initially a home-grown technique and its development was slowed down by several factors. As a result of major technical advances, it has become a reliable and very consistent procedure with a low rate of underestimation. It is now an undisputed technique when suspicious MRI enhancement is seen with no corresponding mammography or ultrasound features.

Introduction

Breast MRI developed in the 1980s. It is a second look examination although the development of screening, patient and media demand and improved access to machines have promoted the widespread use of the technique.

It offers excellent sensitivity, on average of 0.9 (0.88—0.92) [1] and can identify occult infiltrative cancers under a centimeter in size (when clinical examination, mammography and ultrasound are normal).

It has an average specificity of 0.72 (0.67—0.77) [1], which depends greatly on the indications. These are now well defined [2].

Even if these indications and technical quality criteria are followed however, contrast enhancement suspected of being malignant can only be confirmed histologically.

MRI-guided preoperative localization [3—9] and sampling (fine needle aspiration cytologies, core biopsies [8,10] and then vacuum-assisted breast biopsies [11—13]) have therefore been developed.

Abbreviations: MRI, magnetic resonance imaging; CE, contrast enhancement; BI-RADS, breast imaging reporting system and data system; HRT, hormone replacement therapy; PPV, positive predictive value; NPV, negative predictive value; MDT, multidisciplinary team meeting; T, tesla; G, gauge (cannula diameter); CAD, computer-assisted diagnosis; HAS, Haute Autorité de santé (French National Health Authority); ADH, atypical ductal hyperplasia; DCIS, ductal carcinoma *in situ*; Vs, versus.

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Targeted examinations

When suspicious CE (BI-RADS 4 or 5 or even 3) is found on a breast MRI performed for a recognized indication [14] and no corresponding abnormalities are present on a conventional assessment, the average malignancy rate is 30% (20 to 62%, depending on recruitment type) [15—24].

This figure increases with the size of the area of enhancement (3% for < 5 mm versus 31% for > 20 mm) [24] and is reported to be greater if a corresponding mammography or ultrasound abnormality is present [15,21,22,35—37] (Table 1).

Targeted investigations (mammography and/or ultrasound) are then performed in order to investigate for an occasionally subtle abnormality, which is not seen on the initial breast assessment [22].

Ideally, this is performed by the radiologist who carried out the MRI. If not, the radiologist who does carry out the investigation should have access to all of the information, *i.e.* all of the images written to CD, the site on a topogram, reconstructions (MIP, MPR) and distances from the various landmarks [46—49].

The radiologist needs to know the shape of the CE and take account of its change in position between MRI and mammography or ultrasound and be aware that the situation becomes increasingly different with larger breasts and the further away the CE is from the nipple, the only fixed anatomical breast landmark.

Other landmarks such as a benign or cystic tissue structure, scar or macrocalcification, etc. can be used.

Although there is consensus agreement on its use, this guided examination has not been carried out routinely [21,23,50] or has not been described [26] in some series.

Targeted ultrasound

The examination needs to look for nodules, but also a poorly delineated area of tissue (seen particularly in non-mass CE), a complex cyst or local disharmony (texture, outlines or echogenicity).

Ultrasound correlations are usually found in malignancy [21,22], mass CE [15,21,22,35,38,39,43,46,51], target [39], or micronodular lesions [39], and BI-RADS 4 (vs 5) [38], T2 hyperintensity or implants.

It is reported not to correlate with breast density [15,16,39] or size of the CE [21,42] as ultrasound resolution is greater than that of MRI.

Some authors do report however that the correlation is greater for CE > 10 mm [38,39] and BI-RADS 5 (vs 4) [39].

It is described in 61% of cases (23 to 89%) with an average malignancy rate of 34% (16 to 65%) [15—22,35,38,40—45].

Nakano [52] greatly improved the detection rate (90 vs 30%) combining ultrasound-MRI and image fusion, although the 30% rate is very low compared to other published studies.

If ultrasound is negative (39%), the average malignancy rate falls to 17% (2 to 54%) [15—22,35,38,40—45,49] explaining the need for histological proof including the case of small relatively unsuspicious CE [43].

Further films

An enlarged film centered on the CE quadrant can identify fine microcalcifications, which are not visible or not considered significant on the initial conventional assessment, together with subtle architectural disorganization or local asymmetry in density.

These films are particularly useful for non-mass CE.

According to Thomassin [36], the malignancy rate is over 90% in cases of non-mass enhancement over 20 mm in size accompanied by microcalcifications in the same area.

Management

If a concordant abnormality is found the indication for biopsy is based on the worst appearances (MRI, ultrasound or mammography) [51].

This should then be performed stereotactically or under ultrasound guidance as these are the most accessible, fast and least expensive guidance methods. A landmark is then left in place.

In 2005, Taourel [53] proposed labeling the biopsy site with *in situ* gadolinium injection.

Currently, however, a clip is routinely applied [47,48,51,54] and the concordant location of the CE and clip is checked with a high TE T1 weighted echo gradient MRI image [48,51]. Anatomical landmarks are generally sufficient, although in uncertain cases intravenous gadolinium may be required.

A repeat MRI after a short period of time (6 months) is recommended if the correlation is good and the histological result is benign [48,51].

Revision surgery is required for a borderline lesion or carcinoma.

If no concordant abnormalities are seen in a low risk situation (when the indication is debatable on MRI) and enhancement is not suspicious [55], a repeat MRI can be proposed 6 months later after decongestant therapy or stopping HRT.

In all of the other situations listed below, MRI-guided repeat histology is required [11,25—27,48,50,55—60] (Table 2) (Fig. 1):

- BI-RADS 3 in women with mutations or in ipsilateral or contralateral cancer [37,46,50,64] as the PPV of MRI BI-RADS 3 is greater than that of mammography or ultrasound (< 2%) [43,45,65];
- BI-RADS 4 or 5 [11,21,26,32,33,66,67];
- poor agreement between CE and the image found or biopsied on targeted examination (clip distant, unexpected histological result) [48,68].

Wherever possible, the decision is made following an MDT [50,69,70]. ''Simple, intelligible and reliable'' information is then given to the patient about the procedure, limitations, risks and the ''patient's free informed consent'' is obtained according to the terms of article 35 of the Deontology Code (1995).

Table 1 Results of the targeted ultrasound after MRI.

Authors references	Year	Context	On MRI, number of			Number of 2nd look ultrasounds performed	On ultrasound, number of lesions			
			Patients	Lesions	Cancers		Visible	Including cancers	Occult	Including cancers
La Trenta [15]	2003	Pre-treatment or follow up	64	93	19 (20%)	93 (100%)	21 (23%)	9 (43%)	72 (77%)	10 (14%)
Deurloo [16]	2005	Pre-treatment assessment	48	50	20 (40%)	39 (78%)	19 (49%)	12 (63%)	20 (51%)	6 (30%)
Sim [17]	2005	High familial risk	43	48	12 (25%)	48 (100%)	32 (67%)	11 (34%)	16 (33%)	1 (6%)
Beran [18]	2005	Pre-treatment assessment	52	73	45 (62%)	73 (100%)	65 (89%)	42 (65%)	8 (11%)	3 (35%)
Shin [19]	2007	Pre-treatment assessment	62	69	26 (38%)	38 (55%)	27 (71%)	15 (56%)	11 (29%)	3 (27%)
Linda [20]	2008	Various	159	173	49 (28%)	173 (100%)	142 (82%)	46 (32%)	31 (18%)	3 (10%)
DeMartini [21]	2009	Various	155	201	60 (30%)	167 (83%)	76 (46%)	27 (36%)	91 (54%)	20 (22%)
Carbognin [38]	2009	Various		62	17 (27%)	62 (100%)	44 (71%)	12 (27%)	18 (29%)	5 (31%)
Meissnitzer [39]	2009	Various	361	519	121 (23%)	519 (100%)	290 (56%)	87 (30%)	229 (44%)	34 (15%)
Destounis [40]	2009	Pre-treatment assessment	152	196	47 (20%)	182 (93%)	128 (70%)	39 (30%)	54 (30%)	8 (16%)
Abe [22]	2010	Various	158	202	44 (22%)	202 (100%)	115 (57%)	33 (29%)	87 (43%)	11 (13%)
Luciani [18]	2010	Pre-treatment assessment	46	55	31 (56%)	55 (100%)	42 (76%)	24 (57%)	13 (24%)	7 (54%)
Candelaria [42]	2011	Various	83	131	45 (34%)	131 (100%)	88 (67%)	27 (31%)	43 (33%)	18 (42%)
Laguna [43]	2011	Pre-treatment assessment		123	37 (30%)	123 (100%)	76 (62%)	26 (34%)	47 (38%)	11 (23%)
Ha [44]	2011	Pre-treatment assessment	33	34	7 (21%)	34 (100%)	12 (35%)	6 (50%)	22 (67%)	1 (5%)
Kim [35]	2012	Pre-treatment assessment	98	126	17 (13%)	126 (100%)	81 (64%)	16 (20%)	45 (36%)	1 (2%)
Fiaschetti [45]	2012	Various	60	84	9 (11%)	84 (100%)	43 (51%)	7 (16%)	41 (49%)	2 (5%)
Total				2239	606 (37%)	2149 (96%)	1301 (61%)	439 (34%)	848 (39%)	144 (17%)

Table 2 Distribution of MRI-guided vacuum-assisted biopsies by morphology and enhancement kinetics.

Authors references	Year	No. of lesions	BI-RADS 3	BI-RADS 4	BI-RADS 5	Focus	CE-mass	CE without a mass	Progressive	Plateau	Wash out
Liberman [25]	2005	112				3 (2.7%)	61 (54.5%)	48 (42.9%)			
Lehman [21]	2005	38				24 (66.7%)		14 (33.3%)			
Gebauer [30]	2006	42	22 (52.4%)	18 (42.9%)	2 (4.8%)		28 (66.7%)	14 (33.3%)			
Lee [29]	2007	342	21 (6.1%)	319 (93.3%)	2 (0.6%)	7 (2.1%)	167 (48.8%)	168 (49.1%)			
Mahoney [32]	2008	55				6 (10.9%)	30 (54.5%)	19 (34.5%)	17 (30.9%)	15 (27.3%)	23 (41.8%)
Hauth [31]	2008	34	7 (20.6%)	19 (55.9%)	8 (23.5%)		23 (67.6%)	11 (32.4%)			
Han [23]	2008	150				21 (14%)	61 (40.7%)	68 (45.3%)	66 (44%)	36 (24%)	17 (11%)
Li [61]	2009	177					98 (55.4%)	79 (44.6%)			
DeMartini [21]	2009	167				30 (18%)	84 (50.3%)	53 (31.7%)			
Malhaire [33]	2010	72				1 (1.4%)	32 (44.4%)	39 (54.2%)			
Crystal [34]	2011	26					8 (30.8%)	18 (69.2%)	14 (53.8%)	10 (38.5%)	2 (7.7%)
Zebic [62]	2012	14	2 (14.3%)	8 (57.1%)	4 (28.6%)		5 (35.7%)	9 (64.3%)	1 (7.1%)	6 (42.9%)	7 (50%)
An [63]	2013	15		14 (93.3%)	1 (6.7%)		13 (86.7%)	2 (13.3%)	1 (6.7%)	8 (53.3%)	6 (40%)

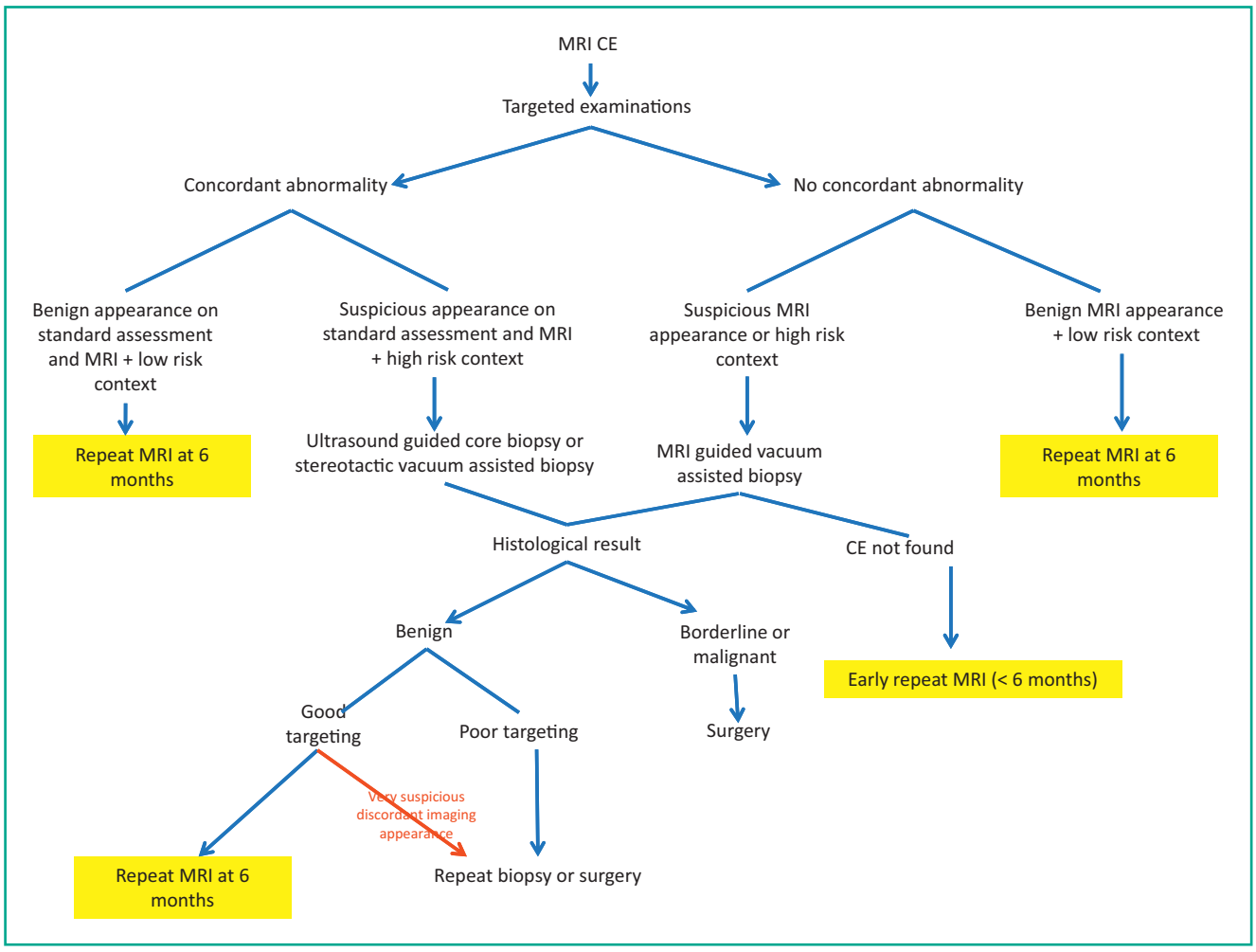

Figure 1. Decision algorithm for the management of an additional CE found on MRI.

Practical conditions

Training recommendations

MRI-guided biopsies should only be carried out in experienced breast centers [50]. The team must have sufficient and regular experience in breast MRI and vacuum-assisted biopsy (over 50 procedures annually) [50,64,71].

In addition, training in MRI-guided vacuum-assisted biopsies with histological confirmation under the supervision of a specialist is required before a practitioner can work alone. The initial training involves three procedures in France (as access to MRI is still limited) [50,69] but 15 procedures are required according to the European guidelines [71].

Ten procedures per site per year are then sufficient [50,64,69,71].

Contra-indications

The contra-indications are those of MRI (claustrophobia, pacemaker, etc.), contrast medium injections (severe renal impairment, allergy) and biopsies (reduced coagulation, allergy to anesthetic agents) although these are generally relative and can be managed. Antiaggregants with a cyclo-oxygenase inhibitor (Aspirine®) or adenosine diphosphate receptor inhibitors (Plavix®, Ticlid®, Efient®) can be continued [69—75]. An initial consultation with a cardiologist or anesthetist in patients on vitamin K antagonists can be used to consider possibly switching to low molecular weight heparin, otherwise the decision is based on the International normalized ratio ([INR], derived from the prothrombin time) on the understanding that the risk of bleeding is low below 2 and high above 3 [75,76].

One-pass en bloc excision with radiofrequency (Intact®) cannot be used because of interference with the electromagnetic wave.

Technique

Equipment

Magnet

The biopsy is generally taken in a closed MRI with an average field of 1 to 1.5 T [11,13,25,27,28,58,60,63]. It can be carried out in a high field (3 T) [63,67,77—80] in which the sensitivity of detecting the cancer is greater for the same specificity [81], although susceptibility artefacts are

increased: using a 14G needle the signal vacuum is 4 mm at 1.5 T [82] and 9.5 mm at 3 T [77].

Open machines provide easier access to the breast and real time monitoring of insertion of the cannula. Few of these instruments are available however and they generally use a low field (0.2—0.5 T), which does not provide sufficient quality imaging [83], although this is still a possibility [84—86].

Samples are therefore taken outside of the magnet to avoid image distortion from the needle [87] and to have sufficient space. Interim checks are made in the tunnel with non-magnetic materials (introducer, clip, etc.) to reduce risks and artefacts.

In more general terms, non-magnetic materials should be used in preference (forceps, etc.) and ferromagnetic materials (scalpel, needles, gun, etc.) must never be put down on their own to avoid accidents from magnetic attraction.

Coils

The coils should if possible be the same as those used for diagnosis in order to obtain equivalent performance. It must be possible to access the breast to take the samples, which assumes that the coil is open.

The initial single breast coils only allowed an external approach and therefore required the practitioner to pass through the entire breast for internal enhancement.

Current dual breast coils allow either external, internal or even superior access (Invivo^{M}, Sentinelle^{M}), although the lateral approach should be preferred as this is the most straightforward [46] (Figs. 2 and 3), using a soft tipped needle if necessary in order to avoid the risk of damaging the internal skin tissue.

Internal access is limited for deep lesions and is inconvenient: the contralateral breast lies on a board and the radiologist works from beneath in a tunnel, when a non-magnetic lamp may be very useful [46] (Fig. 4).

MRI images

Initial and then dynamic images are preferably taken in high-resolution T1 weighted 3D FS echo gradient mode [48]. The acquisition may be taken through axial sections although resolution is often better in sagittal sections [46].

The maximum dose (0.2 mL/kg) or a half dose is injected depending on whether or not a repeat end of procedure injection is planned. Unlike other countries [13,27,31,32,88], in France [46,50], the various groups do not administer a further injection in order to avoid risk of saturating or missing the target (small or poorly vascularized targets).

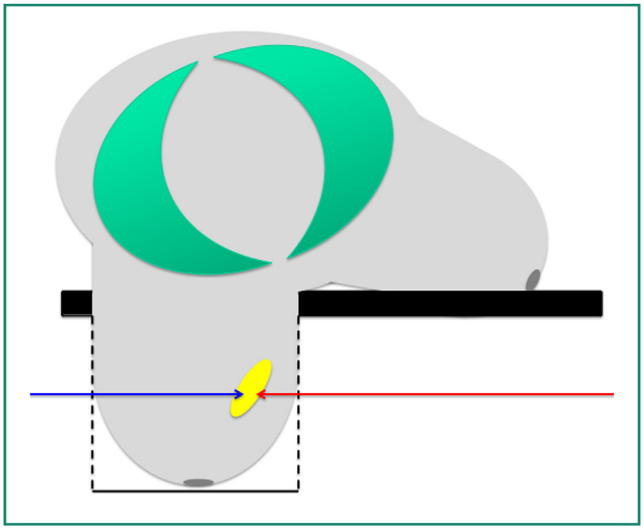

Figure 2. Diagram showing access to an internal CE *via* a lateral (blue) and internal (red) approach.

The injection rate is 2—3 mL/s and the contrast medium is then washed out with 20 mL of serum.

In the interim views, rapid T1 spin echo (TSE) [50] images are preferable in order to reduce needle artefacts [58]. The CE is often poorly visible, in which case anatomical landmarks have to be used.

The principle used is that the same image is taken on four occasions: before biopsy (target identification), after positioning a guide (checking correct position of the biopsy system), after taking the biopsy (confirming that the biopsy cavity is consistent with the target) and after positioning the clip (checking the correct position of the marker) (Fig. 5).

Guiding system

Hand to screen guidance can be used for identifications [84,89—91] but not for biopsies, as it is not sufficiently precise.

The guidance systems, initially incorporated into a single breast dedicated interventional coil [83,87,92], are now removable and can usually be incorporated into conventional diagnostic coils.

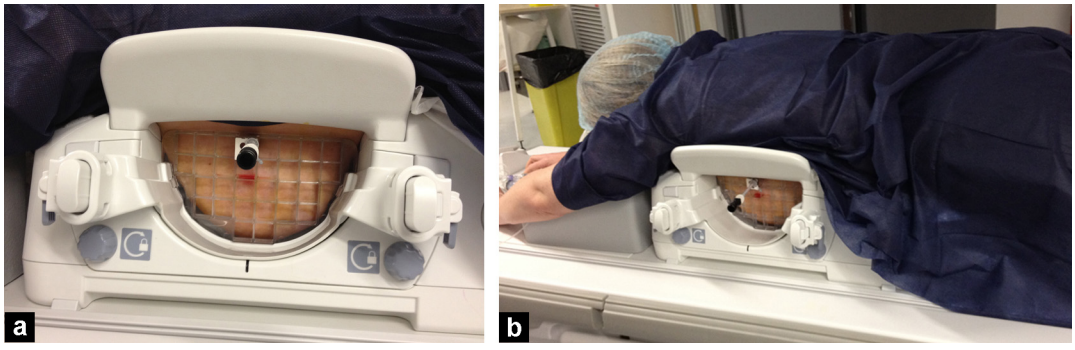

Figure 3. a, b: external approach on a GE® coil.

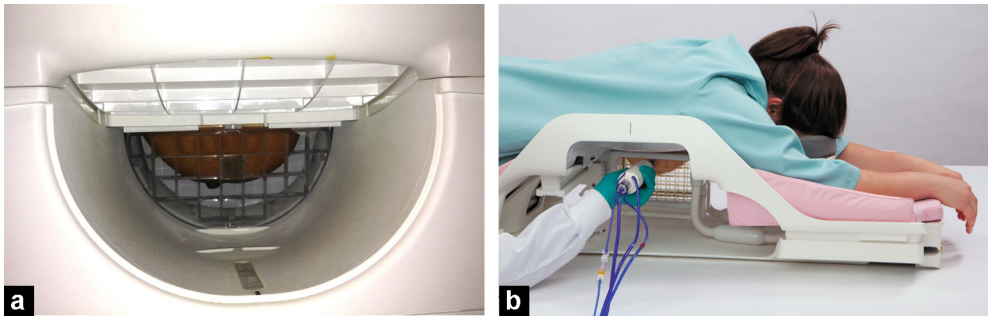

Figure 4. Internal approach: GE® coil b: Sentinelle coil (Hologic®).

The platform may consist of a simple frame (MRI Device®), usually combined with parallel, flexible, vertical or horizontal compression bars (Fig. 6).

This is linked to a graduated pillar fixed to the coil [77] or to the edge of the MRI bed, equipped with rulers to set the x and y coordinates and the angulation (Figs. 7 and 8).

The grid (General Electric®) is now the most widely used target system (Fig. 3) into which a block guide is inserted. This is a sterile, multi-perforated landmark cube through which the cannula is passed. Regardless of targeting method, an opaque landmark (a tube containing gadolinium [10], a glycerin cylinder [46] or vitamin E capsule [25]) is fixed to the compression plate. The end of this is positioned in contact with the breast and used as the landmark (reference 0 in the three spatial planes), to calculate subsequent targeting. This appears as an obvious hyperintensity in an unenhanced view on T1 weighted images (Fig. 5).

Targeting software (distances, angles), provided either in the landmark identification kit or separately depending on the manufacturer, are particularly useful for posterior contrast enhancement.

CAD can highlight the CE, from the subtraction rather than from the unenhanced image. The biopsy system used is recorded, then it calculates the necessary depth taking account of the materials and thickness of the cube.

Biopsy systems

Different vacuum-assisted biopsy systems are used:

- Atec® 9G (Hologic Inc, Bedford, MA) [11,13,23,25,26,29,34,63,93,94];
- Vacora® 10G (Bard Biopsy Systems,Tempe, AZ) [23,28,30,31,33,57,59,60,88,95];
- Senorx® 10G (Bard Biopsy Systems,Tempe, AZ) [32,46];
- Mammotome® 11G (Devicor Medical Products, Cincinnati, OH) [12,27,96—99].

These systems have been extensively described previously [100—102] and have been adapted to MRI with specific 4 m cabling and vacuum tubing allowing the pump to sit external to the Faraday cage. Particularly, long probes with or without a soft tip and introduction kits comprising of a plastic cannula and two styli (non-ferromagnetic metal) are used (Fig. 9).

Large diameter cannulae are preferable, with a minimum requirement of 11G [50], although according to Fischer similar results can be obtained with 9 and 10G cannulae.

An introducer is routinely used for insertion (Fig. 5).

With coaxial guns, the samples return through the cannula and are recovered outside of the breast (Mammotome®) or are stored in a small posterior container (Atec®, Senorx®, Mammotome®Revolve) (Fig. 10).

Vacora® is a compact, easily transportable system and is not coaxial. It does not have an integral system for sample collection meaning that the cannula has to be removed for each sample (Fig. 11). This causes more difficulty from blood [31] and air and it is essential to use a support for the gun in order to reduce the risk of displacing the cannula. The vacuum aspirate is reported to be less powerful and the sampling process slower (69 vs 39 minutes). Coaxial systems are reported to be able to biopsy smaller lesions (10 vs 19 mm), faster and with greater confidence [103].

As these various guns are non-magnetic (Vacora® less than the others), they are not attracted by the magnet although interference with their operation does occur if they come too close to the magnet.

The different stages [12,13]

Preliminary stage: positioning and immobilization

The patient is positioned on her side with her head turned to the opposite side and her arm along her body or above her head and a venous line with long connection tubing in place (Fig. 12).

The breast is wedged in the surface coil and the guiding system is set up from the beginning. The guide mark is positioned in contact with the skin as close as possible to the projection of the CE if no CAD system is being used [46], or further away in order to avoid hindrance if one is being used [28].

The breast is held between the grid and an often-solid plate. Modest compression is used to avoid masking the enhancements [83,104] and to reduce the accordion effect (decompression of the breast may cause displacement of a clip or landmark suture).

Accessibility of the presumed site of the lesion is then checked and positioned in the effective grid compression area.

Stage 1: targeting

The patient is brought into the magnet and an initial enhanced image is taken to find the CE and locate it against the guide marker (this can be identified by the presence of silicone or paraffin which appears as a T1 weighted hyperintensity on an unenhanced image) (Fig. 5a, b, e).

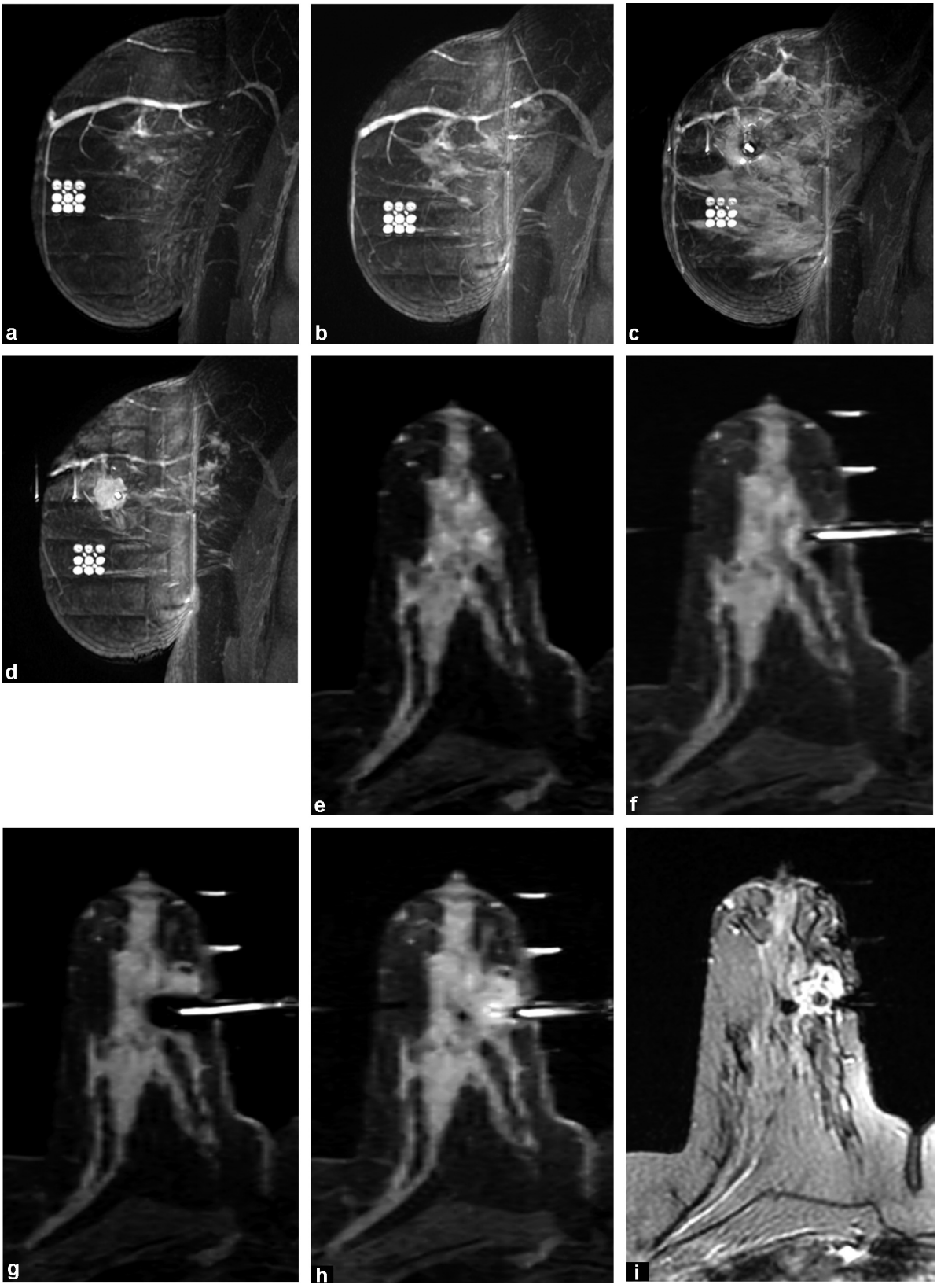

Figure 5. Patient with proven left breast recurrence referred for strategic biopsy of non-mass contrast enhancement located at the junction of the internal quadrants of the right breast. The patient is positioned for an internal approach and MRI images are taken in sagittal sections. Sagittal reconstruction MIP: a: stage 1: target identification: the enhancement is located immediately behind the grid; b: new stage 1: identification of the target; after removal of the coil foams the CE projects onto the grid and becomes accessible; c: stage 2: positioning an introducer; this is located on the posterior surface of the contrast enhancement; d: stage 5: post biopsy phase, visualization of a hematoma of approximately a centimeter in size around the introducer in place of the initial enhancement. Axial reconstruction MPR:

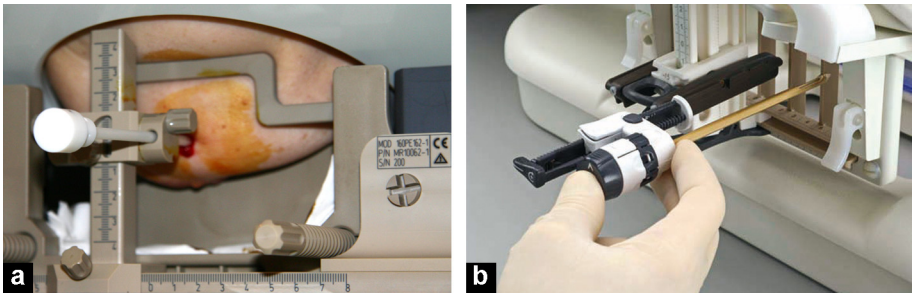

Figure 6. Guiding system: a: Device® MRI system. The introducer is *in situ* with its silicone sheath; b: Devicor® system. The ceramic introducer is equipped with a window opening onto the sampling area.

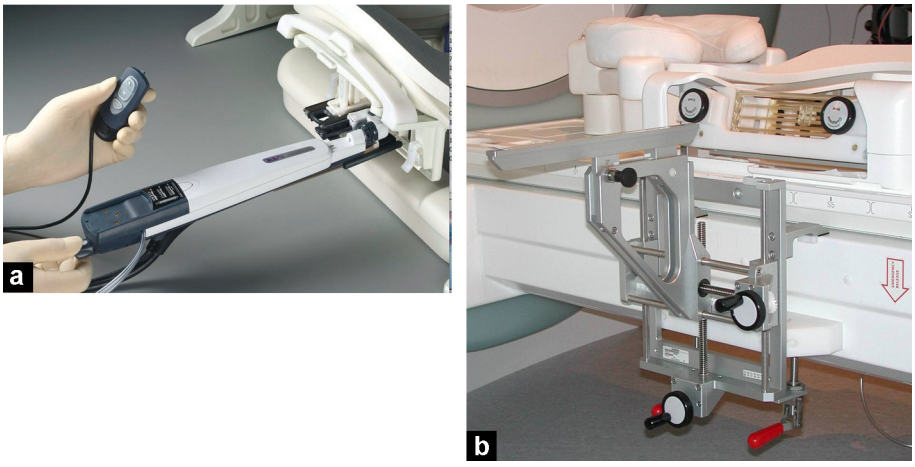

Figure 7. Supports for the biopsy gun: a: with the Devicor®, system the dedicated gun is fixed to the coil; b: the Siemens® system, this occupies more space and is used as the support for the guide. It is fixed to the examination bed.

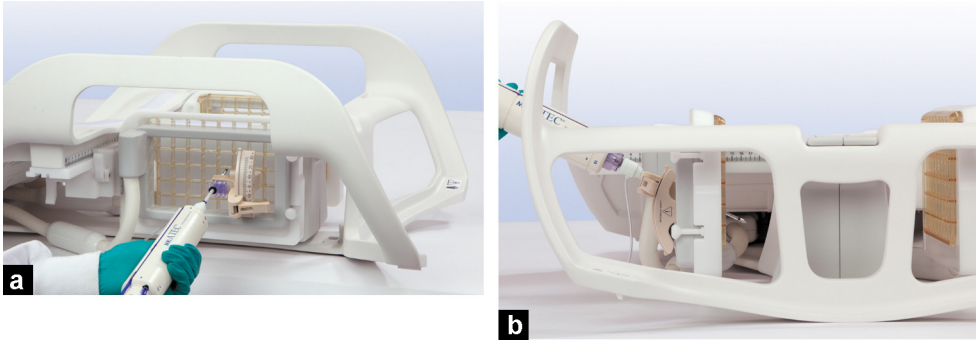

Figure 8. Sentinelle coil (Hologic®) with its grid and angulation system: a: frontal view; b: lateral view.

Distances are measured manually or by software in the 3 spatial planes between this reference point (''zero'') and the abnormal CE.

Stage 2: positioning the introducer

After disinfection and local anesthesia, a skin incision may be required depending on the shape of the end of the cannula.

The sterile cube is then inserted into the grid, possibly after initially tapering the introducer on the cube, which allows the skin incision to be found more easily [46] (Fig. 13).

Depth is then adjusted taking account of the thickness of the cube and adding 20 mm for Senorx®, 10 mm for Vacora®, but nothing for Mammotome® [46].

Once in place the metal sheath is replaced with a silicone sheath or with the position marker. The patient is returned

e: stage 1; f: stage 2; g: stage 2; h: stage 5; i: stage 5: this other image (axial T2*) may be useful to view the clip which is not always clearly visible on the conventional T1 weighted echogradient images. The metal marker appears as a pronounced hypointensity inside the hematoma, which is a pronounced hyperintensity (as very recent). These four stages of the biopsy in sagittal and axial images should make up the two films provided in the summary.

Figure 9. Fitting the materials to the MRI guide: a: the vacuum cabling and tubing are extended to keep the vacuum aspiration pump (Devicor®) outside of the Faraday cage; b: Bard® introducing kit with a cannula and two sheaths (metal and silicone); c: the rounded end of the cannula avoids damaging the covering skin.

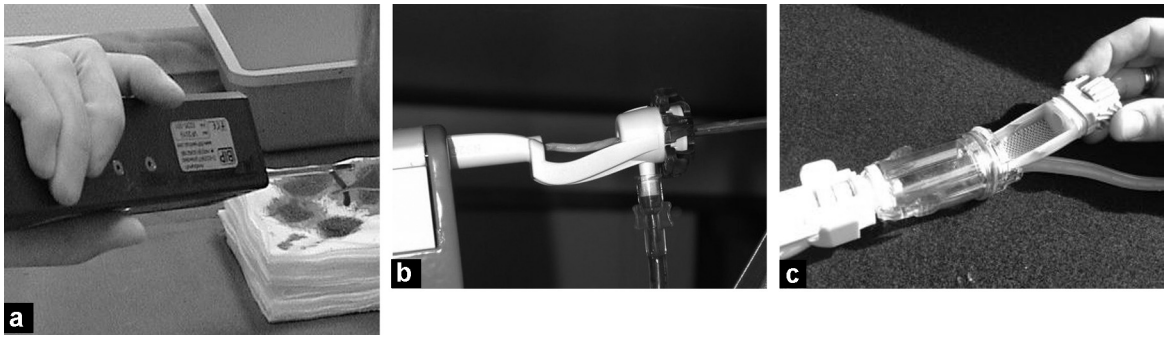

Figure 10. Different means of recovering samples; a: with the Vacora®, non-coaxial system, the cannula is withdrawn from the breast to recover each sample; b: with the Mammotome®, the samples are recovered as the procedure progresses through a window located outside of the breast and in front of the gun; c: with the Encor®, the specimens are stored in a container located at the back of the gun.

inside the magnet and a rapid image is then taken to check the correct position of the introducer. The biopsy window is visible on the Mammotome® cannula (Fig. 5c, f, g, 6a).

Stage 3: biopsy

The introducer is replaced by the cannula and then a series of samples is taken (Fig. 11). The number of samples depends on the size of the lesion, cannula diameter and quality of targeting.

With an 11G cannula, the minimum number of samples required is 24 according to the European guideline [64] and 12 according to the HAS [50], or an equivalent volume when a larger gauge cannula is used [62,64].

The number of samples reported in the literature ranges from 2 to 75 [23,25,28,31,33,62,96,105] with a median of 12 [13,25,31,33,60,62,105].

The samples are then placed in a bottle and sent to the pathologist, together with the full radiological and clinical

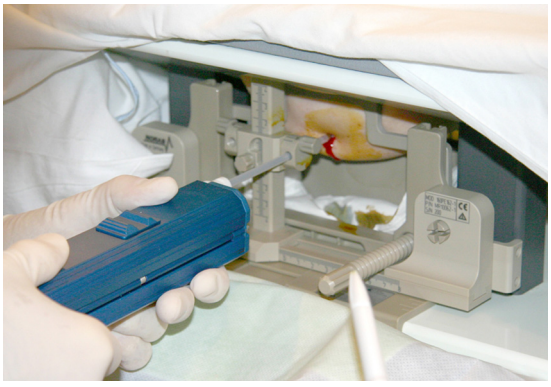

Figure 11. Large core biopsy with the Vacora® 10G, miniaturized, non-coaxial system.

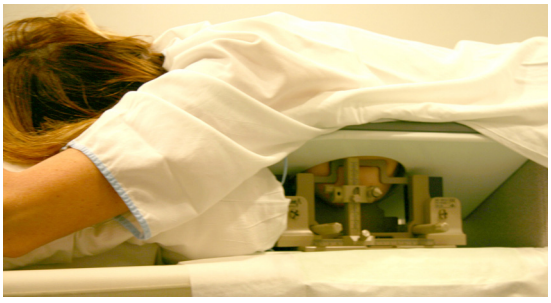

Figure 12. Patient positioning on their side with the breast wedged in an open coil and the stereotactic guiding system positioned from the beginning for a lateral approach.

details, which are absolutely essential for MRI-guided biopsies. The specimens are fixed and then at least three sections are prepared. They must be read by an experienced breast histologist [33,34,50].

Stage 4: labeling the site

A clip is routinely positioned [13,25,26,33,46,50,54,60] as this is the only landmark, which can be used to guide any subsequent revision surgery.

It may not be used if the patient refuses [26], if positioning has failed or if one is not applied routinely [13,26,33,34,88].

It is positioned through the cannula before the cannula is removed or after the check image, through the introducer.

Stage 5: end of procedure check image

The patient is repositioned in the tunnel for a last check sequence, which is essential [50]. This is used to determine whether the contrast uptake has reduced or disappeared [27,87], although it is often sufficient to check that the biopsy area is correctly centered on the initial CE (by comparing with the pre-biopsy image) and that the clip is correctly positioned (Fig. 5d, h, i).

This sequence is carried out with [13,27,31,32,88] or without [46,50] contrast enhancement.

If the result is not satisfactory further samples should be taken or the lesion retargeted.

At the end of the procedure, the patient is removed from the tunnel, placed flat on her back and manual compression is applied followed by a compressive dressing. Monitoring for half an hour after the procedure is generally sufficient [50].

These different stages are illustrated in Fig. 14.

Duration

The average time spent in the MRI is approximately 1 hour [50,63,87,106]: 20 [11] to 70 minutes [27,33,98]. This is increased by 30 to 50% [11,25,50,98] when two sites are biopsied.

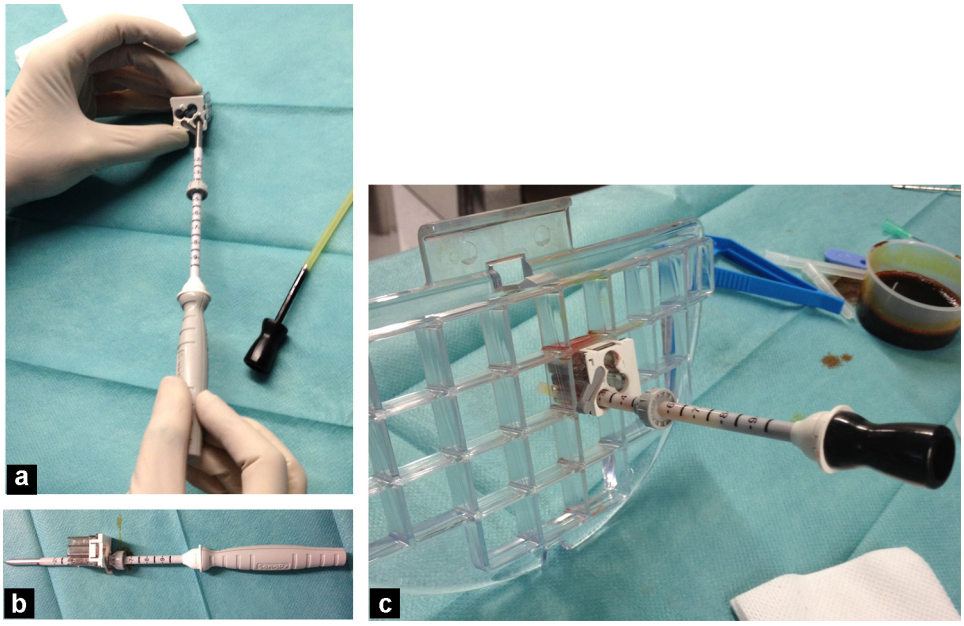

Figure 13. Insertion of the introducer: a, b: the sheath is inserted into the cube; c: the sheath assembled onto the cube passes through the skin and the skin is then fixed to the grid.

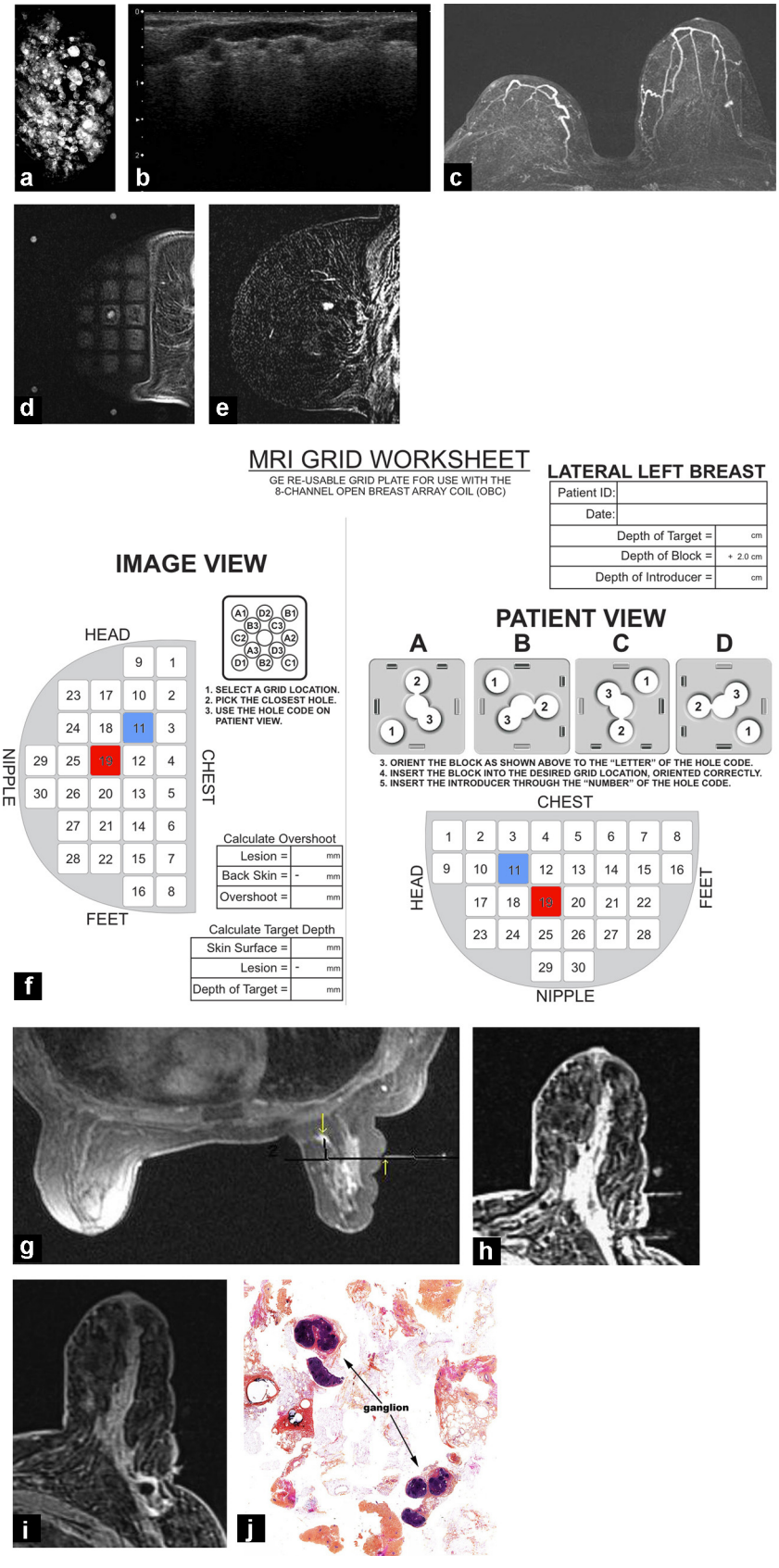

Figure 14. This is a 53-year-old patient who had intramammary silicone injections 20 years earlier and was then treated for right breast cancer 2 years ago: a, b: mammography and ultrasound are difficult to interpret because of the diffuse siliconomas; c: monitoring is therefore mostly based on MRI which showed a relatively unsuspicious CE in the contralateral, supero-external quadrant suggestive of an intramammary lymph node. A second look examination was negative and a repeat MRI was carried out 6 months later. This showed an increase in size of

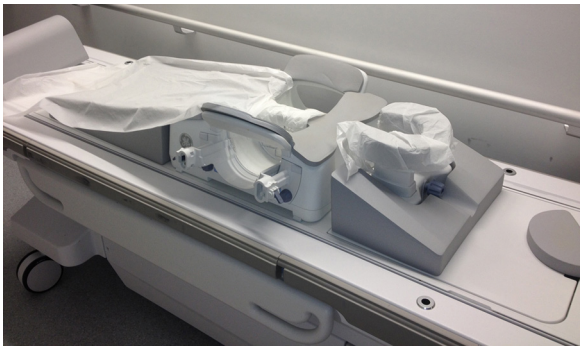

Figure 15. Non-magnetic trolley allowing pre and post biopsy procedures to be carried out, outside of the room and therefore limiting the time in the MRI room.

According to Norozian [106], the length of the procedure depends on the number of images and checks in the tunnel, whether or not an assistant is present and proximity to the nipple, as this is reported to be independent of patient age, size of the breast and type or size of enhancement.

The MRI room occupation time can be reduced with prior planning the positioning and venous access before the procedure [106] and by using a coaxial system [33] or even a second non-magnetic trolley. This enables the pre-procedure (positioning the materials and patient) and post-procedure activities (removing the trocar, compression and dressing) to be carried out outside of the MRI room. The occupation time is thus reduced by approximately a third (Fig. 15) to 35—39 minutes [11,13,46,62].

Some practitioners even take the samples outside of the room, taking advantage of this approach to take more samples (> 18) to reduce underestimation, although they position the clip at the beginning of the procedure and do not take a post-biopsy check image.

Documents to be given out at the end of the procedure

The patient leaves with an information form and instructions, a provisional report and images. This report should describe [69]:

- the clinical context of the biopsy;
- the lesion (appearance, with BI-RADS classification, size and site);
- the approach route;
- the materials used;
- the samples (number, diameter) [76];
- traceability of the materials used (cannula, clip).

Images should be provided if possible in all the three spatial planes.

Four summary images in each of the two planes (axial and sagittal) are essential, showing the initial CE, introducer in place, after biopsy and the clip check [46,50] (Fig. 5).

Two orthogonal mammography films of the breast are taken to check the correct positioning of the clip [46,50,64,69], either immediately or later to avoid moving it.

It is correctly deployed in 93 to 100% of cases [25,26,60,62] and failures are due to non-deployment into a superficial lesion, bleeding or technical error [25,26].

Clip positioning was correct (< 10 mm) in 79% of cases reported by Malhaire [68] and 96% reported by Siegmann [107], with an average distance of 4.5 mm [107]. Siegmann [107] did not find any secondary drift and visualized the clip correctly by ultrasound in 93.1% of cases and by MRI in 86.2%.

Despite a representative sample being taken, incorrect clip positioning may occasionally result in repeat biopsies needing to be performed [61].

Limitations, difficulties and tips

If MRI is contraindicated or technically impossible, the option of CT-guided biopsy should be considered [108].

Strict prolonged immobilization with the patient on her side requires good patient cooperation from 50% of whom find the position uncomfortable [88].

Ten to 25% of procedures [27,57,58,97,109,110] cannot be performed, usually because the CE is not found (2 to 17%) [23,25,27,30,31,33,38,57,63,80,97,98,110,111], although occasionally because of obesity [57,109,110] or lack of accessibility [33,57,109].

The CE may not be seen because:

- it has disappeared because of excessive compression (in which case a further image should be taken with less compression of the breast) or if the initial MRI was carried out at the wrong time of the menstrual cycle [97,111];
- it is no longer clearly identifiable because of masking of the enhancement, small size (< 5 mm), post-treatment changes or limited operator experience [46].

This effect is as common with high fields as with average fields [80].

the CE and guided ultrasound remained negative. The decision was then made to carry out MRI-guided vacuum-assisted biopsy; d: the examination was performed in a sagittal acquisition with a grid system. The skin landmark was located on the lateral sections; e: the CE was seen again and was more intense and posterior. The mouse pointer was placed on the enhancement as a landmark and the images scrolled through until the landmark cube was seen, placing the imprint of the grid on the skin on the section; f: the position of the CE is then transposed to a diagram reproducing the lateral shape of the breast (in this case the CE is colored blue and the skin landmark red). This avoids errors moving from the position of the diagnostic images (sagittal sections shown upright on the console screen/on the left), to the biopsy position (patient lying down on her side/on the right). The x and y coordinates are then calculated on the grid. g. to establish the depth z. The section positions, CE and guide mark, can be subtracted or the distance between the CE and skin measured directly on a reformatted image taking care to position the marker on the theoretical external outline of the skin; h: the introducer is positioned, poorly seen in this axial section, followed by a dozen samples being taken (9G caliber); i: a clip is positioned after the cannula is removed. The check image shows hemorrhagic changes hindering analysis of the residual CE; j: but the histological result is benign and in agreement showing a lymph node containing tumor.

It is then possible to try to identify it using neighboring anatomical structures on the initial diagnostic MRI.

If it has not, however, been possible to take biopsies, a repeat MRI without compression is needed within 24 hours [46] or even in the following months [97,111]. Viehweg [97] however only proposed this repeat in peri-menopausal women or those recently started on HRT. This may not be sufficient, as whilst the malignancy rate for these CE which have disappeared on the day of biopsy and are reviewed subsequently was zero according to Han [23] and An [63], the corresponding figure was 2% for Thomassin [46] and 10% for Hefler [111].

Like the other guiding methods, retro-alveolar or superficial lesions, small breasts or prosthetic implants (Fig. 10) may complicate the procedure (compression, accessibility or complication) [58].

According to Malhaire, 2% of procedures were inaccessible [33].

Cushions can be added for small breasts or the breast swollen artificially with a ''wonder bra'' type bandage (elastoplast applied horizontally or vertically), using soft tipped cannulae and a sampling chamber reducer [46,47].

The lateral approach should be used in preference for deep lesions in order not to be impeded by the sternum [46]. The patients arm can be positioned along her body and the foam removed from the coil the table cushion removed and the opposite side of the patient's body raised to bring the breast down into the coil [46].

If the pectoral muscle is prominent an attempt should be made to flatten it by changing the position of the arm (along the body or above the head).

If the entrance point is located outside of the grid, the procedure can be performed unguided (free-hand technique) although a horizontal path is not guaranteed [47,67,84,89,90].

Some coils (Sentinelle^{M}) allow the grid to be shifted, maintaining a parallel approach to the wall. Others suggest that the cannula can be inserted at an angle, although this carries a risk of wall damage (pneumothorax, etc.) (Fig. 8).

Table cushions can be added for anterior CEs or the breast thickness increased with a ''wonder bra'' bandage.

If a prosthetic implant is present, this should be pushed aside and the cannula positioned on the anterior surface of the CE:

- the procedure should be performed relatively soon after the gadolinium injection (< 15 minutes) as malignant lesions ''wash out'' [46] and the neighboring tissues enhance [47,83]. The blood hyperintensity contributes to masking the CE;
- patient magnetic susceptibility and magnetic field distortions due to the coil and metal needles may cause ballistic approximations because of needle drift [55] or the lesion being pushed aside [83]. Large caliber needles also create a signal void proportional to their diameter which is reduced with MRI compatible needles [55] and may mask the enhancement and/or tip of the needle [55,83,112].

The clip causes a magnetic susceptibility artefact, which is seen on the final images. Air inside the biopsy cavity also generates a signal void, which can cause identification errors [47].

As less compression is applied than for stereotaxis, the risk of the lesion being pushed aside is greater but the accordion effect and therefore the risk of incorrectly positioning the clip is less.

El Khouli [113] found an average overall ballistic error in the space of 4.4 mm on a model and 5.7 mm on patients, independently of operator if a protocol is present and followed and concluded that CE are accessible up to 5—6 mm. In order to improve the reliability of MRI-guided biopsies some therefore recommend preferentially biopsying enhancements of over 5 mm [8,114], or even 10 mm [4,8], given that contrast enhancement of under 5 mm is usually benign [24,115]. Perlet [27], however, felt that vacuum-assisted biopsy performed well and was particularly useful for small lesions as the larger ones were generally visible on ultrasound.

Several pitfalls limit the diagnostic confidence compared to what is achieved with mammography or ultrasound guided biopsies [46,47,58]:

- there is no check with a cannula *in situ*, and even less in real time;
- the sampling radiographs are of no use if they contain no calcium or fibrous signal;
- pathologists have no calcified or nodular lesion.

Management of the result

Technical success

According to Crystal [34], the distance between the cannula and CE must not be more than 3 mm.

Success is assessed particularly however from the reduction or disappearance of the CE.

Perlet [27] and then Tosaki [116] referred to success if the enhancement was reduced by at least 50%.

According to Hauth [31] and Ghate [60], a partial unquantified reduction is sufficient whereas most authors do not report their criteria for success.

The assessment is hindered by bleeding in 9 to 38% of cases [60,63,87], air, the anesthetic agent and movements [47,57,117]. In this situation, Perlet [27] carries out a repeat MRI 2 to 4 days after the procedure. Hauth [31] even routinely replaces the check sequence at the end of the procedure with an MRI 24 hours later in order to optimally assess whether the procedure is representative and uses this to explain her lower success rate than other series.

According to Perlet, success does not depend on the size of the CE or the experience of the radiologist [27].

Malhaire [33] however described failures and missed cancers during the initial learning period.

Enhancements of 4 and 100 mm are reported in the literature with an average of 10 mm [11,13,25,26,33,60,63,105,113]. These disappeared in 33.1% of cases (4—81%), reduced in 59.6% (18—87%) and were unchanged in 7.3% (0—30%) [25,27,29,31,60,87,88,116,118] (Table 3).

Complete excision rates for the radiological signal are similar to those achieved with stereotactic biopsies (≈ 38%) [102,119] and less than those with ultrasound-guided procedures (> 70%) [100,101].

Table 3 Assessment of success of vacuum-assisted biopsy based on the change in CE.

Authors references	Year	No change (%)	Partial resolution (%)	Completely disappeared (%)
Heywang [87]	2001	1	87	12
Liberman [25]	2005	4	66	29
Ghate [60]	2006	30	65	5
Perlet [27]	2006			4
Lee [29]	2007	1	69	30
Tozaki* [116]	2007	0	40	60
Hauth [31]	2008	13.8	72.4	13.8
Perretta [88]	2008			4
Ferré [118]	2011	1	18	81
An [63]	2013	0	87.5	12.5
Mean		6.4	63.1	25.1

*Only five patients.

The average size of the CE, which completely disappeared however was 13.9 mm according to Ferré [118].

Failures are uncommon (0 to 14%) [11—13,25—27,30—33,46,60,62,96—99,118,120,121] and are due to inadequate or discordant samples [25—27,58,87,110].

These may be due to patient reactions (malaise or anxiety) [25—27], technical difficulty with the materials (cannula or table), patient (accessibility, breast too thin) [26,27,60], or operator [27], or bleeding [46].

According Imschweiler [121], therefore, the success rate is similar to that achieved with stereotactic biopsies and lower than that achieved with ultrasound-guided procedures.

Histological result

The distribution of histological results varies greatly depending on recruitment for breast MRI. Benign results are found in 18 to 74% of cases [11,13,25—28,60,87,89,98,99], borderline in 1 to 21% [11,13,25,26,28,60,87,97—99] and malignant in 5 to 61% [11—13,25—28,46,60,87,96—99,120].

The PPV ranges from 5 to 100%, [13,25—27,30,31,33,38,60,63,96,98,121] and the NPV is over 93% [27,38,121].

If the indications for MRI are correctly followed, however, the malignancy rate is over 20%, which justifies the samples being taken (Table 4).

According to Gebauer [30], the malignancy rate was 4.5% (1/22) for BI-RADS 3, 44.4% (8/18) for BI-RADS 4 and 100% (2/2) for BI-RADS 5.

This is reported to be higher in diagnostic compared to screening examinations (personal history, high risk) (32 vs 12%) [23,122] and for CE with a mass appearance or wash out [62,122].

Han [23], however, reported that this rate did not depend on either the time or the kinetics of the CE.

Table 4 Context in which the MRI-guided vacuum-assisted biopsies were performed: distribution by series and corresponding malignancy rate (in brackets).

Authors [references]	Year	Pre-treatment assessment (%)	Post-treatment follow up (%)	High risk family (%)	Suspicious mammography Abnormality on one view (%)	Other indications (%)
Liberman [25]	2005	23 (27)	9 (25)	46 (19)	21 (45)	
Lehman [11]	2005	61	24		15	
Orel [26]	2006	54	15.3		30.7	
Perlet [27]	2006	8 (36)	29 (32)	11.4 (27)	21.9 (20)	29.7
Plantade [28]	2006	40 (50)	10 (100)		50 (40)	
Lee [29]	2007	31	10	34	24	
Gebauer [30]	2007	29.4	2.4		68.2	
Han [23]	2008	41 (36)	16 (23)		13 (28)	30
Hauth [31]	2008	18.2	39.4	9.1	33.3	
Mahoney [32]	2008	21	38		41	
DeMartini [21]	2009	26	10	22	16	26
Malhaire [33]	2010	13	32	32	25	
Crystal [34]	2011	8	39	38	15	

(): malignancy rate.

Mass CE are more often malignant [46] and are usually due to infiltrating carcinoma (64%) [22,25] whereas non-mass CE are due particularly to DCIS (80%) [25].

Discordances

There are two types of discordance:
- site: the biopsy area is located distant to the CE;
- histology: the result is unexpected in light of the CE BI-RADS appearance.

Concordant benign samples make up 0 to 12% of cases [11,13,23,25,26,28–30,32,60,61,88,96,123] with a mean of 5.3% [23,25,26,29,30,32,33,118] and the malignancy rate ranges from 0 [43,65] to 100% [26,28,30] with a mean of 44.5% [23,25,26,29,30,32,33,118] (Table 5).

These results are similar to stereotactic or ultrasound-guided biopsies.

In Lee's study [122], the CE was reduced in 71% of discordant cases although the malignancy rate in this situation was 27%. This highlights the importance of checking radiological and histological concordance, [25,26,69,123] and justifies a further biopsy (percutaneous or surgical) of discordances [123], rather than a repeat MRI after 6 months [61].

Similarly, insufficient samples should be repeated.

Final report and conclusion (Fig. 1)

Once the histopathological diagnosis has been received, a summary of the results, their concordance and future management should be included in the report [69].

For concordant benign lesions authors recommend a repeat routine MRI in 6 to 12 months [10,11,25,58,60,63,64,87], or even in 3 to 6 months according to the HAS working group [46,50], bearing in mind the limitations of this follow-up [61].

Revision surgery is required for carcinomas or borderline lesions [27,34,50].

Finally, all cases [33,64] or at least ambiguous cases [69] should be discussed in the MDT.

In this situation, most authors do not report any missed cases of cancer [25,27,31,32,87,88,95].

The HAS working group [50], however, estimated a missed diagnosis rate of 1–2% compared to 2.3% according to Li [61], which is still acceptable.

Underestimations

These are due to undergrading of the histological lesion (ADH vs DCIS, borderline or DCIS vs infiltrating carcinoma) and are reported overall to occur in 4 to 19% of cases [23,38,96] (Table 6).

Figures range from 11 to 50% for all borderline lesions [23,25,26,33,34,46,60,106,122], with a mean of 28% [23,33,34,46,106,122].

Brennan [79] published a large series of 1487 MRI-guided vacuum-assisted biopsies, with a 5% papilloma rate. Quasi-routine surgical revision (67/75) found underestimations of 5% for papillomas without atypia and 9%, when atypia was present. This is relatively similar to ultrasound-guided procedures [129].

ADH represents 4 to 11% of biopsies and has an average underestimation rate of 32.4% (13–100%) [11,26,27,32–34,60,88,94,95,118] (Table 7), which is twice that of stereotactic procedures [113,121].

No predictive indicators have been identified to reduce the underestimation rate for ADH [94] or for borderline lesions more generally [34].

Underestimations for DCIS range from 0 to 25%, with an average of 10.3% [11,23,25–27,29,33,88,95,99] (Table 8), which is relatively similar to stereotactic biopsies [27,119,129] or ultrasound-guided biopsies [100]. Lee [29] found a significant increase in underestimations when possible concomitant microinfiltration was present (17 vs 80%), although found no other predictive indicators (size, excision, etc.).

Like the stereotactic biopsies, underestimations of ADH appear therefore to occur more commonly than with DCIS.

Complete excision of the carcinoma

Complete percutaneous excision of the carcinoma has been reported in 0 to 25% of cases with an average of 13% [11,19,23,25,27,29,31,33,46,88,105,118] (Table 9).

According to Perlet [27], this only involved lesions under a centimeter in size.

Table 5 Discordance frequencies with their associated malignancy rates.

Authors [references]	Year	Number of lesions	Discordance	Number of surgical cases	Cancers and surgery
Liberman [25]	2005	112	9 (9%)	8	4 (50%)
Orel [26]	2006	85	2 (2.4%)	2	2 (100%)
Lee [29]	2007	342	24 (7%)	20	6 (30%)
Mahoney [32]	2008	55	3 (11%)	2	0 (0%)
Gebauer [30]	2008	42	1 (2.4%)	1	1 (100%)
Han [23]	2008	90	1 (0.9%)	1	0 (0%)
Malhaire [33]	2010	72	3 (4%)	3	2 (66.7%)
Ferré [118]	2011	146	7 (4.8%)	7	5 (71.4%)
Total		944	50 (5.3%)	44	20 (44.5%)

Table 6 Distribution and results of MRI-guided core and vacuum-assisted biopsy punctures.

Type of procedure	Authors and references	Needle diameter Gauge	Year	Number of lesions/patients	Size	Benign	Borderline	Cancer	Underestimation		Complications	Time in minutes	Success
									ADH	DCIS			
Pre-operative localization	Kuhl [104]		1997	97/66		44 (45%)		53 (55%)				40 (30-60)	95 (98%)
	Daniel [89]	20/21	1998	19/17	0.9 (0.3–6)	11 (58%)		8 (42%)			1 (5%)	64 (≤90)	19 (100%)
	Fischer [8]		1998	132		68 (52%)	0 (0%)	64 (48%)				(30-60)	127 (98%)
	Orel [124]	20	1999	137	1.2 (0.3–7)	80 (58%)		57 (42%)					134 (98%)
	Smith [59]	22	2001	16/16		11 (69%)		5 (31%)			3 (19%)		16 (100%)
	Lampe* [125]		2002	132	0.9	62 (47%)		70 (53%)			3 (2%)		127 (96%)
	Bedrosian [126]		2002	41/41		22 (54%)		19 (46%)					41 (100%)
	Morris [5]	18/20	2002	101/69	1.1 (0.2–8)	61 (60%)	9 (9%)						
	Taourel* [127]		2002	264		169 (64%)							
Fine needle aspiration cytology	Wald [128]	22	1996	18/16	1.8 (1–3.6)	16 (89%)							
	Fischer [8]	19.5	1998	31		24 (77%)	0 (0%)						
Core	Smith [59]	16	2001	25/23		20 (80%)							
Biopsy	Daniel [84]		2001	27/19		18 (67%)							
	Kuhl [82]	14	2001	78/59	1.5 (0.6–3)	50 (64%)							
	Schneider [85]	14	2002	21/21	(0.5–1.7)	13 (62%)							
	Chen [10]	14	2004	35/29	1.5 (0.3–7)	21 (62%)	5 (15%)						
Vacuum Biopsy	Viehweg [12]	11	2002	280		208 (74%)							
	Perlet* [98]	11	2002	341		233 (68%)	24 (7%)						
	Heywang [87]	11	2002	87/80		63 (73%)	1 (1%)						
	Orel [120]	12	2003	9/8		5 (56%)							
	Liberman [25]	9	2005	98	1 (0.4–8.5)	52 (60%)	10 (12%)						
	Lehman [11]	9	2005	38/28	1.1 (0.2–7)	22 (58%)	2 (5%)						
	Wiehweg [97]	11	2006	97/63		62 (71%)	4 (5%)						
	Perlet* [27]	11	2006	538	(0.3–2.1)	362 (70%)	17 (3%)						
	Orel [26]	9	2006	95/75	1.7 (0.5–10)	15 (18%)	18 (21%)						
	Ghate [60]	10	2006	20/19	0.8 (0.4–2)	14 (74%)	4 (21%)						
	Plantade [28]	10	2006	10/10	0.8 (0.4–7)	5 (50%)	0 (0%)						
	Gebauer [30]	10	2006	42/32	0.9 (0.3–2.3)	28 (67%)	3 (7%)						
	Liberman [94]	9	2007	237		156 (66%)	37 (16%)						
	Lee [29]	9	2007	373		306 (82%)							
	Tozaki [116]	11	2007	30	1.6 (0.5–2.5)	4 (80%)	1 (20%)						
	Perretta [88]	10	2008	47/47	0.9	28 (60%)	4 (8%)						
	Han [23]	10	2008	172/154	1.5 (0.4–7)	90 (60%)	21 (14%)						
	Hauth [31]	10	2008	29	1.3 (0.5–3.2)	20 (69%)	0 (0%)						
	Mahoney [32]	10	2008	55/47	<1 (–3.7)	38 (69%)	7 (13%)						
	Fischer	9/10	2009	389/365		231 (59%)	50 (13%)						
	Malhaire [33]	10	2010	72	1.2 (0.4–7)	29 (40%)	10 (14%)						
	Oxner [95]	10	2012	187/127	(0.4–1.2)	126 (68%)	16 (9%)						
	Imschweiler*[121]		2013	557		283 (54%)	107 (20%)						

Table 6 (*Continued*)

Cancer	Underestimation		Complications	Time in minutes	Success
	ADH	DCIS			
31 (31%)			3 (3%)	31 (15-59)	101 (100%)
95 (36%)					259 (98%)
2 (11%)				42 (30-80)	11 (61%)
7 (23%)				(30-60)	28 (90%)
5 (20%)			0 (0%)		24 (96%)
9 (33%)				70 (55-90)	27 (100%)
28 (36%)			1 (2%)	60 (45-100)	77 (99%)
8 (38%)				45 (40-65)	20 (95%)
8 (23%)	2 (40%)	1 (100%)	0 (0%)		34 (97%)
72 (26%)				>60	277 (99%)
84 (25%)	(18%)	0 (0%)	16 (5%)	(70-90)	334 (98%)
22 (26%)				>60	86 (99%)
4 (44%)					9 (100%)
24 (28%)	2 (50%)	1 (11%)	6 (6%)	33 (17-60)	95 (97%)
14 (37%)	1 (50%)	1 (25%)	0 (0%)	50 (39-61)	38 (100%)
19 (24%)					
138 (27%)	5 (29%)	3 (4%)	27 (5%)	70	517 (96%)
52 (61%)	2 (25%)	4 (24%)	0 (0%)	(30-60)	83 (98%)
1 (5%)	1 (33%)	0 (0%)	5 (26.3%)		19 (95%)
5 (50%)			0 (0%)	70	9 (90%)
11 (26%)			0 (0%)		32 (100%)
44 (19%)	5 (38%)				
67 (18%)		5 (17%)			
0 (0%)				48 (30-60)	(100%)
15 (32%)	1 (25%)	1 (14%)	2 (4%)		47 (100%)
39 (26%)		5 (19%)			
9 (31%)			4 (14.3%)	65 (52-87)	25 (86%)
10 (18%)	2 (67%)	0 (0%)	2 (4%)		55 (100%)
106 (28%)			(<1%)	43 (17-95)	38 (100%)
33 (46%)	1 (100%)	2 (22%)	3 (3%)	72 (50-131)	69 (96%)
44 (23%)	2 (13%)	0 (0%)	0 (0%)		
137 (26%)	20 (19%)		38 (7%)		548 (98%)

(): range; *: multicenter study.

Table 7 Underestimation for atypical ductal hyperplasia.

Authors references	Year	Number of ADH		Number of carcinomas on surgery	Underestimation (%)
		Diagnosed	Operated		
Lehman [11]	2005	2	2	1	50
Orel [26]	2006	8	8	2	25
Perlet [27]	2006	17	17	5	29
Ghate [60]	2006	2	2	1	50
Liberman [94]	2007	15	13	5	39
Perretta [88]	2008	4	4	1	25
Mahonay [32]	2008	3	3	2	67
Malhaire [33]	2010	7	1	1	100
Crystal [34]	2011	7	6	3	50
Ferré [118]	2011	9	9	3	33
Oxner [95]	2012	15	15	2	13
Total		80	71	23	32

Table 8 Underestimation for ductal carcinoma *in situ*.

Authors references	Year	Number of DCIS		Number of infiltrating carcinomas on surgery	Understimation (%)
		Diagnosed	Operated		
Liberman [25]	2005	13	11	1	9
Lehman [11]	2005	4	4	1	25
Orel [26]	2006	17	17	4	24
Perlet [27]	2006	64	64	3	5
Lee [29]	2007	29	29	5	17
Han [23]	2008	15	10	1	10
Perretta [88]	2008	7	7	1	14
Tozaki [99]	2010	28	28	3	11
Malhaire [33]	2010	9	9	2	22
Oxner [95]	2012	25	25	0	0
Total		211	204	21	10

Table 9 Frequency of complete percutaneous excision of the malignant tissue.

Authors references	Year	No. of cases in which no residual tumour was found on revision surgery	
		Ductal carcinoma *in situ*	Infiltrating carcinoma
Lehman [11]	2005	—2/13 (15.4%)	
Liberman [25]	2005	2/11 (18.2%)	2/9 (22.2%)
Orel [19]	2006	4/17 (25.5%)	3/30 (10%)
Perlet [27]	2006	13/64 (20.3%)	6/74 (8.1%)
Lee [29]	2007	5/34 (14.7%)	
Peretta [88]	2008		2/8 (25%)
Han [23]	2008	0/18 (0%)	0/25 (0%)
Lee [105]	2008	—12/67 (18%)	
Hauth [31]	2008	—1/9 (11%)	
Malhaire [33]	2010	1/5 (20%)	4/17 (23.5%)
Ferré [118]	2011	—4/45 (8.9%)	
Thomassin [46]	2011	—0/19 (0%)	
An [63]	2013	—1/3 (33.3%)	
Total		—57/434 (13.1%)	

And Lee [105] reported that the complete excision rate increased if the lesion was under a centimeter in size (28 vs 9%) or if the CE completely disappeared (36 vs 9%).

Like stereotaxis [130] or ultrasound [131,132] no factors such as disappearance of the radiological finding, currently confirm that no residual tumor is present, although this could be useful in considering additional local treatments such as focused ultrasound.

Complications

The morbidity of MRI-guided vacuum-assisted biopsy is low and ranges from 0 to 6% [11,13,25—27,30,57,100]. This is a similar rate to stereotactic procedures and higher than for ultrasound-guided biopsies [121].

Complications (hematomas, malaise, skin damage) are generally minor [25,26,30].

Ten percent of procedures, however, have to be stopped because of adverse effects (heavy bleeding, malaise, hyperventilation, etc.) [46].

Bleeding requiring surgery only occurs in less than 1% of procedures [25—27,30,33,87].

Comparison with other MRI-guided procedures

Preoperative landmarking, aspirations and core biopsies are less aggressive procedures, which use more readily available and less expensive equipment.

Pre-operative localization, however, is the first stage of a surgical procedure, which is of debatable utility for a potentially benign lesion. Vacuum-assisted biopsy is therefore an attractive alternative [4,5,8,12,20,26]. Fine needle cytology aspiration often returns insufficient material for the diagnosis [96,128].

Core biopsies produced good results [10,82,104,133,134] although the needle has to be removed for each sample. It is reported to be faster than vacuum-assisted biopsies but inadequate for lesions under a centimeter in size [8,58,87,135].

The success rates for core- [10,30,77,80,82,83,134,136] and vacuum-assisted biopsies [11,25,26,62,78,98,103,137] are reported to be similar (> 93%) although vacuum-assisted biopsies are reported to have a better representivity rate [78] (Table 7).

The authors therefore recommend that unless unavailable or technically impossible, vacuum-assisted biopsy be used in preference [78,138,139].

Tariff and accessibility

MRI-guided vacuum-assisted biopsies do not currently have any specific code.

Only item QEHJ006 (= percutaneous mammary gland biopsy with remnographic guidance) exists. This is MRI-guided core biopsy and carries a tariff of 76.80 Euros to which the breast MRI tariff can be added. This is considerably less than the cost of the vacuum-assisted biopsy cannula and the MRI time required.

This applies even more to dual procedures as the examination time is increased and two cannulae are recommended [50].

In order not to lose out financially, some apply the stereotactic vacuum-assisted biopsy tariff (QEHH002: 511.68 Euros) or the tariff for a day hospital admission.

The reimbursement file was however submitted to the HAS in July 2009 and the technical assessment report was published in December 2011, although this procedure is still not included in the French Joint Classification for Medical Procedures.

The tariff for a vacuum-assisted biopsy in the USA and Australia is the same regardless of type of guiding used.

In addition, despite the recent approvals for MRI, in France the numbers of instruments available are still far below those in its European neighbours, particularly since MRI screening for at risk women has been introduced.

Access to interventional MRI is therefore still restricted and far less open than in other western countries, although the country is gradually equipping itself through technological advances (coils, biopsy systems etc.) and investments from the different parties involved. Only 43 procedures were recorded in 2006 and of the 200 French sites where breast MRI was being performed in 2009, 36 had an interventional breast coil and 14 were using it (survey by the Société française de radiologie — Société française de mastologie et d'imagerie du sein). At least 20 procedures were carried out per year in four centers and a maximum ten in the other centers.

The five main centers currently carry out an average of around fifty procedures annually.

According to the HAS, the target population is 100 to 700/year (this number was obtained from the annual activity of the 14 reference centers) [50].

Some recommend that all sites where breast MRI is performed also offer MRI-guided vacuum-assisted biopsies [47], although currently this appears unrealistic in France and the aim is rather that these sites collaborate with a neighboring center where the different MRI guided procedures are performed [50].

Conclusion

MRI-guided, vacuum-assisted biopsy has remained a confidential home-grown technique for years [7,89,92,140], reserved for some centers only as it is a time consuming examination with very limited indications and no specific tariff in France.

In addition, the lack of a radiological image to confirm that the samples were representative and the radio-histological correlation clearly raise technical difficulties.

Despite these various limitations, it is a major technique, which can optimize the information provided by breast MRI, an essential condition for it to develop [96].

Major technical advances (coils and software, etc.) have increased reproducibility in recent years. This is now a validated technique offering high levels of concordance and low underestimation rates, which is reserved mostly for specialist centers [50].

Tools such as spectroscopy and high fields may in the future increase the specificity of MRI allowing better selections of lesions to be biopsied and the detection of possible post-biopsy residual tumor.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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