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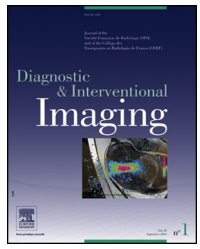

REVIEW / *Breast imaging*

Interventional radiology: The corner-stone of breast management

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KEYWORDS
Breast cancer;
Core needle biopsies;
Large core biopsies;
Preoperative marking;
Tumor destruction

Abstract There has been considerable progress in recent years in both diagnostic and interventional breast imaging. Percutaneous procedures improve multidisciplinary management and provide patients with better information. Biopsies allow precise and accurate diagnosis avoiding repeated examinations causing the patient anxiety and unnecessary surgical procedures. Preoperative marking guides surgery, thus limiting insufficient or excessive ablation. Tumors' destruction can sometimes replace surgery in older or frail women.

Introduction

The incidence of breast cancer is progressing at a regular rate in industrialized countries: it reached 53,000 new cases per year in France in 2011 and was the cause of 11,400 deaths [1]. It is the most common cancer in women and the primary cause of mortality between 40 and 55 years of age. Its prognosis is directly correlated with the stage of development at the time of diagnosis. Mammographic screening is thought to result in a 25% reduction in the risk of mortality due to breast cancer [2,3]. Extending it would help detect subclinical abnormalities, for which various percutaneous procedures controlled by imaging have been developed over the last 20 years to optimize therapeutic management.

Abbreviations: EUSOBI, EUropean SOciety of Breast Imaging; MRI, Magnetic Resonance Imaging; ADH, Atypical Ductal Hyperplasia; DCIS, Ductal Carcinoma In Situ; HAS, Haute Autorité de santé (French National Authority for Health); BI-RADS, Breast Imaging Reporting And Data System; ANAES, Agence Nationale d'Accréditation et d'Évaluation en Santé (French National Agency for Healthcare Accreditation and Evaluation); INCa, Institut National du Cancer (French National Cancer Institute); G, Gauge; LIN, Lobular In situ Neoplasia; ROLL, Radioguided Occult Lesion Localisation; SNOLL, Sentinel Node Occult Lesion Localisation.

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The interventional environment and prerequisites

Concerning all areas of medical imaging, interventional radiology has become essential in the diagnostic and therapeutic management of various organs. It requires specific initial training followed by regular practice. The equipment and actions can be mastered by learning on phantoms, without stress or danger for the patient. The European Society of Breast Imaging (EUSOBI) has published recommendations for interventional breast imaging [4]:

- training necessitates at least 20 procedures per type of guidance, with histological verification and checking by a specialist, before being able to work alone;
- to maintain a sufficient degree of competence subsequently, 25 procedures per year are considered to be necessary [4,5] http://www.ear.online.org.

In addition, for MRI procedures, regular practice in breast MRI is required, initial training of three MRI procedures then maintenance of the skill with 10 procedures per site and per year [6,7]. Depending on the degree of technical difficulty and risk, the French interventional radiology federation (Fédération de radiologie interventionnelle) has classified the various interventional procedures in three levels, from one (minor) to three (major). With the exception of tumor destruction (level 2) interventional breast procedures are considered to be 'minor' (level 1) and are carried out in an outpatient department in a simple medicalised environment (Fig. 1). The use of an interventional room and access to an anaesthetist or an operating theatre is not necessary. It is recommended that a defibrillator should be available if an electric current is used (large core en-bloc using radiofrequency or tumor destruction).

For biopsies and destruction there is a significant risk of bleeding, which means certain precautions must be taken: cyclooxygenase inhibiting antiaggregants (Aspirin®) and adenosine diphosphate receptor inhibitors (Plavix®, Ticlid®, Efient®) can be continued.

In the case of antivitamin K treatment, there should be prior consultation with a cardiologist or anaesthetist to discuss the possibility of using a low molecular weight heparin relay. Otherwise, a decision should be taken based on the international normalized ratio (INR, derived from the prothrombin concentration): the haemorrhagic risk is minor below two and major above three.

Management is best provided by specialists forming a multidisciplinary breast team [8].

Before any procedure, the entire file should be reviewed and validated by the radiologist responsible for performing it, who should:

- look for any anticoagulant treatment, allergy or seroconversion;
- check the indication and technique against a validated reference system, possibly during a consultation or a multidisciplinary consultative meeting (biopsies, ablation or tumor destruction) [9,10].

Simple, intelligible and honest information should be given to the patient concerning the procedure, its limitations and risks (article 35 of the French Code of Deontology, 1995). Her freely given informed consent must be obtained and noted in the file [9].

A written protocol which is systematically applied during the procedure will limit undesirable events. The check-list sets out all the points which must be verified:

- before the procedure: identity of the patient, validation of the procedure, topography of the lesion, compliance with contraindications, verification of the equipment, preliminary identification of vials;
- and after the procedure: traceability of the disposable material (Fig. 2), specimen identification and information forms, report of the irradiation delivered and any incidents, recording of the images, provision to the patient of an information sheet and an appointment for learning the results.

The patient and radiologist must be comfortably installed with the examination couch correctly adjusted to a height that avoids any fatigue or poor position and allows easy control of the field of intervention and the screen (Fig. 3).

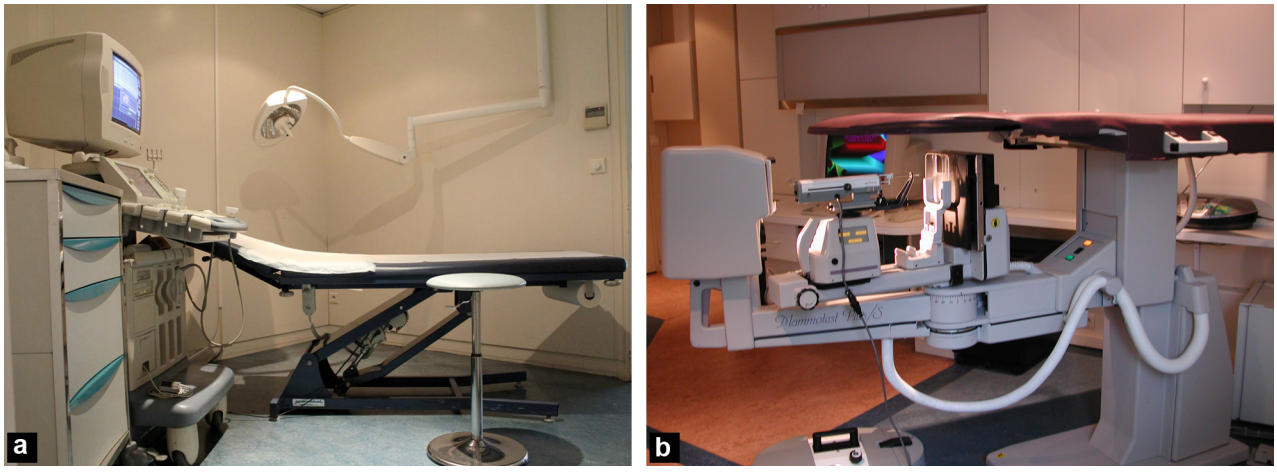

Figure 1. a: ultrasonography room not exclusively for interventional procedures but which allows them to be performed under good technical (height adjustable examination bed, strong, centered lighting) and aseptic conditions; b: room reserved for interventional breast procedures with its digital stereotactic table.

Figure 2. Label glued onto the bag of any disposable material stating its technical characteristics (length, caliber) and its traceability (brand, description, batch n°, expiry date).

Strict asepsis rules must be observed throughout the procedure, in particular for preoperative marking: disinfection chain, gloves and sterile material, waste elimination circuit (Figs. 3 and 4).

Local anaesthesia is often necessary depending on the type of procedure, sometimes combined with light premedication. There must be compliance with contraindications and cumulative doses of anaesthetic and any associated adrenaline. Where there is allergy to aminoglycosides, xylocaine can be replaced by articaine, and where there is an allergy to the preservative, xylocaine without adrenaline can be used. Anaesthesia must above all concern the skin and avoid masking the lesion.

Malaise and inopportune movements must be limited by providing a relaxed environment, continually talking to the patient, not displaying the instruments and working rapidly.

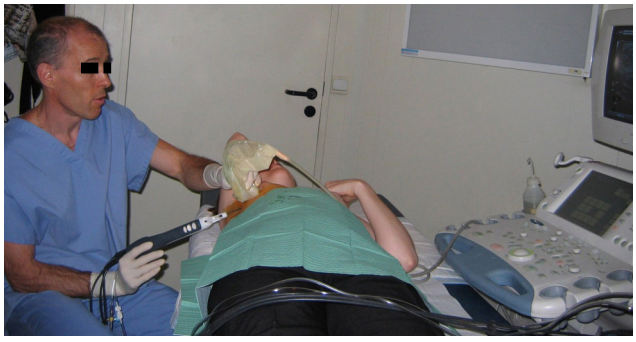

Figure 3. Installation for an ultrasound-guided vacuum biopsy. The radiologist is installed comfortably and can, without turning, control the ultrasound screen, the ultrasound probe, the biopsy needle and the patient.

At the end of the procedure, a dressing is applied and verbal and written instructions given to the patient concerning dealing with any complications and how she will be told the results [9].

The various guidance methods

Interventional breast procedures are guided by the clinical examination or imaging. For palpable lesions, clinical guidance may be sufficient but radiological control allows more precise targeting [11].

For subclinical lesions, radiological guidance is essential, and several different criteria affect the choice of type of imaging used: rapidity, cost, irradiation, better visualization of the abnormality, availability of the technique, the team's experience etc. The two main guidance methods used are mammography and ultrasound.

Mammography

Mammography provides optimal visualization of microcalcification clusters and clips. For preoperative locating examinations, guidance may be 'free-hand' (the skin entry point determined by distances from the nipple), with a grid with holes or a windowed compression paddle. The depth (z)

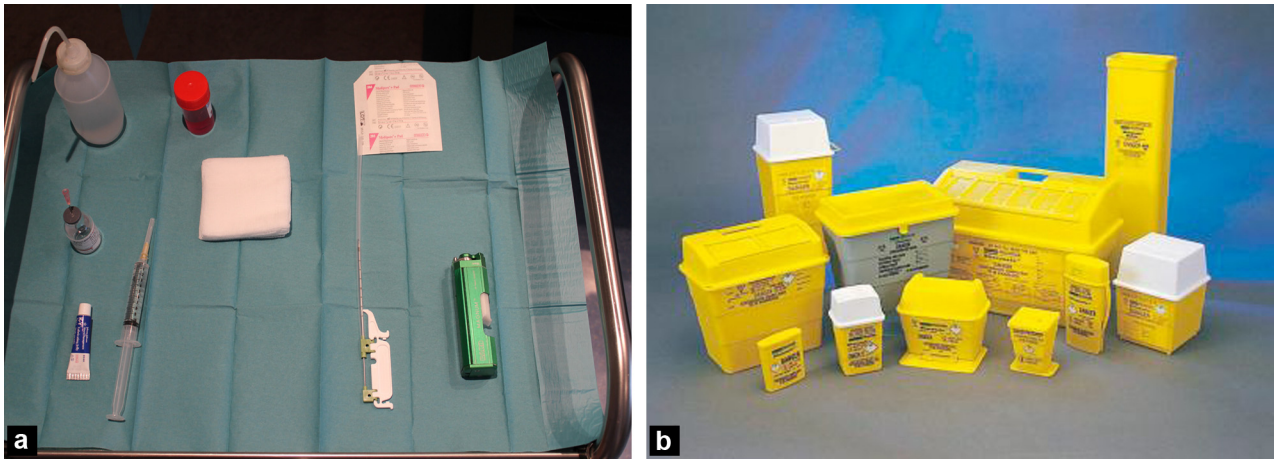

Figure 4. a: core biopsy tray; b: medical waste collectors of varying size and shape.

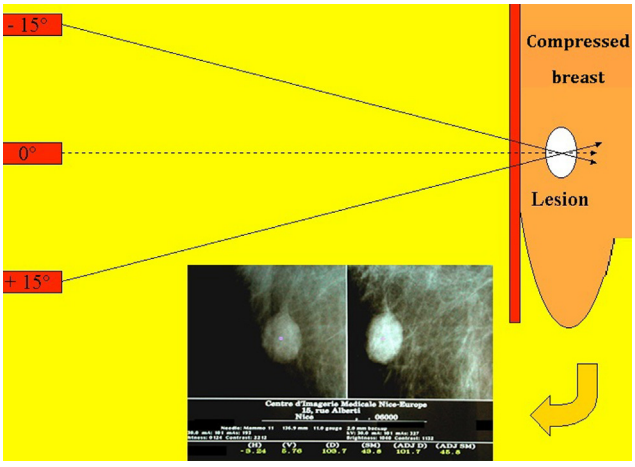

Figure 5. Stereotactic guidance: the opacity is accurately targeted using two of the three incidences (−15, 0 and +15°).

is then optimized, unlike with stereotactic guidance where the adjustment is made on images which are non-orthogonal to the needle and where there is an accordion effect during decompression of the breast.

For sampling where targeting must be precise in the frontal plane (x, y), stereotactic guidance is necessary (Fig. 5): it is performed on a stereotactically equipped mammogram machine or on a digital radiological table specifically for interventional breast procedures (Fig. 1b). Both are equipped with a specific computer program, which calculates the Cartesian or polar coordinates of the target from two or three images (generally at 0°, +15°, −15°).

Ultrasonography

This guidance method is particularly suitable for nodules and is preferred whenever possible. Ultrasonography is readily accessible, rapid, inexpensive, non-irradiating and performs very well due to the development of high frequency linear sensors and real-time control (Figs. 1a, 3, 6, 7).

As the ultrasound gel could alter the cells it should preferably be replaced by an antiseptic for fine needle biopsies with cytological smearing. The skin can be marked to show the position of the probe and the lesion, for anaesthesia purposes and for inserting the needle.

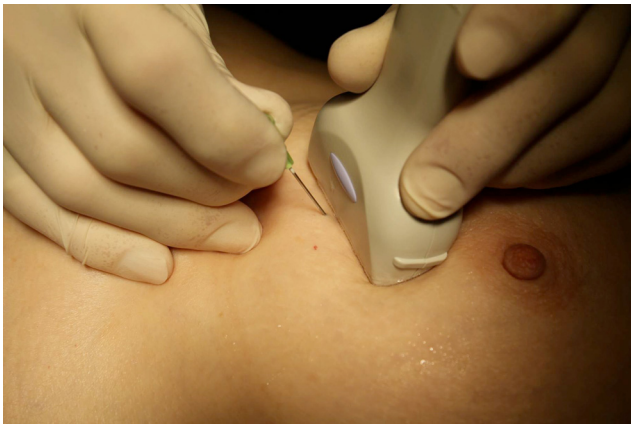

Figure 6. Ultrasound-guided fine needle capillary biopsy with a vertical approach.

Particularly during this initial phase, the position of the needle relative to the ultrasound probe should be checked visually rather than using the screen, because the area explored by the probe is narrow. There are two techniques for approaching the lesion:

- perpendicular: the needle crosses the skin perpendicular to the long axis of the probe and a few millimeters away from it (Fig. 6). As its path is vertical, only the extremity is visible as a very attenuating echogenic spot (tip echo). This technique can only be used for fine needle aspiration as there is a major risk of pneumothorax in the case of other biopsies;
- parallel: the needle approaches the skin parallel to the long axis of the probe and 10—20 mm from it (Fig. 7). It is visible throughout its course, which appears oblique or better still, horizontal. Correct positioning of the needle in the lesion is checked by turning the ultrasound probe through 90°.

MRI or CT

Slice imaging is only used for abnormalities (= contrast uptake) invisible in the mammogram and ultrasound image (20 to 80%).

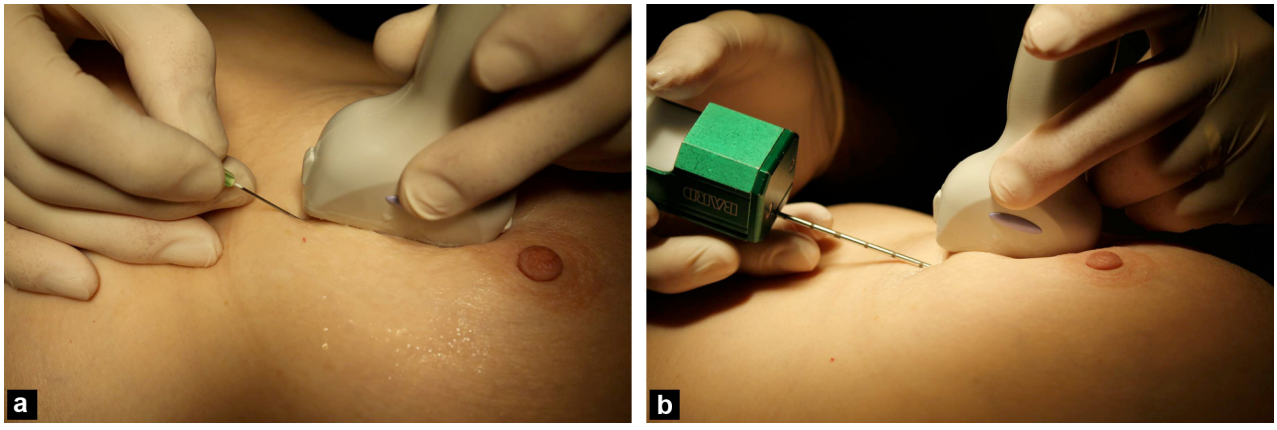

Figure 7. Ultrasound-guided collection of samples with an oblique approach. a: fine needle biopsy; b: core needle biopsy.

Performed using MRI, vacuum biopsy has proved to be more appropriate than markers and more effective than core biopsy, with a failure rate of less than 10% and underestimation of the lesion of less than 5% for ADH and less than 3% for ISDC.

Nevertheless, the level of diagnostic confidence is still lower than with other guidance methods because of the limited means of control. These procedures require specific non-magnetic equipment, real patient participation, and a decidedly longer examination time (Fig. 8). The indications are very limited and at present there is no specific rating, but the care management file submitted to the HAS in July 2009 is being evaluated [7].

These various aspects have put a brake on the development of this indispensable technique, but availability over the country is gradually increasing.

Installing the patients

The woman is seated or in a lateral decubitus position for add-on stereotactic guidance. She lies in the dorsal decubitus position for ultrasonic or CT procedures, and in ventral decubitus for procedures on the dedicated table or with MRI.

Samples

Indications

Percutaneous biopsies are recommended in the following situations:

- lesion which is probably benign (BI-RADS 3) in a breast cancer staging examination, where there are risk factors, or discordant images, monitoring difficulty or early pregnancy;
- systematically for suspect lesion (BI-RADS 4);
- for very suspect lesion (BI-RADS 5) with a strategic objective.

These international recommendations have been adopted by ANAES then taken up by INCa and by the medical imaging good practice guide [12—15].

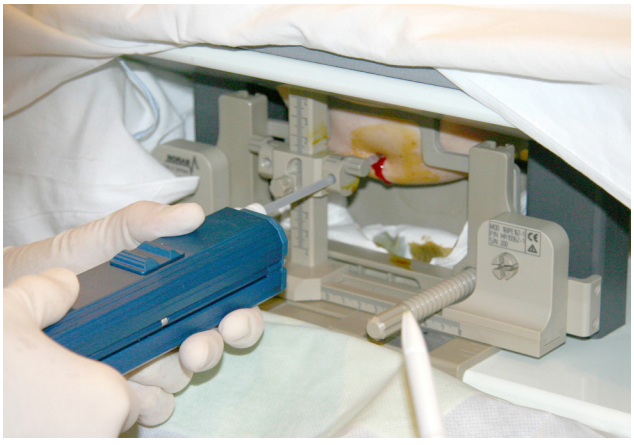

Figure 8. MRI-guided large core biopsy: the patient is installed prone with the breast held firmly in the open coil. The biopsy is performed via a strict profile lateral route.

What is the strategy?

Extemporaneous examination is not advised for microcalcification clusters and masses of less than 1 cm. It should not be requested for a percutaneous biopsy.

If two suspect lesions are more than 20 mm apart, both must be biopsied, and if a focus is extensive, it is sometimes necessary to biopsy two sites (depending on its location, the size of the breast and the caliber of the needle): this helps determine the extent of the surgical procedure (complete or partial mastectomy).

If a sample shows the lesion to be invasive, lymph node dissection will be performed.

If another sample shows lymph node involvement, a classic lymph node dissection of the first two Berg levels will be required; a sentinel procedure can no longer be envisaged.

Why biopsy a cancer seen by imaging (BI-RADS 5)?

The HAS recommends that any lesion suspected of being malignant should be confirmed histologically before any surgical procedure, with the objective of more than 70% of cancers, palpable or not, being diagnosed cytologically or histologically before surgery [4,8,16]. This is also to limit the number of unnecessary surgical procedures (a benign/malignant ratio of less than 1 and if possible less than 0.5) and the number of surgical procedures required (a successful 1st surgical ablation in at least 95% of cases) [4,8].

Obtaining a prior diagnosis of malignancy has several advantages:

- it officially confirms this diagnosis and informs the patient so that she can accept the therapeutic proposals more easily;
- it determines the initial surgical or medical treatment;
- surgery can be optimized (incision, volume of the ablation) and a single procedure performed (immediate reconstruction, removal of microcalcifications, implantation of a vascular access device);
- chemotherapy or neoadjuvant hormone therapy can be initiated;
- a protocol for detecting the sentinel lymph node or nodes can be set up;
- organizational limitations can be considered.

But this must not delay therapeutic management [16]. The time between the appointment and treatment should not exceed 1 month [13].

The different types of samples

Cytological samples: fine needle biopsy

Fine needle cytological biopsy is a very inexpensive and very rapid procedure that requires the whole team to be greatly experienced, in particular the pathologist, so as to limit the number of non-contributing samples [17,18] (Table 1). It is performed with a needle measuring less than 1 mm [18 to 27 Gauge (G)] alone (capillary technique) (Figs. 6, 7a) or attached to a syringe (aspiration technique).

The needle effects back and forth movements rotating about its own axis. The cells are detached then spread onto

Table 1 Performance of the various sampling methods.

	Ultrasound guidance (opacities)			Stereotactic guidance (microcalcifications)			Surgery
	Fine needle biopsy	Core biopsy	Vacuum biopsy	Core biopsy	Vacuum biopsy	One-pass en-bloc excision	
		14 G	11 G	14 G	11 G	2 cm	
Failures			0.1—2%		0—5%		0.5—22 (2.5) %
False-negatives	5—11	0—3.7%	0.1—1.4%	0.1—11%	0—6%		
Insufficient material	0—12			3%	2%		
Sensitivity	89—98	86—100 (97) %	94.5—97%	70—84%	90.5—97%		
Specificity	91—98	95—100%	98—100%	96—100%	98—100%		
Underestimation		33%	0—6.2%	20%			
Atypical ductal hyperplasia		0—100 (33) %	0—50 (17.9) %	18—100%	0—35 (19) %	0—20 (12)	
Ductal carcinoma in situ		16—55%	7—38 (23) %	16—44%	0—26 (12.5) %	0—21 (7.5) %	

Results as % (): mean %.

a slide (dried in the air or fixed with lacquer) or placed in fixing fluid (monolayer technique) (Fig. 9).

They are less numerous, but less affected, with the capillary technique. Cytology is particularly suitable for flow cytometry analysis (DNA ploidy and S phase) and hormonal receptors can also be measured if there are sufficient cells.

False-positive are sometimes encountered in florid mastopathies. Certain quality criteria are recommended [4]:

- no more than 10% of the fine needle biopsies should be inadequate for cancer, and if possible less than 5%;
- an adequate fine needle aspiration sample should contain at least five aggregates of epithelial cells, with at least five cells in each.

However, fine needle biopsy has two major limitations:

- it does not allow a distinction to be made between a carcinoma in situ and an invasive cancer;
- it is totally unsuitable for exploring microcalcifications.

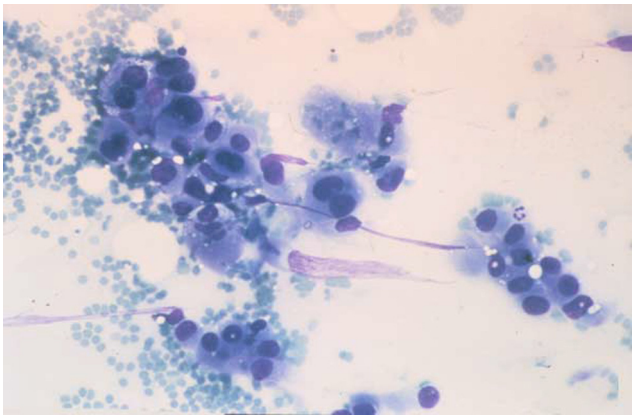

Figure 9. Rather abundant cell sample after fine needle breast biopsy.

Histological sampling: core biopsy

This involves taking tissue cylinders, the caliber and length of which vary depending on the instruments used (Fig. 10). Diagnostic performance is improved, particularly for microcalcification foci, by increasing the tissue volume taken, which is proportional to the number of samples and the caliber of the needle used [19—27].

Unlike a fine needle biopsy, a core biopsy requires a local anaesthetic and the result cannot be obtained immediately [28,29].

Tolerance is generally good or very good (> 95%) [30].

Samples must be handled as little as possible and with care. They are placed at best in separate cassettes, fixed (formol, AFA etc.) then included in paraffin at 60 °C. After cooling, compact blocks are available which may then be sectioned with a microtome. The sections are spread out, stained and studied at several different levels, providing all the information necessary for management of a tumor: its invasive character, differentiation, grade, hormonal receptors, immunological or genetic markers. False-positives are exceptional.

Core needle biopsy

Core biopsy first appeared in 1989 in the United States and has become the standard technique for diagnosis of mammary nodules. They are automatic guillotine type systems, propelling in a fraction of a second a sharp notched needle, immediately covered by a cutting cannula, which sections the tissue fragment and closes the biopsy chamber (Figs. 7b, 11). To recover the sample the needle is extracted from the breast each time. The equipment used is not very expensive and the examination lasts about 15 minutes.

Sensitivity increases with the cross-section of the needle (1.2 mm to 2.1 mm = 18 to 14 G) and the length of its course (10 to 22 mm): the rate of inadequate results falls from 19% to 3% on moving from a 16/18 G to 14 G, and

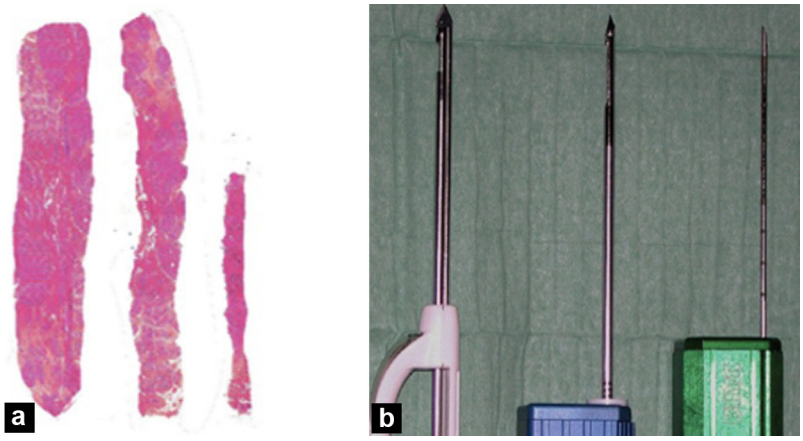

Figure 10. a: tissue samples 8, 10 and 14 G caliber (from L to R); b: 8, 10 and 14 G needles (from L to R).

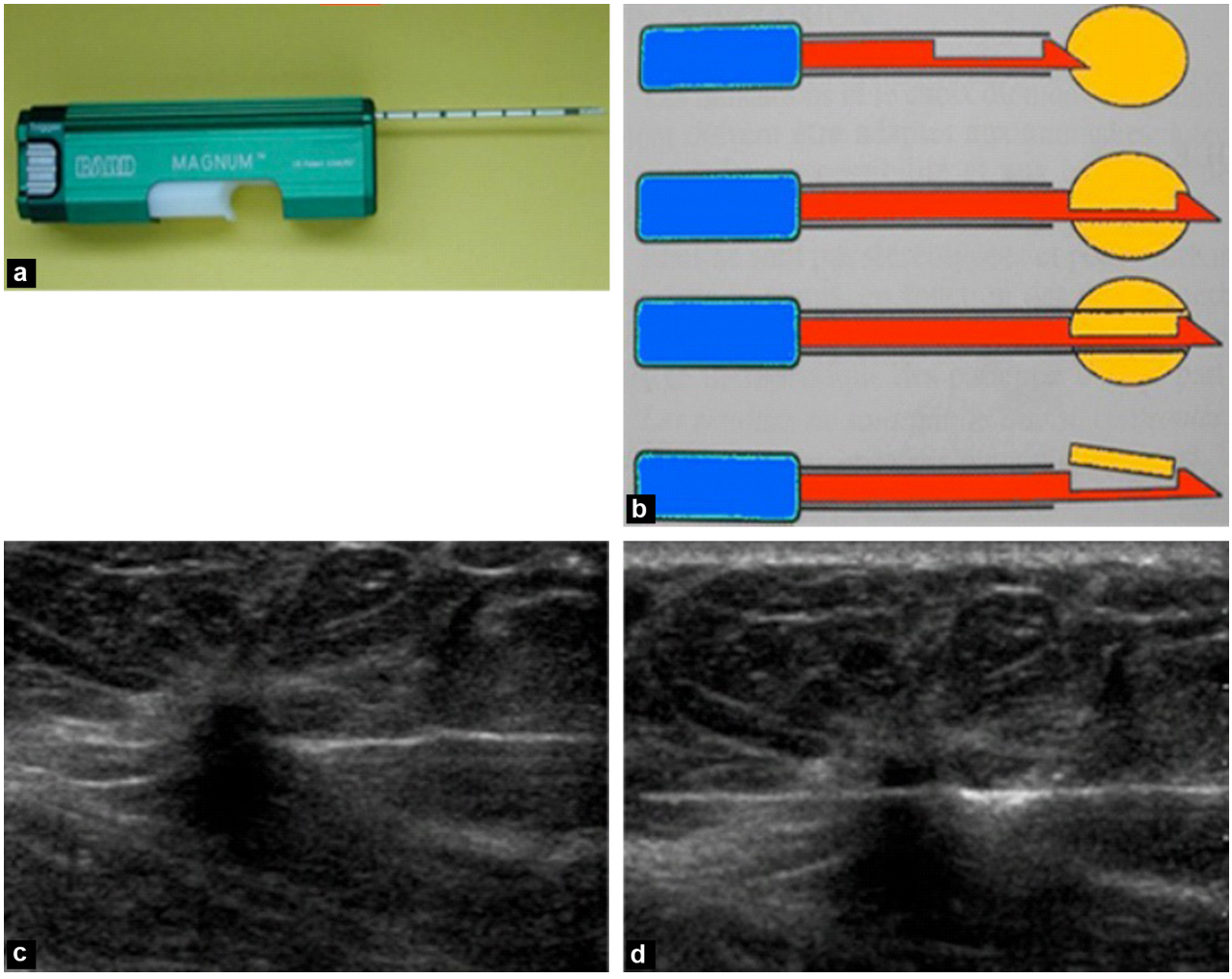

Figure 11. Core biopsy. a: non-disposable automatic gun; b: diagram of the various successive phases; c: the needle is placed in front of the very suspect deep nodule (BI-RADS 5) using ultrasound guidance; d: on firing, the needle transfixes the nodule while remaining parallel to the pectoral plane.

sensitivity increases from 84 to 99% (for opacities) and from 47 to 92% (for microcalcifications) on increasing from one to five cores (Table 1).

The recommendation is to obtain these samples with an automatic gun [11], 14 G needles and a length of course of 20 mm [4,31]. The number of samples necessary varies with the type of image but above all it is their representativeness, which counts. For a mass, some authors recommend at least five samples but for others two biopsy cores are adequate [19,32,33].

Be that as it may, sampling is systematically partial, which is a limitation for diagnosing complex lesions (border or DCIS).

Some authors combine cytology and histology in order to obtain an immediate diagnosis, which is confirmed later, the histology correcting the cytology's false-positives [34].

Large core biopsies

The caliber of the needles is larger and the samples are generally more numerous. Due to the larger volume of tissue taken, vacuum biopsies are the technique of choice for analyzing microcalcification clusters, architectural distortions and MRI procedures.

After incision of the skin, the cannula is inserted into the breast manually or by firing, when a vacuum assisted system is used. At the end of the procedure, it is best to apply a compressive dressing. There are three types of large core biopsies:

- biopsy without aspiration: a stylet crosses the lesion, then a helix (Spirotome®) or freezing (Cassi®) fixes the lesion onto this axis. The cutter sections a cylinder of tissue then the receiving needle is withdrawn from the breast so that the core can be recovered. The operation is repeated as often as necessary for the required number of samples. These two systems allowing limited but less costly sampling are not widely distributed in France, particularly not for the breast;
- vacuum assisted biopsy: this is the system most widely used, with needles ranging from 7 to 12 G. Vacuum aspiration pulls the mammary tissue into the biopsy window then the rotary cutter sections a cylinder of tissue. This rises through the interior of the needle due to aspiration and is recovered manually outside of the breast (Mammotome®), or stored in a receptacle to the rear of the device, which limits the number of manipulations required and shortens the length of the procedure (SenoRx®, Suros®) (Figs. 3, 8, 12—14). A series of samples is taken therefore with the device left in place in the breast. Each is 10 to 20 mm long, 2 to 3 mm in diameter, and weighs between 60 to 400 mg. By rotating the needle, contiguous samples can be obtained through 360°. The number of specimens is adapted to the size of the lesion

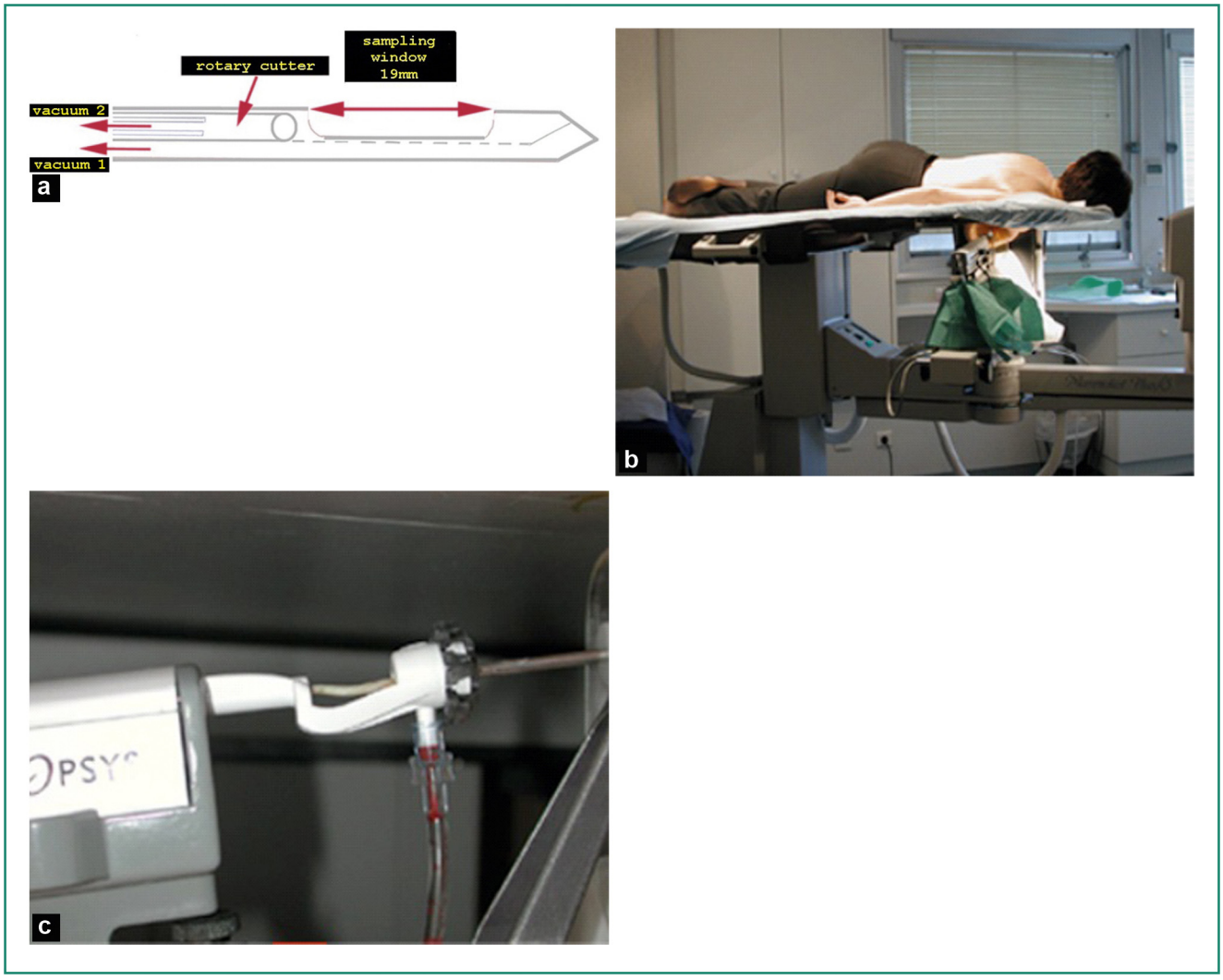

Figure 12. Vacuum-assisted biopsy. a: diagram of a probe with a double aspiration system; b: the patient is installed prone on the special stereotactic table; c: with the Mammotome®, the samples are collected one by one, manually, outside of the breast.

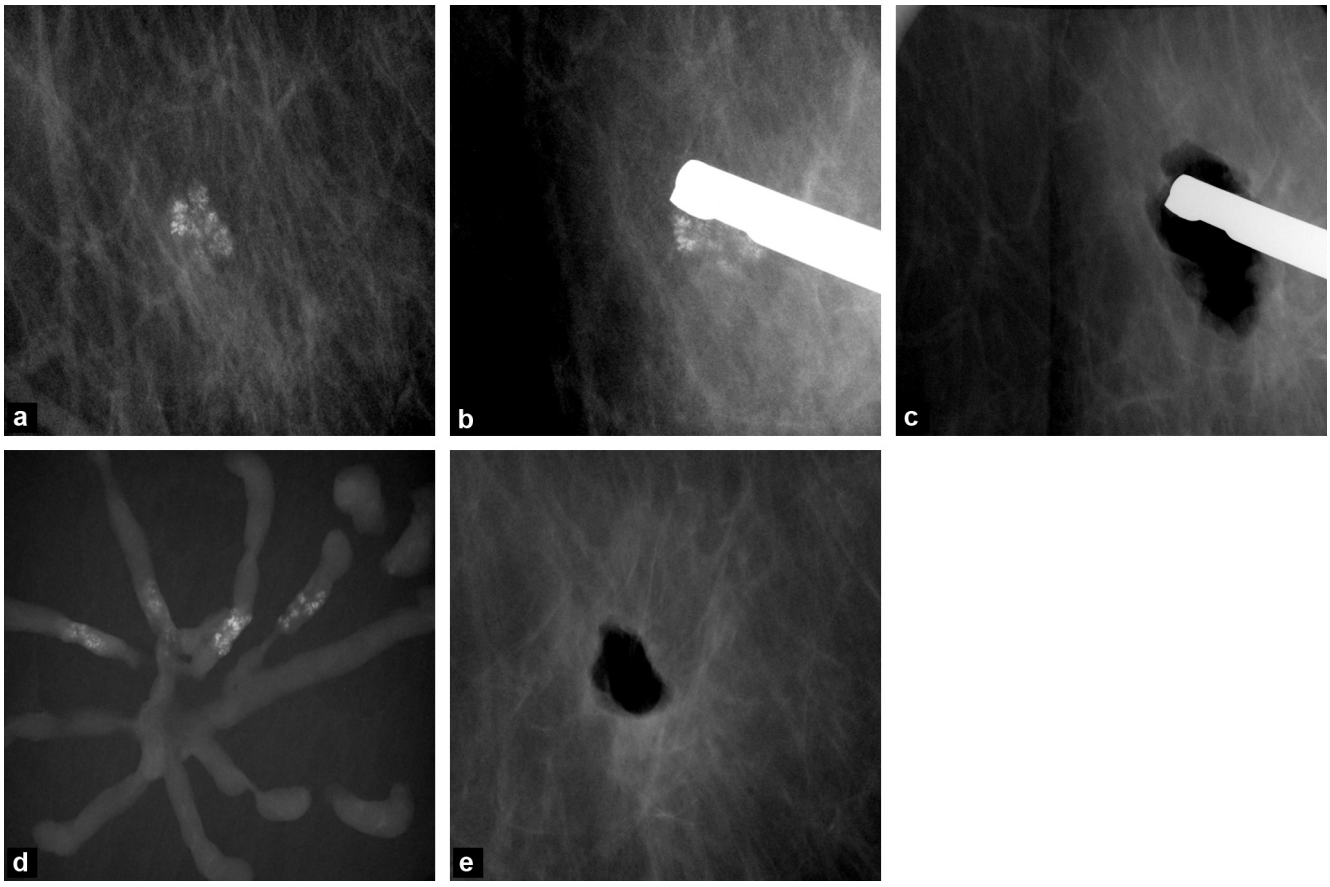

Figure 13. Stereotactic vacuum biopsy. a: sub-centimeter microcalcification cluster, indeterminate BI-RADS 4; b: the probe's sampling window is placed opposite the cluster; c: after taking a few centered samples, the cluster in no longer visible; d: microcalcifications are found on the radiograph of the specimens; e: after removing the probe, the cluster has disappeared, replaced by a gas-filled cavity.

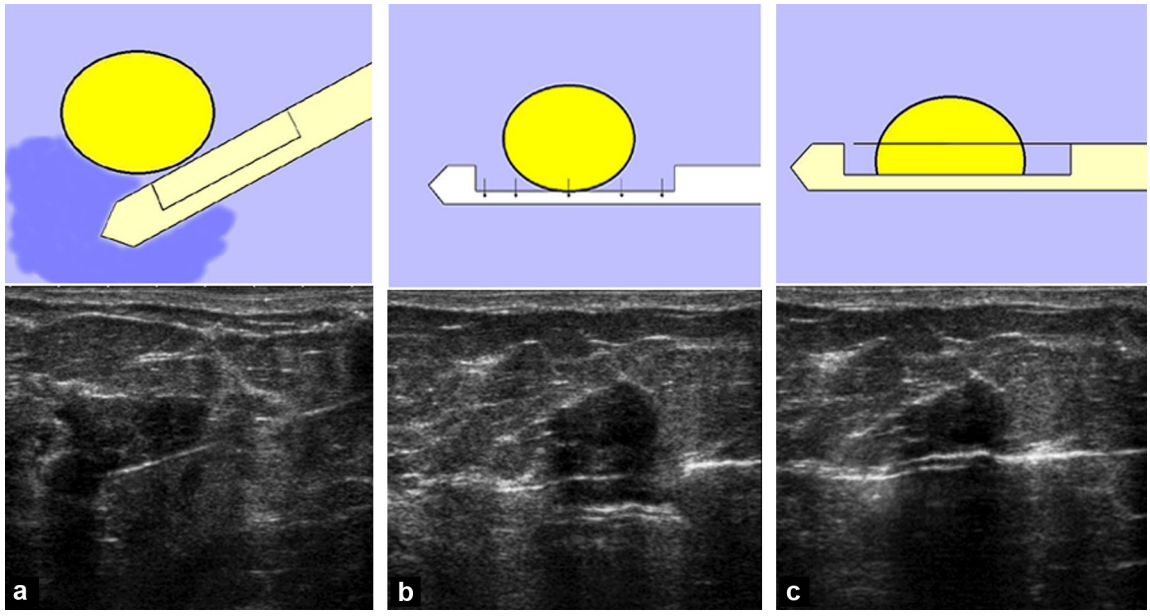

Figure 14. The various phases of an ultrasound-guided vacuum biopsy. a: diagram of insertion of the probe under the nodule. The probe is inserted with ultrasound guidance, along an oblique axis; b: diagram illustrating centering the biopsy window under the nodule. The probe is placed under the nodule with the sampling window opposite it; c: diagram showing the progress of the rotary cutter. The cutter has sampled the deep surface of the nodule.

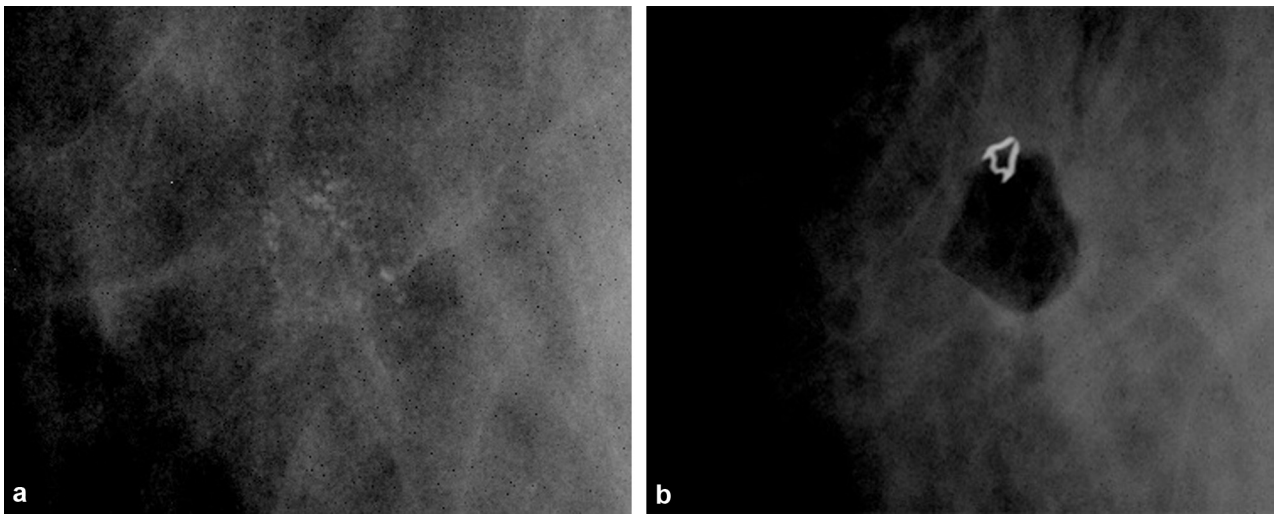

Figure 15. a: suspect cluster of amorphous microcalcifications (BI-RADS 4); b: after vacuum biopsy, the cluster is replaced by a small gas-filled cavity and a marker clip.

and the caliber used [9]. For an image measuring less than 1 cm (a mass or focus), the biopsy can be considered as representative if it explores at least 50% of the lesion and the ideal number of samples with a needle $\leq$ 10 G would be six [35]. On the other hand, with a needle $\geq$ 11 G, best performance would be obtained with 12 samples [35]. The whole procedure lasts about 30 minutes. If the abnormality shown on the radiological image has been completely ablated, a microclip is placed for possible later peroperative location (Figs. 15 and 16) [9]. ADH is underestimated by about 19% and DCIS by 12% (Table 1);

- BLES biopsy (Intact®): the wand (a probe) has a larger caliber and therefore necessitates a larger skin incision, of 10 mm as against 4 mm. At the end it has a capture basket consisting of five double metal supporting elements joined by a distal filament. Three basket sizes are available (12, 15 and 20 mm) so that a single sample of respectively 1.1, 2.1 and 3 grams can be collected. The end of the wand is placed in front of the radiological image. When the basket expands, radiofrequency passes through the filament, sectioning and coagulating the mammary tissue. After withdrawing the wand, the sample is recovered by cutting the metal supporting elements with pincers. Analysis of the single block of tissue obtained provides a better picture of the architecture and size of the lesion and of the clear ablation margins (Figs. 17 to 20). Coagulation artifacts may be observed at the edges of the sample, but they are usually less than a millimeter and do not interfere with histological interpretation.

On the other hand, the risk of burning related to the radiofrequency restricts the conditions under which it can be used:

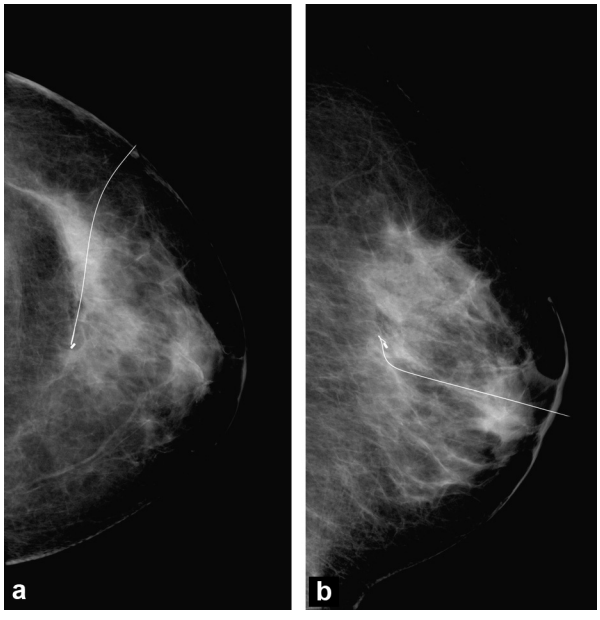

Figure 16. Preoperative marking after large core biopsy (DCIS). The end of the metal wire is correctly situated in contact with the clip on the two orthogonal mammographic images. a: frontal image; b: profile image.

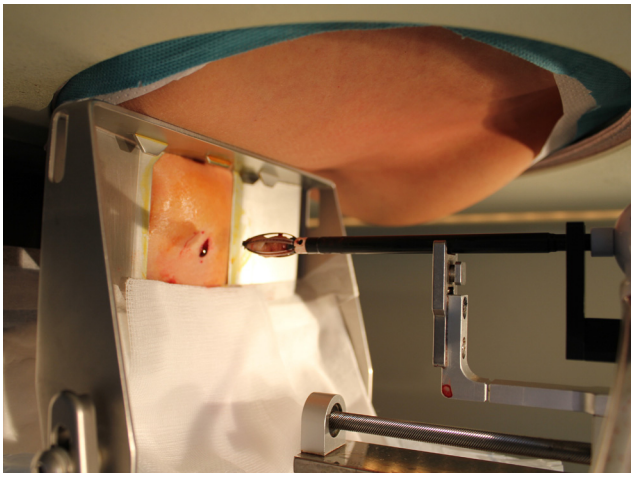

Figure 17. BLES biopsy using stereotactic guidance: the sample is in the 20 mm metal basket.

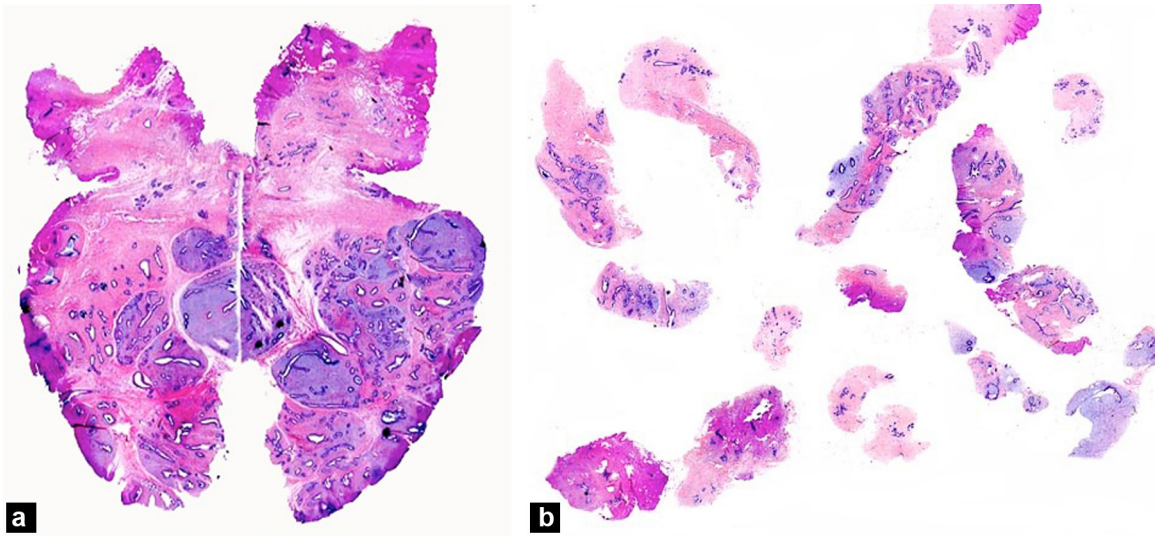

Figure 18. Large core biopsy samples for the same 17 mm sclerosed periductal fibroadenoma. a: BLES ablation (15 mm basket) is partial. The margins have been invaded by benian proliferation; b: the ablation was then completed using vacuum system.

- the breast must be sufficiently thick (at least 25 mm when compressed);
- the distance between the lesion and the skin or muscle must be at least 6 mm;
- use with MRI, the presence of mammary implants or a pacemaker is contraindicated.

Underestimation of ADH and DCIS is considered to be reduced compared with vacuum biopsies [36,37] (Table 1). Tumor ablation is considered complete with a clear margin of at least 1 mm in 75% of cases [38].

What should be done in practice?

If the radiological image is isolated, clearly visible and accessible, the standard technique for the abnormalities shown below should be the guidance methods as follows:

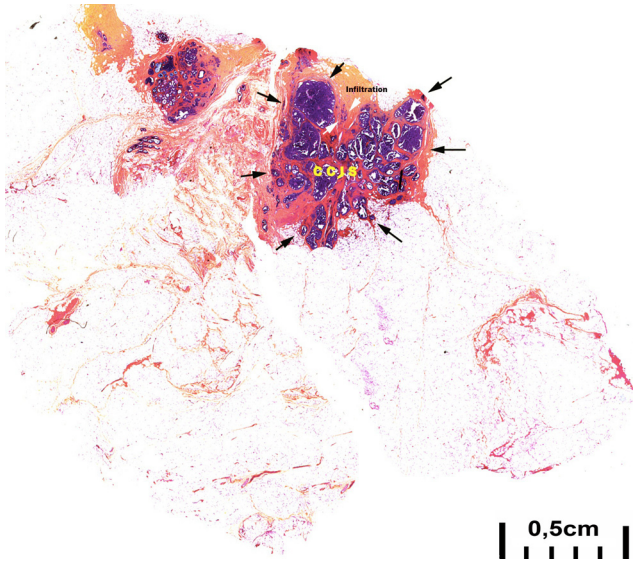

Figure 19. BLES biopsy sample (20 mm basket) for a suspect sub-centimeter opacity (BI-RADS 4), which was a microinvasive 8 mm intermediate grade DCIS invading the sample margins.

- for masses: ultrasound-guided core needle biopsy [39] (Fig. 11);
- for microcalcification foci or architectural disorganization [4]: stereotactic large core biopsy (Fig. 12);
- for large areas of microcalcifications associated with an ultrasound nodule: ultrasound-guided core biopsy;
- for cysts or lymphadenopathies (axillary, supra- or sub-clavicular): ultrasound-guided fine needle biopsy (Fig. 6).

Percutaneous ablation of a nodule by ultrasound-guided large core biopsy (Figs. 3, 14) can sometimes be discussed if a sample of it has previously been shown to be benign. The main indications are microbiopsies that are discordant or have contributed nothing, solitary papillomas with no atypia (Fig. 21) and secondarily, benign lymph nodes (if the patient desires ablation).

Control images

Whatever the guidance method, images are taken before, during (with the needle in situ) and at the end of the procedure [9].

For clustered microcalcifications, a radiograph of the biopsy samples is essential to confirm that they have been correctly sampled: the calcifications must be visible there and resemble the calcifications targeted [9,19,40].

In addition, two orthogonal mammography images should be taken immediately, or when the results are given to the patient, to assess the percentage of calcifications removed and/or to check the correct positioning of any clip [9].

Post-biopsy management

A radiology/histology/clinical comparison is essential to ensure that the samples are representative.

If the results are benign and concordant, it is advisable to resume monitoring appropriate to the patient's level of risk. MRI-guided biopsies are an exception because their degree of confidence is lower: a control MRI is recommended after 6 months [9].

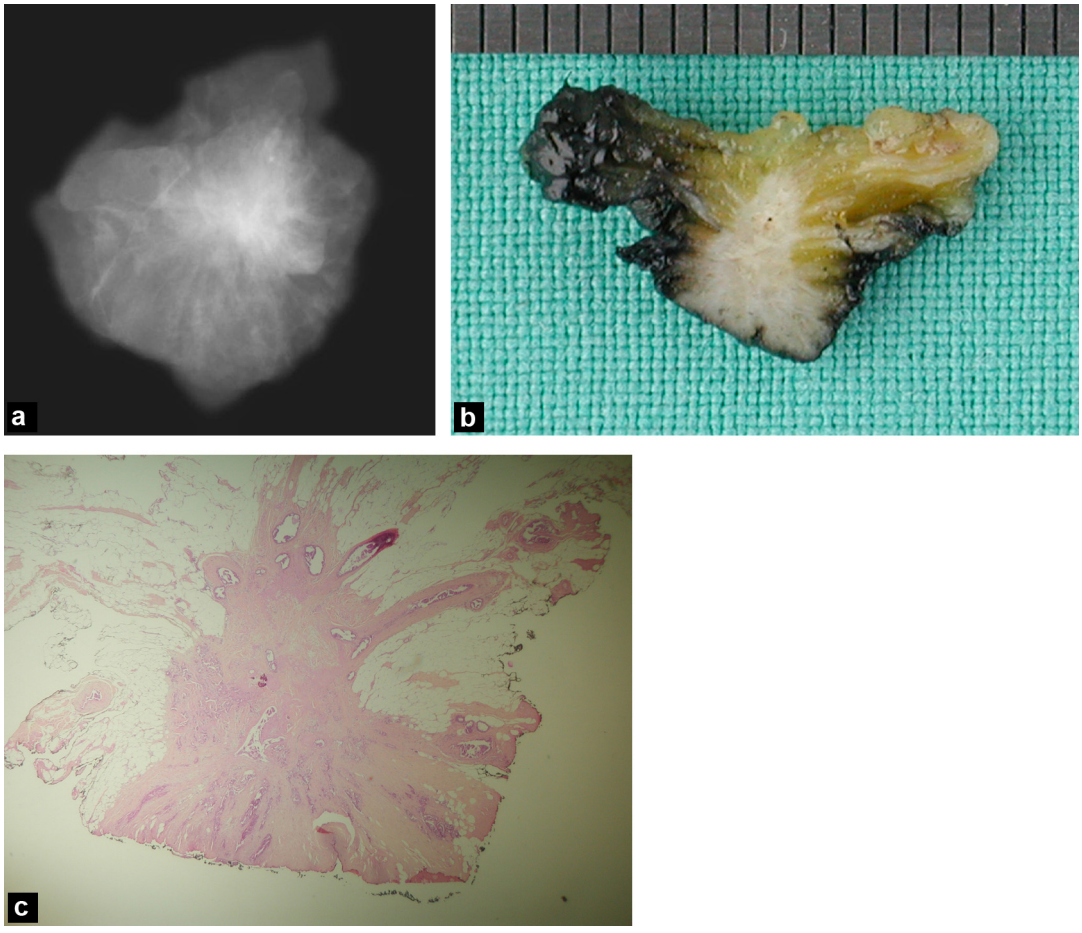

Figure 20. BLES sample with a 20 mm basket, for a convergence area which has been stable for more than 5 years; a: the radiograph shows a small well-centered spiculated opacity accompanied by a few microcalcifications; b: the macroscopic scirrhous appearance is concordant; c: on microscopic analyses, it was a 6 mm tubular infiltrating carcinoma. The margins of the sample had been invaded.

In the case of a border lesion, surgical revision is usually necessary, particularly in the following situations where the risk of underestimation exceeds 15% [41]:

- small tissue volume sampled (core needle biopsy or few samples taken);
- extensive radiological image (> 20 mm);
- incomplete disappearance of this image after biopsy;
- good agreement between the radiological image and the histological lesion;
- at-risk context;

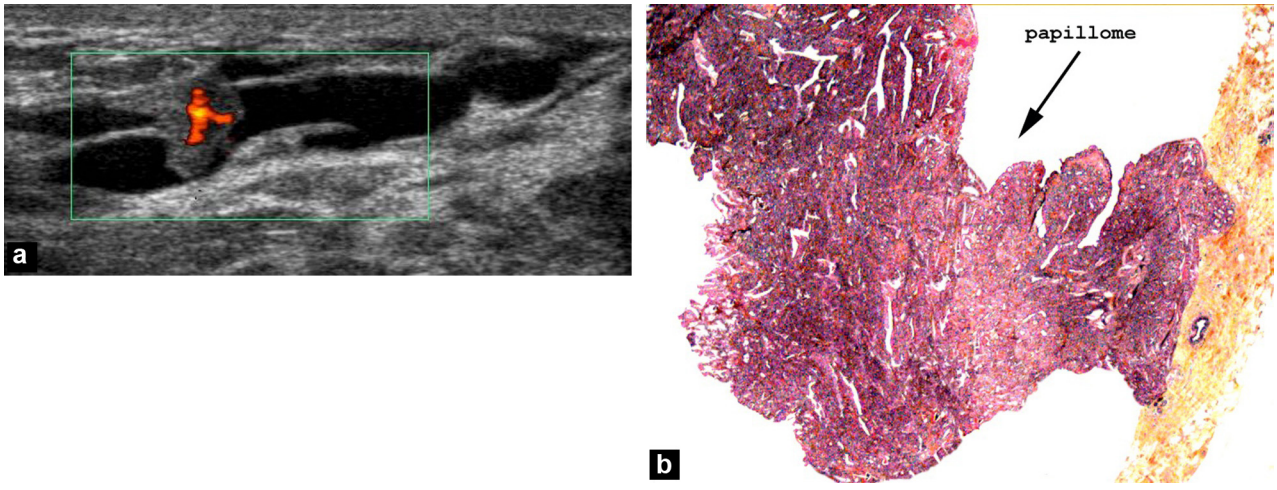

Figure 21. Uniporous, serous nipple discharge. a: ultrasound showed well delimited parietal burgeoning of a proximal lactiferous duct fed by a vascular pedicle; b: this intraductal proliferation was totally present on the 11 G vacuum-assisted biopsy, and was a dendritic papilloma without atypia. The base of the implantation was healthy. The discharge disappeared after this percutaneous procedure.

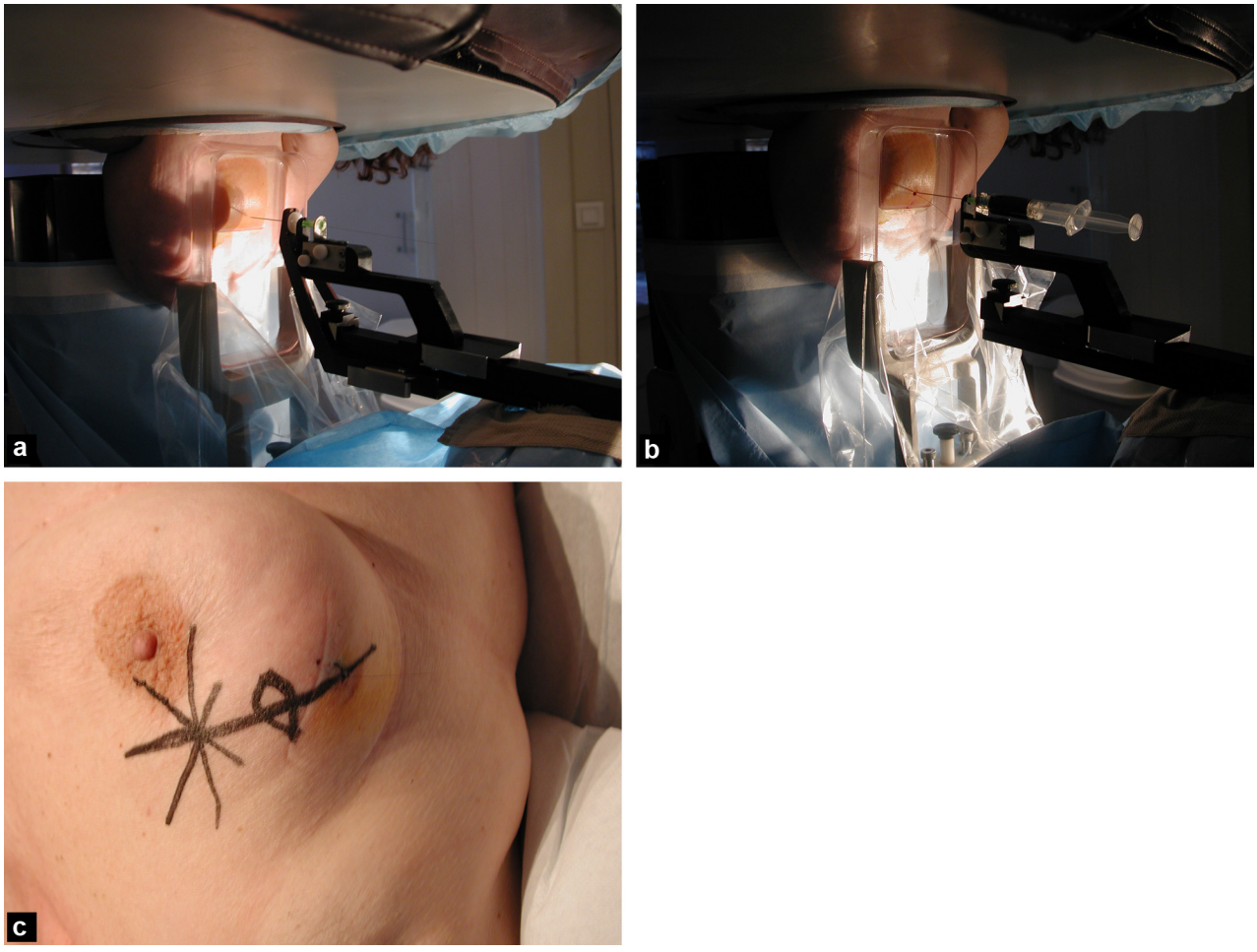

Figure 22. Stereotactic preoperative location on a table reserved for the purpose. a: insertion of a metal thread; b: injection of blue stain; c: skin marking in the surgical position.

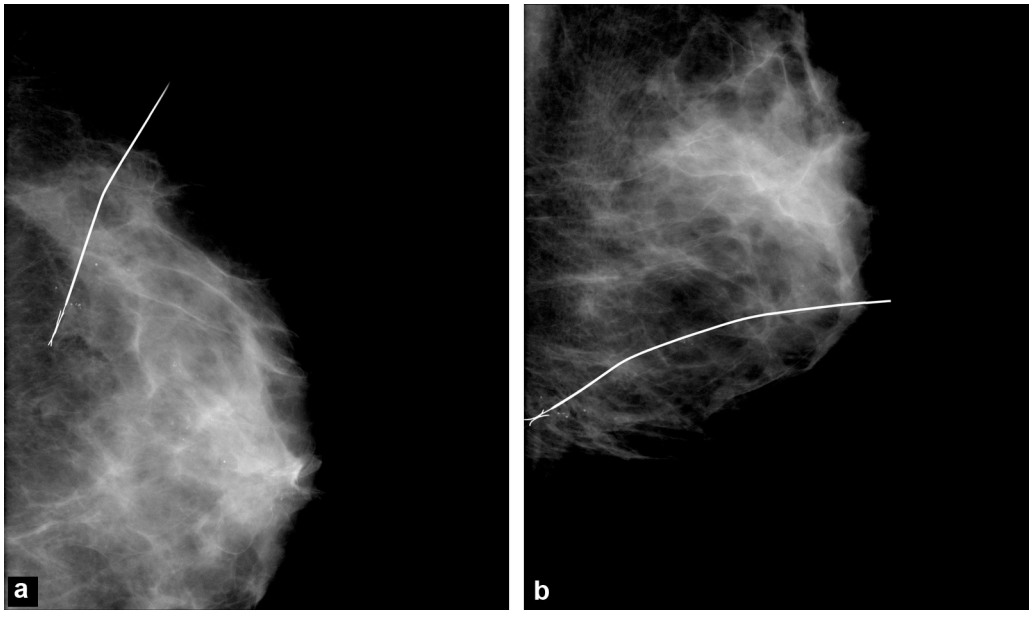

Figure 23. Preoperative marking: on the two orthogonal mammographic images, the wire (X) crosses the cluster and its end is situated a few mm beyond it; a: frontal image; b: profile image.

- severe lobular neoplasia: LIN 2 > 2 foci; pleomorphic LIN 3 or with necrosis or in a signet ring.

If these different criteria are absent, the risk of underestimation is lower (< 10%) and percutaneous ablation (Fig. 21) or close monitoring can be discussed [4,42].

Finally, for carcinomas, surgical revision is essential because tumor remains can persist, even if the radiological abnormality has completely disappeared [43—48].

If the histological result conflicts with the radiological image, another percutaneous biopsy or surgery is necessary: it can be performed with the same equipment if all the quality criteria were not observed initially, but if this is not the case a larger caliber sample must be obtained [4].

This biopsy will also be necessary if the lesion has not been sufficiently sampled.

Quality criteria and results

The rates of false negatives and underestimates must be evaluated and limited. The percentages recommended by EUSOBI are [4]:

- false negative for cancer on percutaneous biopsy: < 2% (acceptable < 5%);
- diagnosis of cancer in situ on biopsy, classified as invasive after surgery: < 5% (acceptable < 15%);
- diagnosis of border lesions on biopsy, classed as invasive cancer after surgery: < 10% (acceptable < 25%).

Percutaneous biopsies thus help limit the number of surgical procedures by increasing the positive predictive value of surgery (which was lower than 50% before the use of such biopsies) and lowering the number of revisions for insufficient margins [49—56].

Implanting markers

Various types of markers are implanted by the radiologist, as a guide for himself or for the surgeon. Three types of markers can be used and they are often used in combination.

Metal markers

The clip

A clip is implanted any time there is a risk that the radiological image will not be clearly visible in the future, i.e.:

- before or during neoadjuvant chemotherapy;
- after a biopsy in the following situations:
  - difficult and random targeting,
  - multiple samples taken from the same breast,
  - complete or subtotal ablation of the abnormality seen in the radiological image by large core biopsy (Figs. 13, 15),
  - image of less than 5 mm in the case of a core needle biopsy,
  - systematically after an MRI-guided biopsy.

The intramammary clip is a marker for the radiologist for later monitoring or for possible preoperative guidance (Figs. 15 and 16).

Preoperative marking is performed in the 24 hours before the procedure and enables accurate and reliable surgery.

The wire marker

This is a wire, which may or may not be repositionable, the extremity of which is bent (into a V, X, etc.) to limit its migration (Figs. 16, 22a, 23).

The term 'harpoon' needs to be replaced by synonyms, which are less worrying for the patient (wire, marker, pointer or metal guide).

Sometimes several markers are needed to delineate a large focus, being aware that tumorectomy will remove the block of tissue from the skin to the pectoral muscle, including the lesion. The lateral ablation margins need to be marked to indicate the superior, inferior, medial and lateral limits.

Certain quality criteria must be observed:

- the distance between the end of the marker and the lesion should not exceed 10 mm, in at least 80% of cases (Figs. 16, 23) [8];
- the failure rate must be less than 1% [57].

Otherwise, the marker is repositioned or replaced by another.

It must be longer than the lesion, even be too long, but falling short of it must be completely avoided. Using stereotaxy, 10 mm can be easily added to the z calculated by the program in order to anticipate the accordion effect.

Placing the end of a marker (particularly X markers) in the centre of a focus must be avoided, as the pathologist could damage the operative specimen when extracting it.

Injections

Intra or peritumoral injections are only possible for unifocal lesions. Only a very small quantity is injected (0.2 mL), possibly combined with an X-ray contrast agent to check the correct location on mammograms. Two types of products are used: stains and radioactive colloids.

Stains (blue, carbon) (**Fig. 22**b)

Patent blue may in exceptional cases cause anaphylactic shock, which should mean that its use is limited to establishments ready to provide emergency treatment of this type of complication [9]. The risk is considered lower with methylene blue, but the latter diffuses more rapidly.

There is no allergic risk with carbon (carbon black, India ink). It does not diffuse and is not resorbed. There can therefore be a long time between marking and surgery but if it is not totally removed at the time of surgery, a tattoo remains. This product is not authorized in certain countries such as the United States and there is no marketing authorization for this indication in France.

Radioactive colloids (ROLL or SNOLL technique)

The radioisotope cannot be taken outside the nuclear medicine department. It is injected by or under the responsibility of the nuclear medicine doctor. Scintigraphy images are made 30 to 120 minutes after injection. If the sentinel lymph node is not visible, a new injection is given intradermally in the periareolar region.

Skin marking

Performed in the surgical position (in dorsal decubitus, the homolateral arm abducted to 90°) it indicates the cutaneous projection of the lesion (Fig. 22c).

Orthogonal mammography images are taken [4,9]: they are optional in the case of colloid injection alone, recommended for lesions only visible with ultrasound and systematic in all other cases [9]. Some surgeons ask for these images to be made with radio-opaque marking of the nipple (metal bead) and/or of the skin entry point (possible with a wire).

The cutaneous point of entry of a wire is fixed on the skin; the wire is rolled onto itself and protected by a dressing. In no case must the wire adhere to the dressing to avoid its being pulled out in the operating theatre [9].

An oriented radiograph of the ablated tissue (Faxitron) is necessary for calcifications or clips and it is sometimes useful for masses. It should be interpreted whenever possible by a radiologist [9].

Tumor destruction

Tumor destruction techniques have been shown to be effective for the lungs, liver and bone. They are being evaluated for the breast and the results are very promising.

However, surgery remains the standard technique because the breast is a superficial organ. This limits the consequences of a surgical approach and the prognosis for small tumors operated is excellent. Moreover, percutaneous destruction is only possible if the thickness of the compressed breast is at least 30 mm: a safety margin of 10 mm between the lesion and the skin or the pectoral muscle avoids any burning. Prior percutaneous biopsy is necessary to be able to diagnose the indication for percutaneous destruction and allow suitable management.

Destruction is by heat (hyperthermia) or by cold (cryotherapy).

The main complication is cutaneous or parietal burning.

Hyperthermia

Above 60 °C, proteins coagulate, resulting in cell death. The temperature is stabilized at approximately 90 °C, not reaching 100 °C to avoid carbonization.

Several techniques are available: radiofrequency, microwaves, focused ultrasound, interstitial laser, electroporation, etc.

Radiofrequency is the oldest technique, the best known and the least expensive. Mainly performed with ultrasound guidance, it uses alternating current, which creates agitation and ionic friction thus raising the temperature.

The percentage of necrosis observed varies according to the size of the tumor: from 76% (diameter < 40 mm) [58] to 100% (< 20 mm) [59,60].

Cryotherapy

The temperature is lowered to −160 to −190 °C, creating an ice-cube at the end of the probe.

This technique has several advantages over hyperthermia:

- it is not adversely affected by the heterogeneity of breast tissue (gland + fat);
- it is not painful because cold acts as an anaesthetic, which means that the procedure can be performed under local anaesthesia;
- it is perfectly suitable for MRI because it does not perturb the magnetic field.

The report

The following will be described in the report:

- the lesion: size, appearance, BI-RADS classification;
- its site: clock radius, distance relative to nipple, depth;
- implantation and site of any marker (clip, wire) relative to the lesion;
- guidance method;
- approach;
- targeting quality, number of specimens, their radiological appearance and of the lesion after biopsy when sampling has occurred;
- any complications;
- any dose;
- references of the disposable equipment used (needle, wire, clip): brand, description, batch, date of expiry (Fig. 2).

The labels could be glued into a file kept by the establishment where the procedure was performed, thus providing double traceability [9].

Incidents and complications

It is essential to monitor patients to check the results and provide them with them, to detect any discordance, underestimation, failures and complications.

Recording the various data from the examination (the indication, technique, results and monitoring) allows you to evaluate your practices, correct drifting and errors, and thus improve the quality of patient management.

If a risk-carrying situation is encountered before, during or after the procedure, it can be declared voluntarily under the process for accreditation of doctors with risk-carrying activities. The modalities for this were laid down in two decrees in 2006 (nº 909 and 1559) and the HAS has been responsible for setting it up (www.has-sante.fr/accreditation-des-medecins) It aims at improving practice by declaring and analyzing certain risk-carrying events or situations encountered and by publishing recommendations.

However the complications encountered in interventional breast imaging are more often than not minor. Above all they involve bleeding which is reduced by simple compression. A haematoma, usually limited and well tolerated, is observed in less than 7% of breast biopsies.

Vagal malaise, sepsis, burns (tumor destruction), migration or malpositioning of markers is more rarely encountered, and sometimes failure.

Pneumothorax and surgical revision (bleeding, abscess) are exceptional.

Cells are sometimes displaced during these procedures, but they would not be viable. Indeed their frequency on ablated tissue decreases as the length of time from the procedure increases. This possible tumor seeding, in any case, would have no clinical consequences [61—65].

Conclusion

Despite the increase in incidence of breast cancer, mortality has declined since 2000 (—1.3% between 2000 and 2005) through earlier diagnosis and improvements in treatment [1]. Management is best provided by a multidisciplinary team composed of experienced specialized practitioners who regularly evaluate their practice and results. Interventional procedures contribute greatly to this structure by allowing histological diagnosis and accurate localization of subclinical breast lesions and providing better information to patients. This early management and reduction in the number of surgical procedures is helping to make savings in the cost of healthcare.

Disclosure of interest

The author declares that he has no conflicts of interest concerning this article.

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