Interventional Radiology

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13.1 Introduction

Modern diagnosis of breast disease is a multidisciplinary approach requiring breast professionals using up-to-date diagnostic and tissue sampling techniques. Triple assessment, i.e. clinical examination, imaging, and cytological/histological sampling, is still considered as gold standard. The widespread use of percutaneous breast biopsy techniques represents the most important practice-changing progress in breast radiology in the last decades. Today, the radiologist plays a fundamental role in the detection and assessment of breast disease. Interventional radiology is safe, accurate, and cost-effective. Image-guided minimally invasive interventional procedures have led to the replacement of the open excisional biopsy for most breast lesions requiring a histological diagnosis (Fig. 13.1). Guidelines and training programmes ensure that minimum standards are met for these techniques (ACR; EUSOMA). Audits of certified screening and certified breast centres review the outcome parameters of interventions to guarantee a standard of care. According to most national accreditation guidelines, in those cases without a definitive diagnosis, a multidisciplinary case conference is required. The following article respects modern guidelines, but cannot convey all different variations of each health system [1–7]. Therefore, the reader should adopt the following statements according to local standard guidelines.

13.2 Indications and Contraindications

Suspicious imaging findings or suspicious clinical signs or symptoms of breast cancer may warrant breast biopsy. Prior to any interventional diagnostic procedure, a complete imaging assessment is mandatory for palpable and non-palpable lesions. This includes mammography (Mx), ultrasound (US), as well as additional mammographic projections, spot magnification, or advanced ultrasound Doppler and elastographic techniques. Today, tomosynthesis can be used as an alternative technique to spot magnification. The aims of these techniques are:

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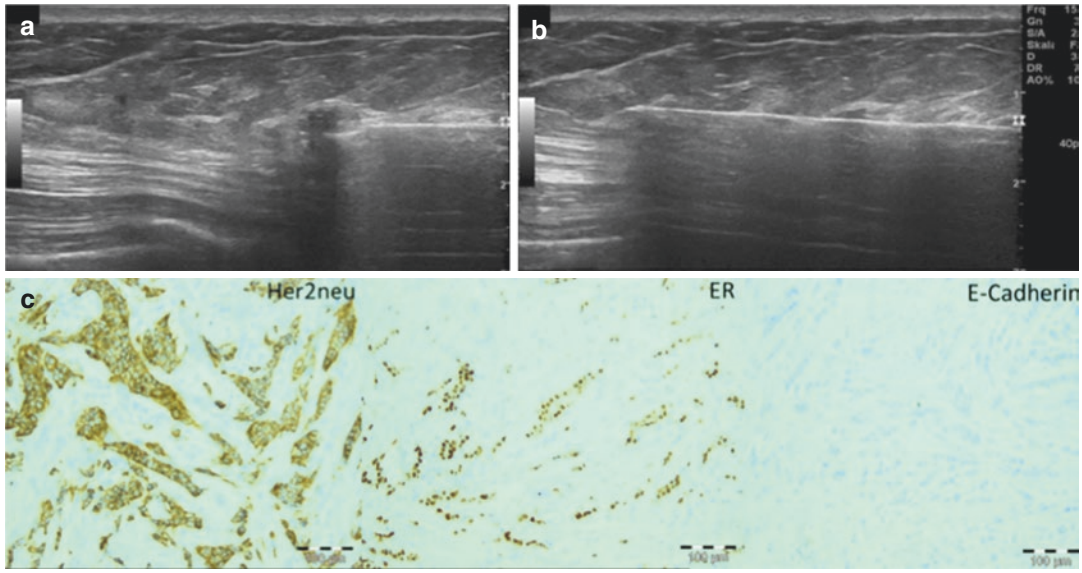

Fig. 13.1 (**a**) Ultrasound-guided core needle biopsy of a monofocal lesion. (**b**) Histology showing positive Her2-neu staining, positive oestrogen receptors staining, and negative E-cadherin staining compatible with lobular invasive cancer. Typical Indian file pattern

- To exclude a pseudolesion that simulates a mass, an architectural distortion, or asymmetry by superposition of breast tissue at mammography or fat lobules at ultrasound, as pseudo findings do not need to be biopsied.
- To identify scattered distribution of calcification that simulates a grouped, segmental, or regional distribution of calcifications.

The role of magnetic resonance imaging (MRI) focuses on the preoperative assessment of patients with a high risk of multifocal, contralateral, or residual disease high risk. This includes patients with known or suspected mutations, aggressive molecular subtypes (luminal B and HER 2 positive), and lobular cancer. Further, a difficult tissue background in heterogeneously and extremely dense breast and associated strong tissue heterogeneity, scarring, or fibrocystic changes at US may require supplemental MRI [5–8].

Modern diagnostic standard requires addressing the final BI-RADS® assessment categories for all findings in mammography, ultrasound, or MRI according to the ACR BI-RADS® Atlas or an analogue system such as presented in the European Guidelines. Each BI-RADS® assessment category defines the further management strategy. Short-interval (6 months) follow-up or continued surveillance is suggested in BI-RADS® 3 (probably benign; ≤2% likelihood of malignancy) and tissue diagnosis in almost all other lesions of BI-RADS® 4 (suspicious; >2 but <95 likelihood of malignancy) or BI-RADS 5® (highly suggestive of malignancy; ≥95% likelihood of malignancy). The latest update of BI-RADS® Atlas suggests minimal invasive procedures also in probably benign or benign lesions such as needle aspiration of symptomatic cysts, drainage of abscess, or core needle biopsy in anxious patients (Fig. 13.2). BI-RADS® 1 and 2 do not demand any further intervention [9, 10]. Today, all surgical options and oncologic decisions depend on tumour biology [11]. Almost all information can be obtained by evaluation of core needle or vacuum-assisted biopsy specimens. Tissue or cell sampling of suspicious axillary lymph nodes received by core needle biopsy or fine-needle aspiration (FNA) contributes to the axillary staging and tailored oncologic decisions in neoadjuvant therapy. Neoadjuvant strategies

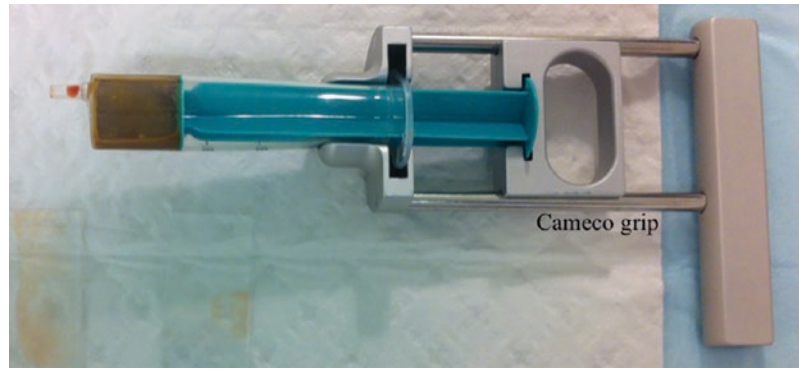

Fig. 13.2 Purulent aspirate in a syringe fixed by a Cameco grip following puncture of a breast abscess

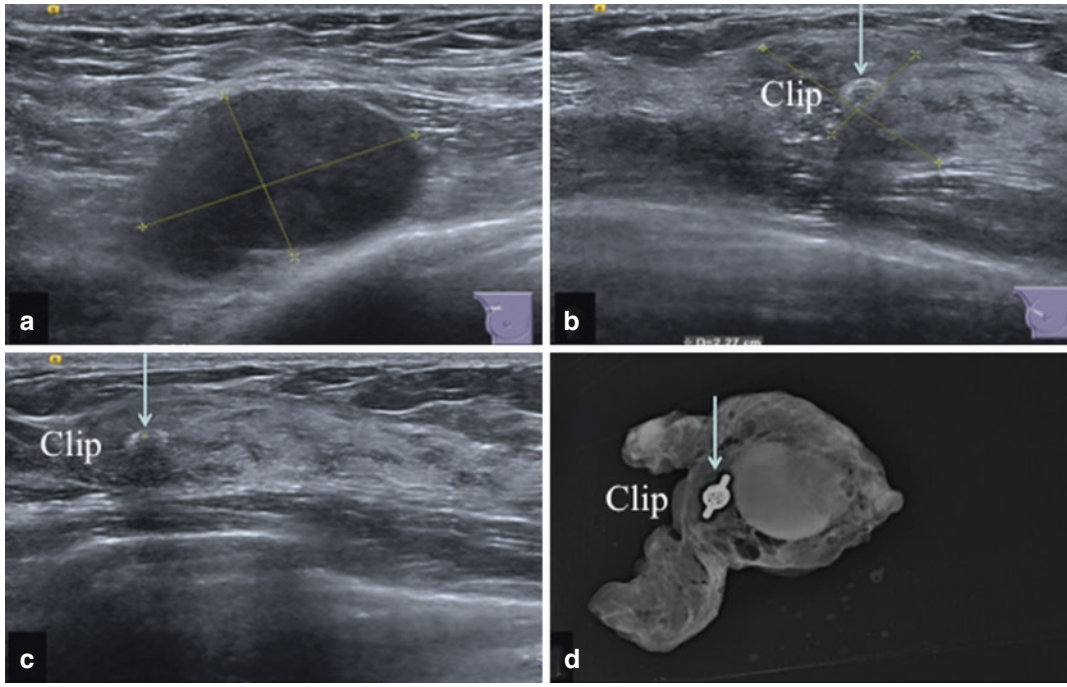

Fig. 13.3 Lymph node metastasis. (**a**) US before neoadjuvant therapy (NAT). (**b**) US after hyperechoic transformation under NAT and clipping. (**c**) US before excision after NAT. (**d**) Radiography of axillary specimen including clip

would not have been possible without interventional techniques (Fig. 13.3). Preoperative information of all relevant staging parameters has optimized tailored approaches to a modern oncologic and oncoplastic therapy. The histological findings have to be addressed to one of the five subgroups of the cytological or histological bore classification. The key decision for preoperative planning is whether or not breast conservative surgery can be performed. Frozen sections have been widely replaced by image-guided minimally invasive preoperative tissue sampling and are rarely used for sentinel procedures. The resulting reduction of surgery time is of economic relevance. Multiple lesions of the same side or contralateral lesions should demand for image-guided tissue sampling in order to clarify the surgical procedure prior to informed consent. Reasonable targets amongst multiple lesions are the lesion that shows the greatest distance to the primary tumour and the lesion that looks most suspicious having an impact on a larger resection volume [12–19].

13.3 Pre-Interventional Planning

13.3.1 Selection of Patients

The selection of patients to percutaneous biopsy procedures is limited by anatomic characteristics that comprise the possibility to remain without motion in the prone position for stereotactic biopsy based on spine problems, neurologic disease, or severe coughing. Obese patients might not tolerate MR biopsy. Patients with severe bleeding diathesis or those taking dual or triple platelet aggregation inhibitors, or anticoagulation therapy, should not be examined by vacuum-assisted biopsy. Change on heparins is recommended for VAB in such conditions. If anticoagulation therapy cannot be stopped due to cardiovascular or other severe reasons, small core needles <14 Gauge and prolonged compression are recommended (Fig. 13.4.). Antibiotic therapy is usually not required in patients with prosthetic valves or joint replacements [16–18].

13.3.2 Patient Information and Legal Informed Consent

Patients need to be informed about the intention and techniques of the procedure by the physician. National legislation defines the mode of consent, which is in writing or orally with additional documentation in the patient record. Additional written information is recommended and should balance the advantages and disadvantages of the procedure and illustrate with drawings the practical procedure, risks, complications, false-negative and false-positive results, as well as possible alternatives. The appropriate time for informing the patient may equal some minutes before the procedure in a cyst aspiration or core biopsy and in some opinions more than 24 h for VAB. Every percutaneous puncture resembles body injury by law in many countries. Informed patient consent offers the lawful justification for carrying out an interventional procedure. Therefore, a copy of all signed documents should be handed out to the patient and be stored in the patient's record. Written notices by the physician may testify or even increase the documentary evidence of trustworthy consent, particularly that the patient understood the content of the information and has used the opportunity to ask questions. Any pressure from any person on the patient would undermine the consent process. Formal written consent is compulsory for clients or patients participating in clinical research study. The institutional committee for ethics in research wants or demands to approve the written patient information and consent form in advance [20–22].

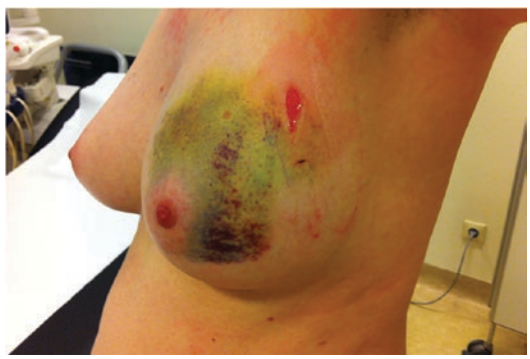

Fig. 13.4 Extended haematoma and erosions due to plaster reaction after VAB

13.3.3 Patient Preparation and Observation

Nearly all breast interventions can be performed on an outpatient basis. Blood tests including coagulation status plus questioning about medication are mandatory if the patient history points to bleeding disorders. The patient should experience an atmosphere of calmness, competence, and trust spread by the interventional physician and assistance working in a professional setting. Written protocol instructions for the interventional procedure increase patient safety and secure a more uniform procedure. Checklists may ensure that the patient is completely prepared and all equipment is present. The transport of the patient by another person back home should be organized in advance to avoid potential accidents due to an altered state of mind. Application of local anaesthetics under imaging

guidance is strongly recommended in all percutaneous procedures. A variety of anaesthetics from the classes of aminoamide and aminoester can be applied locally with comparable success (Fig. 13.5). Only ropivacaine and mepivacaine induce weak vasoconstriction and show a prolonged duration of anaesthesia without additional vasoconstrictors (e.g. epinephrine). Sedation should be limited to very anxious patients or if strict immobilization cannot be achieved otherwise, for example, in MRI intervention. Heart frequency, blood pressure, and oxygen blood saturation need to be controlled in strong procedural sedation that may be necessary in special situations. Administration of drugs for sedation needs knowledge and experience according to national legal regulations. Use of propofol results in a faster recovery of patients compared to midazolam. Any potential retrograde amnesia has to be mentioned before the procedure. Blood tests including coagulation status plus enquiring about medication are mandatory if the patient reports a history of bleeding problems. For most percutaneous breast procedures, the risk is low for contamination if the procedure is performed under sterile or semi-sterile conditions. These conditions comprise hand disinfection and personal protective equipment and coverings. For minor invasive procedures that are not associated with an increased risk of infection, a hygienic hand wash, wearing of protective clothing, or disposable gown and sterile gloves are adequate. Further precaution includes local skin disinfection, sterile ultrasound gel, and use of disposable transducer covers whenever in contact to the sterile hollow or biopsy needle. Generally, disposable, single-use items should be preferred in comparison to cleaning and disinfection of biopsy guns followed by sterilization. All steps require detailed standard operating instructions. Postinterventional observation is usually not needed after minimal invasive procedures such as cyst aspiration or core needle biopsy or VAB (Table 13.1). Clinical observation should be extended in individual cases with higher risk for complications, and hospitalization is recommended in very rare cases of severe local or systemic post-procedural complications [1–7].

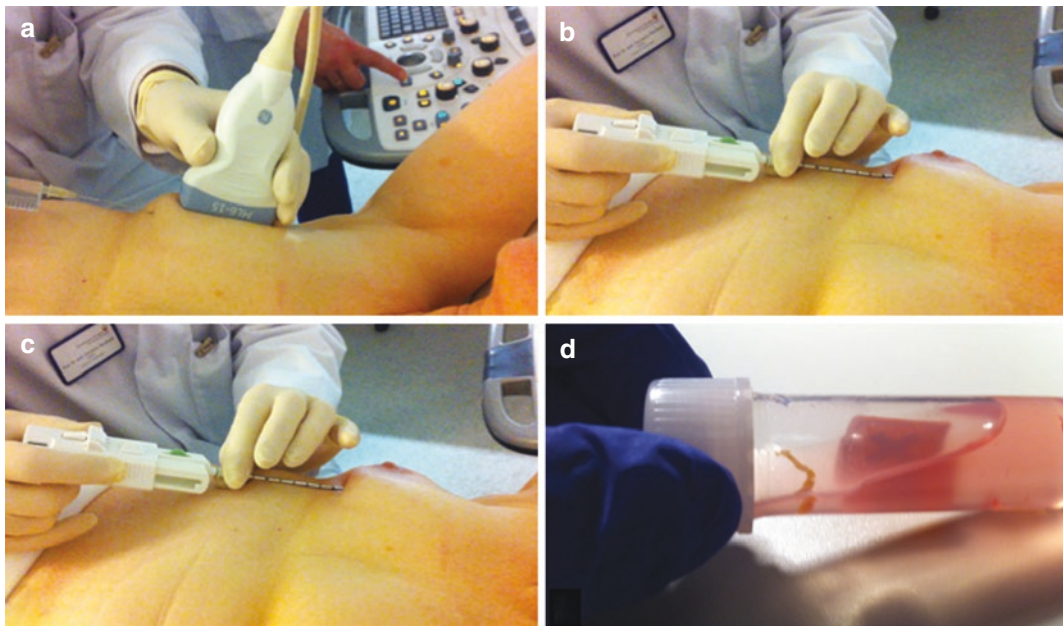

Fig. 13.5 Ultrasound-guided core needle biopsy. (**a**) Local anaesthesia with parallel alignment of the needle to transducer plane. (**b**) Advancing of the outer coaxial needle. (**c**) Advancing, firing, and retraction of the biopsy needle. (**d**) Specimen in formalin

13.4 Image-Guided Interventional Techniques

13.4.1 Guiding Techniques

The central technique of image-guided puncturing in ultrasound and MRI is the synchronized alignment of two planes, namely, the "scan plane" that shows the target lesion on the screen and the "needle plane" of the puncturing tool. The principle of the stereotactic two-dimensional approach is the calculation of a target point on angulated mammographic images and direct forwarding of the needle within the calculated track directly to the target. Digital breast tomosynthesis defines the depth of the lesion by selection of the three-dimensional index plane that visualizes the target structure most sharply. A pre-shot image and following the biopsy of a post-shot image are the documents proving that the lesion was hit accurately. Also any dropped clip has to be depicted and correlated to the previous biopsy site to exclude clip dislocation. The positioning of the patient depends on the modality the location of the lesion within the breast. The key principles for all modalities include adequate patient selection, appropriate technique, pre-procedure preparation and post-procedure patient care, and imaging-pathology correlation (Figs. 13.5, 13.6, and 13.7) [15, 23, 24].

Table 13.1 Comparison of minimal invasive methods

	FNA	Core biopsy	VAB
Invasiveness	+	+	++
Complications	–	+	+
Representative	+	++	++
Diagn. performance	++	+++	+++
Costs	+	+	++
Purchase price €	160	720	35,000
Material/examin. €	1	25	285

13.4.1.1 Ultrasound

Real-time ultrasound allows the visualization of the whole needle from the tip to the proximal end at the screen. Forwarding the needle optimally parallel or slightly angulated up to 30° within the transducer plane is essential for a perfect control of the needle while steering it through the breast tissue towards the target lesion (Fig. 13.8). Any transversal rotation between the screen plane and the needle plane will result in a shortening of the needle depic-

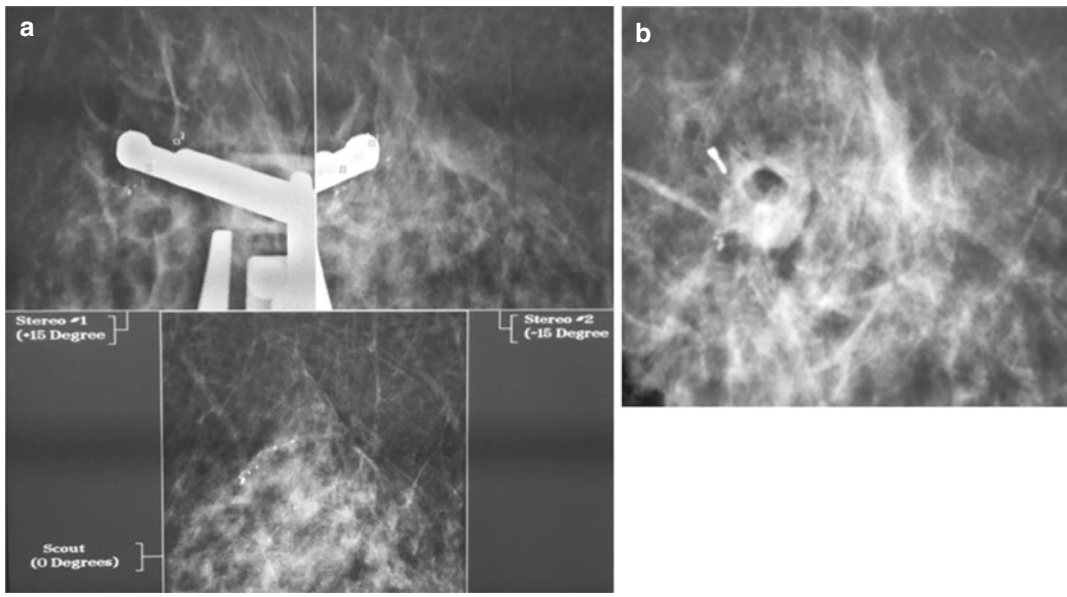

Fig. 13.6 Stereotactic G-8 vacuum-assisted biopsy. (**a**) Target points on ±15° ± angulated mammographic images in relation to biopsy window. (**b**) Biopsy cave and clip

Fig. 13.7 MRI biopsy coil. (**a**) Before biopsy. (**b**) During biopsy outside the magnet

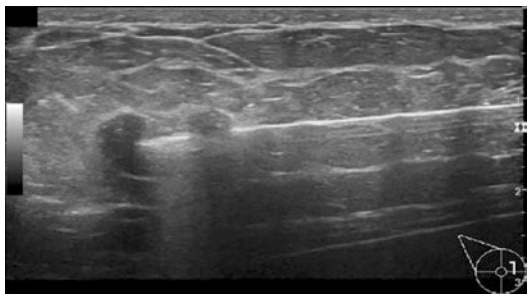

Fig. 13.8 G-8 core needle adjusted parallel to the transducer within the transducer plane and ready to biopsy. Histology was fibroadenoma

tion. Either the needle tip or other part will disappear from the screen. A rotation of the needle plane back to the transducer plane overcomes this problem. The intensity of the echoes reflected by the needle plane changes with needle size, the scanning depth, angulation toward the transducer surface, and selected imaging parameters. Higher needle diameters, parallel approach to the transducer surface, and lower grades of compounding at the highest possible frequency promise best needle control. Accuracy of adequate tissue sampling of more than 95% for 14-gauge automated biopsy guns and 98–100% for 11-gauche or bigger VAB needles is standard of care [15, 25–28].

13.4.1.2 2-D and 3-D Mammography

2-D stereotactic mammography uses "stereo" paired small X-ray exposures acquired at predetermined angles from a centre line (such as + and −15 degrees) to ascertain the presence of the index lesion in both images for the later proper placement of breast biopsy instruments. The centre point of the Cartesian system resembles the zero reference of the x-, y-, and z-coordinate axes. The polar system determines each point of the three planes by a distance from the reference point and an angle from a reference direction. The reference point (analogous to the origin of a Cartesian system) is called the pole, and the ray from the pole in the reference direction is the polar axis. Review of angulated 2D projections as related pairs is critical to determining the target tissue's third dimension by software-assisted triangulation ("Z coordinate"). The target point is calculated within a Cartesian or polar coordinate system. After it's identification, the biopsy needle is advanced after cleansing and local anaesthesia and the tissue sampling is performed. Additional paired images are obtained to confirm needle positioning, subsequent placement of a tissue marker, and documentation of successful extraction of the targeted tissue. The multiple image pairs are denoted as "Scout", "Pre-fire plus/minus", "Post-fire plus/minus",

"Post-biopsy plus/minus", "Post-marker plus/minus", and single Post-biopsy or Post-marker images. Prone stereotactic VAB is considered to represent the reference standard for tissue sampling under mammographic guidance (Figs. 13.9 and 13.10). Modern prone stereotactic systems allow free 3-D angulation of the biopsy device and are more flexible than the upright sitting

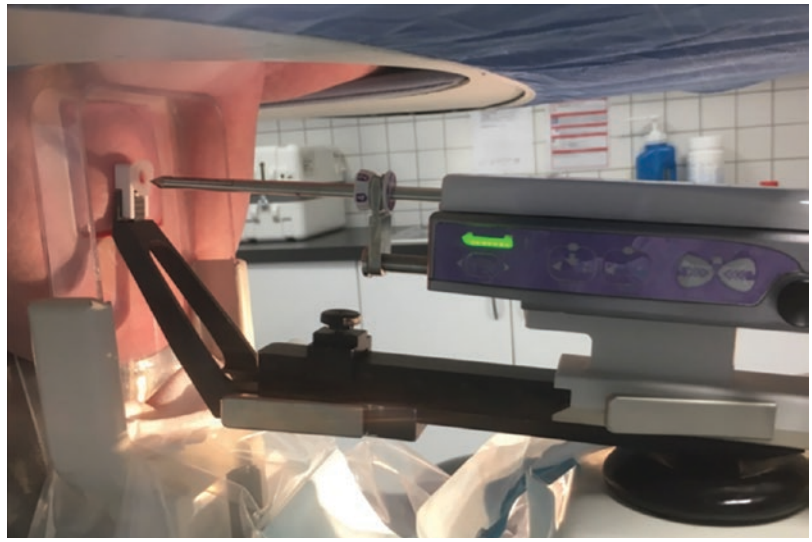

Fig. 13.9 Stereotactic biopsy. Positioning in the polar axis before advancing towards in-breast target

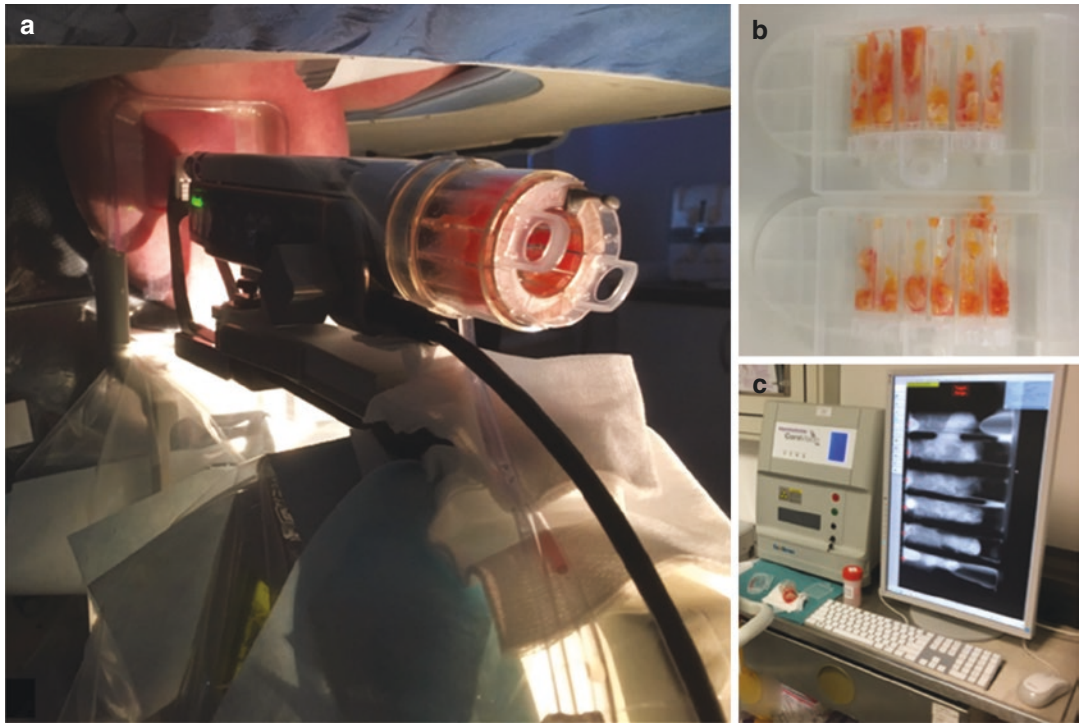

Fig. 13.10 Chamber for tissue sampling. (**a**) Connected to the biopsy needle. (**b**) Disconnected from biopsy system for radiography and transport to pathology

position systems using a dedicated biopsy chair. Compared with add-on upright systems, prone stereotactic VAB allows the patient to rest in a stable, relatively comfortable position and prevents the patient from facing the biopsy. 3-D digital breast tomosynthesis (DBT) and prone 2-D stereotactic systems can be operated also with the patient positioned in a lateral decubitus. The biopsy coordinates, including z-axis location, are determined directly from the DBT images by identifying the DBT section that shows the sharpest depiction of the target and is being forwarded to the biopsy software system for automated preparation of the biopsy system. Performance of DBT-guided VAB allows use of the full detector size for imaging and provides immediate lesion depth information without requiring triangulation; it facilitates target lesion re-identification and sampling of even low-contrast targets, such as uncalcified masses or architectural distortions. Further, the procedural time of DBT VB is lower, and this technique is going to become a candidate to substitute stereotactic VAB for routine use in patients with suspicious abnormalities demonstrated on regular 2D digital mammograms without correlative finding in ultrasound [2, 16, 27, 29, 30].

13.4.1.3 Magnetic Resonance Imaging

The principles of MRI-guided percutaneous biopsy are similar as those for ultrasound and mammographic approaches with a few exceptions. Firstly, only non-ferromagnetic biopsy material can be used in addition to the dedicated breast biopsy coil. Secondly, the lesion may become invisible after biopsy by washing out the gadolinium contrast, and thirdly, there is no way to generate a specimen MRI. The available equipment modifies the particular technique to perform a prone MR-guided VAB, which is the current standard of care. Most commercially available biopsy systems can access the breast from a medial or lateral approach. An opening of the breast immobilizing compression paddle is indispensable for placing the needle in the breast. An external grid with perforating holes allows needle advancement parallel to the breast. A separate needle guide may permit additional angulation within the scan plane, which is useful in pre-pectoral lesions. An external fiducial marker filled with gadolinium or oily fluid serves as external spatial reference that is placed on the skin, the grid, or the guiding system. After the diagnostic sequences, the patient is removed from the magnet, and the operator calculates the coordinates of the enhancing index lesion (superior-to-inferior, anterior-to-posterior, and right-to-left) and the distance from the reference marker manually or using automated software. An appropriate hole in the perforated plate corresponds to the biopsy plane and is chosen for placing the biopsy system. Local cleansing and anaesthesia outside the magnet is followed by skin incision with a scalpel before the standard biopsy procedure starts outside the magnet. A plastic introducer sheath is placed over the large solid titanium trocar introducer core needle, which resembles a stylet. The depth stop is placed to assign the appropriate depth. The introducer needle is advanced into the appropriate depth and replaced by a plastic obturator trocar. If it's position is concordant with the index lesion's position at a repeat three-dimensional gradient-echo MR imaging, the VAB is performed outside the magnet. The vacuum-assisted biopsy needle is advanced through the sheath, and multiple contiguous samples are obtained. A final repeat MR imaging control highlights post-biopsy changes including the post-biopsy titanium clip that marks the biopsy site. Mammography may be performed to identify the location of the clip within the breast for later mammographic guidance of wire localization if required based on histological results. In general, the total time required for the MR imaging examination performed before biopsy, the biopsy procedure itself, and the post-biopsy care usually ranged from 30 to 60 min. Since the cancer detection rate is low using MRI guidance, a short-term follow-up is appropriate. Before MR biopsy, the patients should be directed to a second-look ultrasound or DBT that promises to identify the MR lesion in >60% and offer an alternative guiding method (Fig. 13.11) [4, 6, 24, 27, 31, 32].

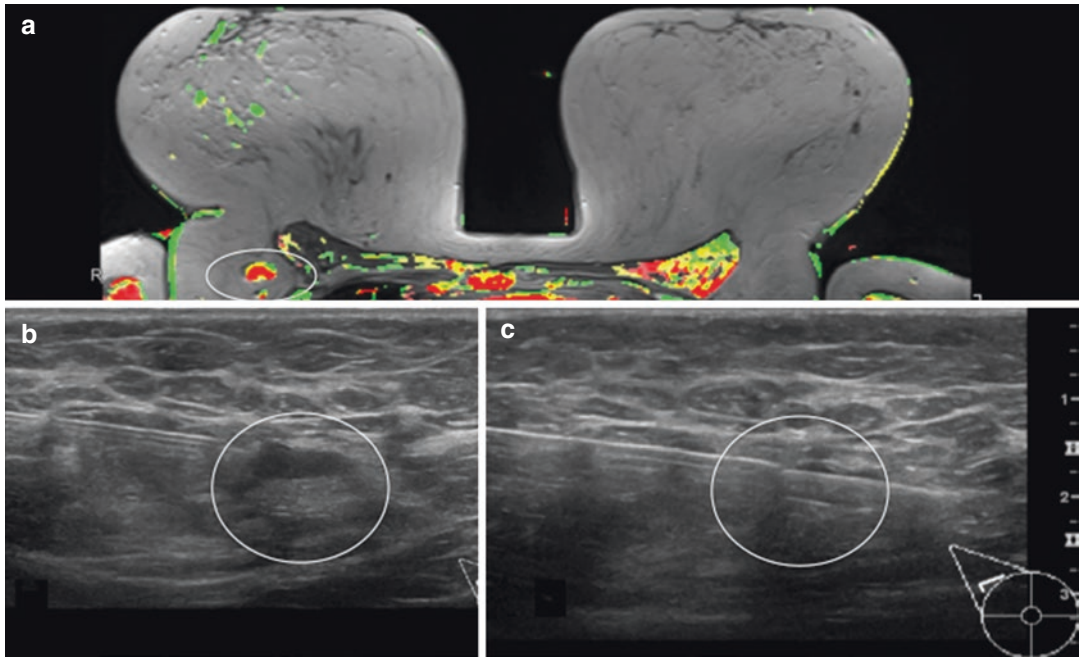

Fig. 13.11 (**a**) MR shows suspicious lymph node recurrence (circle). (**b**) G-16 core needle biopsy of the corresponding lymph node before firing. (**b**) After firing the spring mechanism. Histology: breast cancer metastasis

13.4.2 Biopsy Tools

13.4.2.1 Tissue Amount Harvested by Hollow Needles

While fine-needle aspiration only receives cells for the cytopathology, core needle biopsy yields tissue cylinders of approximately 20 mm^3 per cylinder, and vacuum-assisted biopsy harvests the largest amount of tissue with approximately 90 mm^3 tissues per cylinder. The precision of guiding the needle into the target defines the necessary amount of tissue for a reliable histopathological diagnosis and is best under US guidance and lower for mammographic and MRI-guided biopsies. Therefore, the recommendation to perform mammographic and MRI-guided biopsies using a vacuum-assisted needle prevents false-negative results due to oversampling of tissue. Various hollow needles used in image-guided biopsies present with a variable design, length, diameter, and cost. Structured hands-on training with phantoms allows physicians to learn the proper handling of image-guided biopsy techniques [1–3, 6, 8, 12, 14, 15, 32] (Fig. 13.12).

13.4.2.2 Fine-Needle Aspiration (FNA)

The technical advantages of fine-needle aspiration (FNA) and as an alternative expression fine-needle aspiration biopsy (FNAB) compared to other methods are plenty. Low morbidity is combined with low costs, and the procedure can be done promptly anytime. The problem starts with the need for an optimally trained and skilled cytopathologist who will achieve accurate results. Those cytopathologists can be found only rarely to date. As a consequence, FNA is recommended only in lesions with a high probability of benignity or extended clinically advanced cancers with a high probability of malignancy and the prerequisite of sufficient competence of the cytopathologist. Using FNA can be difficult to harvest adequate material. The reported sensitivity varies between 65% and 98%, while the specificity ranged from 34% to 100%. The usual application field for FNA are symptomatic and painful breast cysts without intracystic structures. In this case, FNA is both diagnostic and therapeutic. However, in case of intracystic lesions, a vacuum-assisted

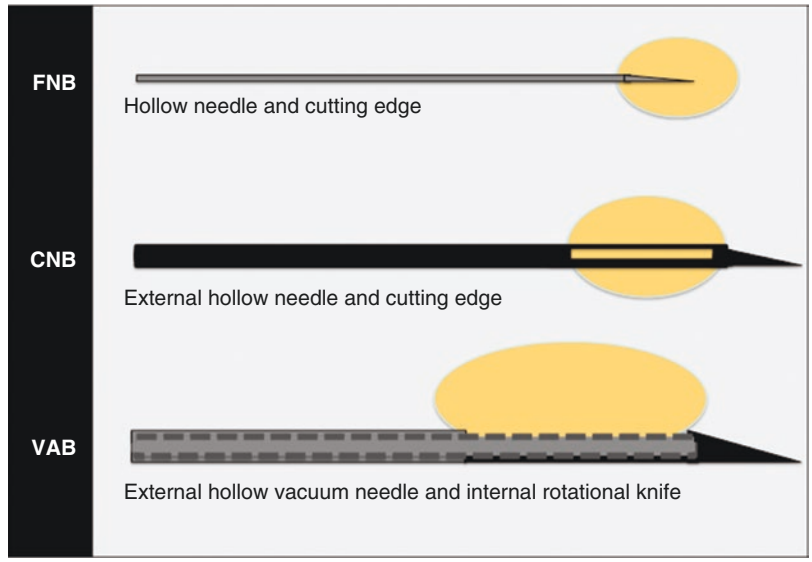

Fig. 13.12 Puncture tools for cell or tissue sampling. (**a**) Hollow needle. (**b**) Core needle biopsy with notch of the internal needle and cutting edge of the external needle. (**c**) Vacuum-assisted biopsy needle with big notch of external needle and cutting edges of rotating internal needle

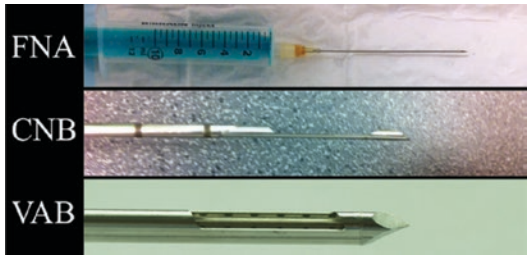

Fig. 13.13 Different principles used in breast biopsy needles. (**a**) Fine-needle aspiration needle and syrinx for suction of cells into the needle. (**b**) Core needle biopsy characterized by high-speed "fire-forward" movement of the inner needle (obturator with notch) and sequential cutting of the biopsy specimen by the outer needle. (**c**) Vacuum-assisted biopsy characterized by in suction of tissue through the open window into the stationary hollow needle and sequential cutting off by a rotational internal knife

biopsy is more accurate than FNA. Fine-needle aspiration biopsy may be done in solid BI-RADS 3 lesions and suspicious lymph nodes of the axilla. In highly suspicious lesions, it is recommended to use core needle biopsy rather than FNA, because the latter is not able to distinguish between invasive carcinoma and carcinoma in situ. A second procedure can be necessary in case of malignancy or missing correlation. Depending on the patient's age, a complete imaging workup should be considered prior to the procedure [33–35] (Fig. 13.13).

13.4.2.3 Core Needle Biopsy

Compared to FNA, core needle biopsy (CNB) provides more than adequate material to allow a valid interpretation by a trained pathologist; a specialized cytopathologist is not a necessity. In the case of breast cancer, the extracted material also provides the analyses of oestrogen and progesterone receptors, Her2/neu, and ki-67. CNB under ultrasound guidance has a very high sensitivity (up to 100%). Therefore, even in a palpable lesion, ultrasound-guided biopsy is the method of choice. CNB is recommended for symptomatic, solid breast lesions; suspicious BI-RADS® 3–5 lesions, which must be reproducible on ultrasound; suspicious scars after previous breast surgery; and axillary lymph nodes. A biopsy of intracystic or intraductal lesions can be performed. However, leakage of the surrounding fluid makes these particular lesions afterwards often hard to find. Thus placement of a clip marker is needed to ascertain the correct localization of the lesion in case of malignancy. No significant difference of local recurrence after breast conserving therapy can be shown between CNB as compared to surgical biopsy, even so tumour cell displacement through CNB is observed. Prior to the procedure, patients should be informed of various aspects of CNB: A second procedure might be unavoidable in case of malignancy or missing concordance. It should be

Fig. 13.14 Examples of core needle biopsy systems. (**a**) Metal automated high- speed biopsy gun. (**b**) Needles for metal automated high-speed gun system. (**c**) Coaxial needles (i.e. trocars) characterized by an external hollow needle and a central obturator that will be retracted before biopsy. (**d**) Disposable plastic biopsy guns that can be used in a fire-in-place (semi-automated) mode or fire-forward (automated) mode

addressed that superficial bruising could occur. However, injuries of the thoracic wall and the organs beneath are very rarely seen. Furthermore, if the lesion is located close to the axillary vessels, it needs to be addressed that bleeding with consequences of a surgical intervention could occur [33–36] (Fig. 13.14).

13.4.2.4 Vacuum-Assisted Breast Biopsy

Vacuum-assisted breast biopsy (VAB) can be used diagnostically and therapeutically (in benign lesions only) as well. With VAB, in contrast to other needle techniques, a complete removal of solid tumours, lymph nodes, and intracystic/intraductal lesions up to 25 mm is possible. An easier positioning of the needle within dense breast tissue is achieved by the tip design of the triple-action needle, which contains a sharp stiletto. After positioning of the needle window, the breast tissue to be removed is sucked into a needle window by a vacuum. Then, a rotating knife cuts off the breast tissue inside the needle window. Finally, the specimen is transported to the proximal side of the instrument outside the breast. There, an assistant can receive the specimen while the needle stays within the breast and acquires the next specimen. This process allows removal of lesions up to a maximum diameter of 25 mm. The needle sizes range from 14 gauche to 8 gauche. The samples allow a valid pathological workup. In the case of breast cancer, the extracted material also provides the analyses of oestrogen and progesterone receptors, Her2neu, ki-67. VAB is recommended for symptomatic, solid breast lesions; suspicious BI-RADS® 3–5 lesions, which must be reproducible through ultrasound; and intracystic and intraductal lesions. Furthermore, some authors suggest VAB for symptomatic scares after previous breast surgery and for removal of hema-

tomas. However, experienced physicians are needed for performing VAB of axillary lymph nodes. As a re-biopsy using VAB produces a higher amount of tissue compared to CNB, VAB allows a validation of the pathologic result after CNB and a lack of concordance between the suspicious diagnosis and the pathological result. VAB allows a complete removal of particularly small suspicious lesions (<5 mm), which are difficult to biopsy with CNB. In these cases, VAB is a very valid technique. Prior to the procedure, patients should sign a written informed consent. The patients have to be informed of false-negative and false-positive results and the possibility of missing concordance of it and the possibility of a second-step procedure in case of malignancy or missing concordance. In addition, superficial bruising is most likely to appear. Especially after removal of lesions >20 mm, large hematomas are likely. However, further treatment is usually not necessary. Injuries of the thoracic wall and the organs beneath are very rarely seen. If the lesion is located close to the axillary vessels, the patient must be informed that bleeding with the consequences of surgical intervention could occur. Depending on the patient's age, a complete imaging workup should be considered prior to the procedure. It is always recommended to present malignant or premalignant results from the biopsy in an interdisciplinary conference. As VAB enables a complete removal of tumours, a clip marker has to be placed to ascertain correct localization of the lesion in case of malignancy. The VAB technique takes more time to master completely than FNAB or CNB. It is recommended that the operator is experienced in ultrasound and CNB [18, 36–40] (Figs. 13.15 and 13.16).

13.4.3 Practical Approach with Focus on Ultrasound Guidance

13.4.3.1 FNA

Ultrasound guidance offers the best circumstances for FNA. If ultrasound is not feasible, FNA should be undertaken in palpable lesions only. The patient is put in a reclined position on the back with the ipsilateral arm elevated above the head. The skin of the breast is disinfected with alcohol, and the patient should be questioned about previous allergic reactions. A local anaesthetic is not generally used but should be offered to the patients. Performing the FNA under ultrasound guidance, the lesion location should be documented (breast side, clockwise, nipple distance) and measured in two planes.

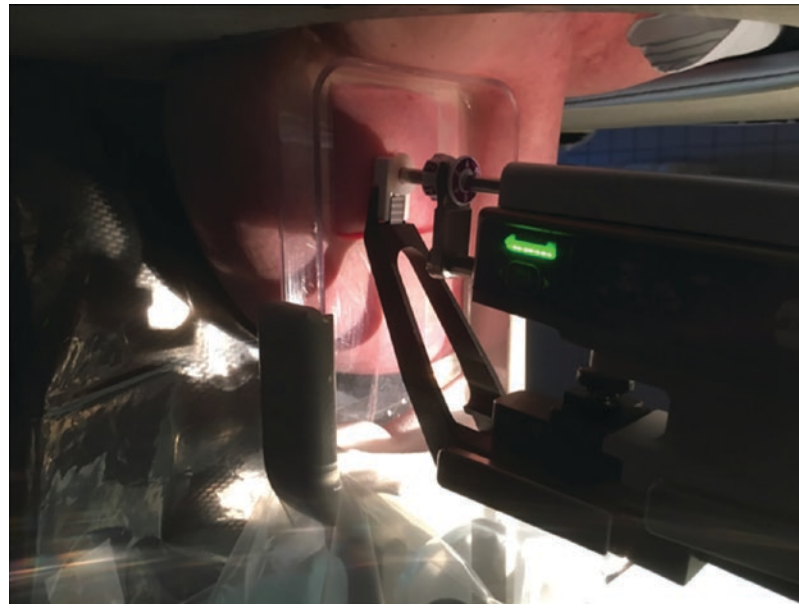

Fig. 13.15 Stereotactic vacuum-assisted biopsy needle within the breast after reaching the target point

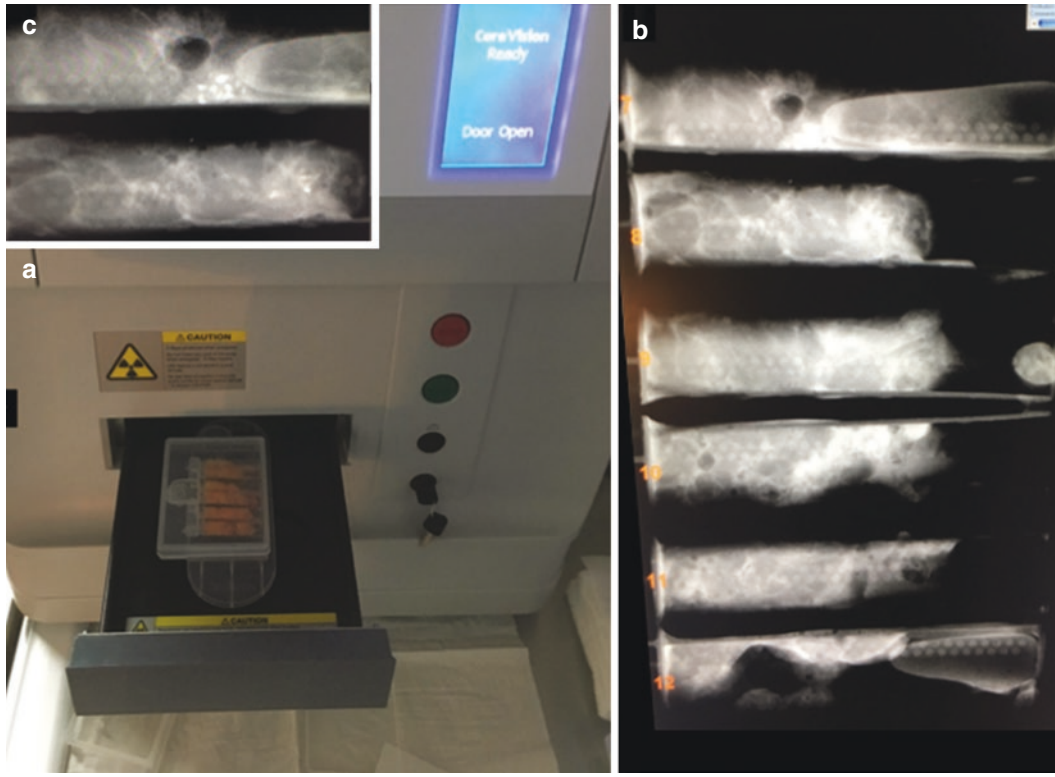

Fig. 13.16 Specimen radiography following stereotactic vacuum-assisted biopsy showing (**a**) loading of specimens for x-ray exposure, (**b**) radiographic array of six specimens, and (**c**) details of calcifications

Therefore, sterile ultrasound gel is applied. The ultrasound probe is held in the non-dominant hand. Slight pressure is given on the probe in order to retain the lesion such as a complicated cyst. For aspiration, a 21-gauge needle is used. The size of the syringe may vary and depends upon the size of the cyst. The needle is inserted with the dominant hand through the dermis approximately 1 cm distant to the ultrasound probe. The direction of the needle should be parallel to the probe. Thus, needle visualization is guaranteed, and the possibility of injuries of the skin or thoracic wall is minimized. When the needle tip reaches the cyst, inner palpation of the cystic wall is possible to reassure the correct position of the needle. Afterwards, the needle is inserted into the cyst. An ultrasound documentation of the needle within the cyst in two planes is performed. Aspiration should then be done carefully. After removing the needle, ultrasound documentation is repeated in two planes, and it should be documented whether the cyst is completely empty or whether additional masses are left. In case of additional masses on ultrasound, e.g. intracystic papilloma, the relocation of the lesion is assured by placing a marker clip under sonographic guidance. The patient is instructed to put pressure with the thumb on the biopsy side for at least 10 min. The syringe is sent for cytological exam even though studies have shown that the cytological exam of simple cysts is of little value. Depending upon the cytology results, persistent residual masses must be considered for removal of adequate material for pathologic exam. The technique of FNA in aspirating cystic fluid is the same for cutting off small fragments of cells of a solid lesion or axillary lymph node. The needle used in FNA may vary in size from gauge 21 to gauge 27. Best results are achieved by using the coaxial technique using a needle with a trocar in order to avoid a primary contamination of the needle content with surrounding

breast tissue. A 2 ml syringe is used for aspiration. However, also, the use of bigger syringes in combination with dedicated devices to increase the negative pressure during suction can be recommended. Under ultrasound guidance, the needle is passed in and out of the lesion about five times, thereby building up a mild vacuum through the syringe. This procedure should be documented on ultrasound in two planes to assure the correct lesion has been aspirated. It is important to disconnect the syringe from the needle, before the needle is removed! Otherwise, there is a risk that the specimen gets completely aspirated within the syringe resulting in a false-negative examination. After the needle is removed, the syringe gets filled with air and placed back on the needle. Carefully, the specimen is dropped on a microscopic slide by emptying the needle by applying mild pressure upon the syringe. The cells on the slide are immediately spread with another slide. Afterwards, two slides are prepared, one is wet fixed in 95% ethyl alcohol, and the other is air-dried. The patient is instructed to put pressure with the thumb on the biopsy side for at least 10 min. In cases of complete removal of a suspicious lesion, relocation has to be assured by placing a marker clip under sonographic guidance.

13.4.3.2 CNB

The CNB needle is a double-action needle. An inner part of the needle, including the sample notch, shoots inside the tumour first. A cutting cannula surrounding the inner needle follows the first shot at once. This procedure is so fast that the operator realizes just one shot. It is recommended to receive at least three specimens. To avoid tumour cell displacement while putting the needle in and out of the breast, some operators prefer to use a coaxial needle guiding the cutting needle. The standard needle size for CNB of the breast is 14 gauge; some physicians may prefer 16- or 12-gauge needles. CNB is best performed under sonographic guidance. The smallest lesion size that should be examined through CNB depends upon the experience of the physician. However, experienced operators can biopsy a lesion as small as 2–3 mm. Similar to FNA, the patient is put in a reclined position on the back with the ipsilateral arm elevated above the head. The skin of the breast is treated with alcohol for disinfection. A local anaesthetic is necessary. The patient should be asked for previous allergic reactions. Prior to the procedure, the location of the lesion should be documented (breast side, clockwise, nipple distance) and measured in two planes with ultrasound. Sterile ultrasound gel is applied. During the biopsy, the ultrasound probe is held in the non-dominant hand. Slight pressure is given on the probe in order to retain the tumour. Ideally, the operator is sitting on the ipsilateral patient's side and focuses straight on the ultrasound monitor. A comfortable position is recommended. 5–10 ml of local anaesthetic is applied. Local aesthesia should be used sparingly around the tumour. If too much fluid is injected, small tumours may disappear on ultrasound. If this should occur, it is wise to wait until the tumour becomes visible at a later stage. After the area to be punctured is numb, the core needle is inserted with the dominant hand going through the dermis approximately 1 cm distant to the ultrasound probe. Some operators prefer a stitch incision with a no. 11 scalpel to insert the needle. This is not really necessary. The core needle should hit the tumour within its centre. For an optimal visualization, the direction of the core needle should be parallel to the ultrasound probe. Thus, it is important to insert the core needle straight towards the thoracic wall, but only as deep as the tumour is dislodged from the skin. The thoracic wall must not be punctured! Then the needle needs to be angled and launched forward to the tumour parallel to the ultrasound probe. When the needle tip reaches the tumour, inner palpation is performed to reassure the correct position of the needle. Before firing the core needle, ultrasound documentation of the needle location in two planes is performed. The core needle is fired. Again ultrasound documentation in two planes is recommended in order to prove the correct localized strike of the needle. Since the core needle penetrates about 21 mm depths, one should avoid hitting the skin or thoracic wall. At least three specimens should be taken from the tumour. In case of very small lesions, the relocation of the lesion is assured by placing a marker

clip under sonographic guidance. The inserted marker clip should be documented using ultrasound. Then, the patient is instructed to put pressure with the thumb on the biopsy side for at least 10 min. An elastic thoracic bandage is applied for 24 h. A mild pain medication, e.g. ibuprofen, is recommended. All specimens are sent to the pathologist.

13.4.3.3 VAB

Similar to FNA and CNB, the patient is put in a reclined position with the ipsilateral arm elevated above the head. The skin of the breast is treated with alcohol for disinfection. A local anaesthetic is necessary, and the patient should be asked for previous allergic reactions. It is recommended to assure proper functioning of the system before placing the needle. Prior to the procedure, the location of the lesion should be documented (breast side, clockwise, nipple distance) and measured in two planes on ultrasound. Sterile ultrasound gel is applied. During the biopsy, the ultrasound probe is held in the non-dominant hand. Slight pressure is given on the probe in order to retain the tumour. The interventionist sits on the ipsilateral patient's side and focuses straight ahead on the ultrasound monitor. A comfortable position is recommended. 10–20 ml of local anaesthetic is applied. It is recommended not to apply too much local anaesthetic around the tumour; in particular, small tumours have the tendency to disappear on ultrasound. If this should happen, it is useful to wait until the tumour is visible again. After the patient is analogized, a stitch incision with a gauge 11 scalpel is performed approximately 1–2 cm before the edge of the ultrasound probe. Then the needle is inserted through the dermis. Compared to CNB, the VAB needle is placed right below the lesion and not within its centre. Due to artefacts, ultrasound can just visualize the tissue, which is above and not below the VAB needle. To avoid unnecessary injuries, ultrasound visibility is very important during the complete procedure. For an optimal visualization, the direction of the VAB needle should be parallel to the ultrasound probe and always below the lesion. It is important not to steer the needle on its way through the breast too close to the thoracic wall or the skin, as the sharp needle tip can cause injuries. It is helpful, in cases of very dense breast tissue, to release the ultrasound probe from the non-dominant hand and stabilize the breast with it, while the dominant hand guides the VAB needle. With this technique, it should be less difficult to place the VAB needle through dense tissue. When the needle reaches the lesion, the needle window is placed below it. Before starting the VAB, ultrasound documentation of the needle location in two planes is performed. Then the needle gets specimen from the lesion removed from the breast. Thereby, the needle window is turned through the needle axis in order to harvest the lesion's edges until it has completely disappeared on ultrasound. In case of complete removal, the relocation of the lesion is assured by placing a marker clip under sonographic guidance. The inserted marker clip should be documented on ultrasound. The needle is removed from the breast. The patient is instructed to put pressure with the thumb on the biopsy side for at least 10 min. After a sterile tape is placed, an elastic thoracic bandage is applied for 24 h. A mild pain medication, e.g. ibuprofen, is recommended. It is also recommended after the procedure to document the number of specimens removed and the degree of removal (complete, incomplete, not representative). All specimens are sent to pathology.

13.4.3.4 Breast Localizations and Other Interventional Procedures

The localization procedures of breast masses, calcifications, asymmetries, and architectural distortions under imaging guidance follow the explained principles to locate an index lesion within the breast. Metallic clips are used during neoadjuvant therapy in tumours that respond to chemotherapy.

Wire guided localization (WGL) is applied in most centres as a safe and tested technique that allows for flexibility in selected cases when faced

with extensive microcalcifications preoperatively and for ultrasound masses pre-or intraoperatively. Radio-guided occult lesion localization (ROLL) and radioactive iodine (125) I seed localization (RSL) can be offered to patients as a comparable replacement for WGL as they are equally reliable, however have to fulfil national radiation protection rules. Magnetic tags or radiofrequency markers are new non-radiating alternative localizers that allow measuring the distance between the marker and a probe from various angles. A cheap alternative for US-visible lesions is skin marking above lesions and reporting lesion's depth and distance from the nipple and pectoral muscle. Cannulization of a pathological duct with intraductal abnormalities accounting for discharge allows identification of the duct after injection of 0.2–0.3 cc contrast material and stain by preoperative mammography and intraoperative [41, 42] (Figs. 13.17 and 13.18).

Percutaneous ablation of breast tumours by thermotherapy, cryotherapy, or irreversible electroporation aims at the destruction of histologically proved benign lesions. The use of these techniques in malignant lesions is currently limited by the inability to assess the tumour margin pathologically. Clinical trials evaluate the efficacy of these techniques [28, 43].

13.5 Post-Intervention Management

Local manual compression is sufficient after FNA, FNAB, and CB. A compression bandage is wrapped around the patient following VAB.

A short surveillance of the patient is recommended after any puncture. If the patient feels well at a final check by the physician, she (or he) can go home and continue care in an outpatient setting or is directed to stationary surveillance after sedation.

13.6 Complications

Pain, bruising, infection, and prolonged or secondary bleeding may occur during or after puncture, dependent on the type of biopsy and type of anaesthesia used and anticoagulant status. The majority of complications are minor, and overall procedure complication rate varies from 1.4 to 9% in the literature. However, major complications are very rare after FNA, FNAB, or CP. Following VAB, the following frequencies are reported: severe haemorrhage without open revision 7%, severe haemorrhage with open revision 0.1%, vago-vasal syncope 3.5%, and infec-

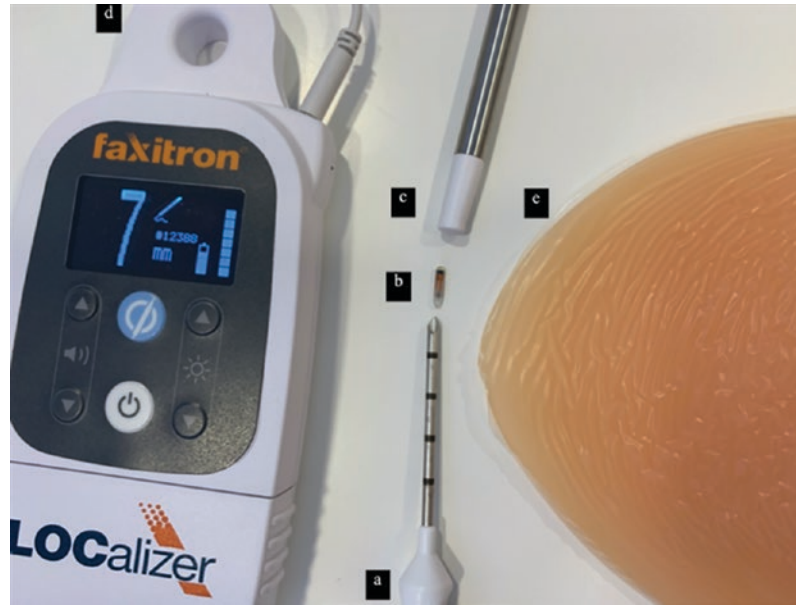

Fig. 13.17 Radiofrequency localizing system with (**a**) introducer, (**b**) radiofrequency chip, (**c**) probe, (**d**) connected distance measuring monitor, and (**e**) breast phantom

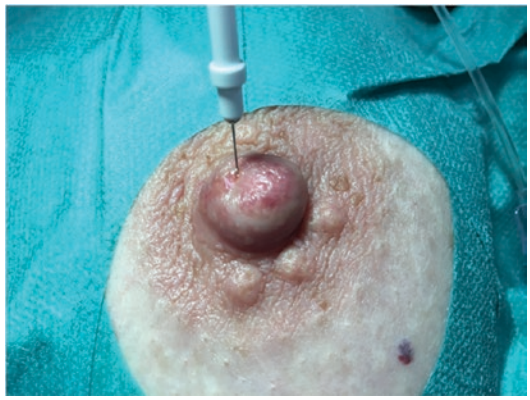

Fig. 13.18 Cannula in place at preoperative ductography. The procedure includes staining of the duct by contrast material and methylene blue

tion 0.04%. Casuistic reports refer to abscess formation, arterial-venous fistulas, pseudoaneurysms, tissue infarcts, milk fistula, or pneumothorax. A reactive fibrosis after VAB develops in up to 10%. Tumour cells may seed along the biopsy tract in any puncture, particularly during VAB. These malignant cells are not viable on the long term. The probability of tumour recurrence as a consequence of a biopsy procedure appears to be very low [44–47]. Complication rates after US-guided biopsy of the axilla are higher for US-guided CNB compared with US-guided FNA (7.1 versus 1.3%). Conversely, the requirement for repeat diagnostic procedures was significantly greater for US-guided FNA (4.0 versus 0.5%). The diagnostic algorithm facing a possible complication of a percutaneous breast procedure starts with a new ultrasound study with Doppler assessment to exclude a life-threatening vascular complication.

13.7 Tips and Tricks

13.7.1 US-Guided Biopsy

Best indication for US-VAB is assessment of discordant results between CB and histology and further assessment of small B3 lesions.

One should prefer anterior oblique position for US interventions from the side.

Always advance the needle parallel to the chest wall at peripheral puncture. Guide needle is always parallel with the ultrasound transducer.

13.7.2 Stereotactic Biopsy

Stereotactic or DBT-guided VAB is the method of choice to assess microcalcifications.

DBT-guided VAB is superior to stereotactic VAB in small masses, asymmetries, and architectural distortions.

VAB has lower complication rates and costs less than surgical biopsy.

13.7.3 MR-Guided Biopsy

Second-look ultrasound detects suspicious MR lesions in up to 75% of cases.

Mass and non-mass lesions are suitable for assessment.

Only MR lesions with biopsy-proven histology should change the planned surgical approach.

13.7.4 General Recommendations

Application of a metallic marker is necessary in small lesions or totally removed index lesions.

Specimen radiography is necessary in lesions with microcalcifications.

In several lesions at ultrasound, mammography, or MR, the precise location within the breast volume of each lesion has to correlate between the modalities.

13.8 Comparison of Results Between Imaging and Pathology

With minimal invasive biopsy techniques, the risk of missing a cancer is always present. The pathologist interprets the tissue received. As specimens from minimal invasive biopsies are usually just fragments of the suspect lesions, the correlation between suspected diagnosis and the

pathological results is necessary. A mismatch must lead to further steps until the valid diagnosis is found. Underestimation of the sampled biopsy specimens with reference to the final histological diagnosis depends on the total volume of the biopsy specimens and the accuracy of the guiding imaging tool to hit the suspicious lesion or area. The accuracy of the expensive VAB is better compared to CNB or FNA, and ultrasound guidance is superior to guiding by stereotactic mammography or MRI. To date, interdisciplinary conferences have become standard in breast centres. The consensus on imaging-pathology correlation is one of several critical parameters to fulfil state-of-the art management of patients with breast disease. A mismatch or discrepancy between imaging findings and pathologic results can be defined as controversial meanings of information that induce cognitive dissonance. The discrepancy can occur at the level of morphologic information, the assumed meaning or interpretation of the detected abnormality, or the management recommendation to the patient. Both the imaging specialist and the pathologist have to detect any relevant abnormality, exclude an artefact, make a threshold decision in borderline cases, and correlate the finding to an imaging or pathologic classification that determines the management decisions such as BI-RADS or B-classification. A radiologic inter-modality correlation needs to assign the index lesion to corresponding findings in other modalities, palpation, or clinical signs and symptoms. In health systems without strict litigation, a specificity approach allows to downgrade the BI-RADS classification from tissue diagnosis to follow-up, if benign indicators of one modality override the suspicious judge of another modality. The new overall assessment category may end up in BI-RADS 3 or 2 overall assessment categories. In health systems with strict litigation, a given biopsy recommendation cannot be taken back upon on the results of other modalities. This would decrease sensitivity and increase the frequency of litigation. The final imaging-pathology consensus has to agree whether or not the localization of the biopsy is representative and whether or not the quality of the specimens is representative for the imaging index lesion. The most suspicious judgement of experts defines the further management. Experts may use the same diagnostic criteria and note the same morphological features in a case, but sometimes have different opinions about whether or not the features meet a diagnostic threshold. As a consequence, management options focus on a second expert opinion, the gaining of additional information by minimal invasive or surgical re-biopsy, or imaging follow-up along with guideline recommendations. In summary, after obtaining the pathology report, the previously suspected diagnosis has to be matched with the pathology result. In cases of a mismatch or malignant result, further steps must be considered. In case of a benign histology, a clinical and sonographic follow-up after 6 months should be considered. Lesions of uncertain malignant potential in the breast (B3 lesions) represent a heterogeneous group of abnormalities with an overall risk for malignancy of 9.9%–35.1% after total resection. Underestimates of malignancy in excised B3 lesions are associated with increasing size of the lesion and the presence of atypia. Several studies also indicate that B3 lesions are predominantly upgraded to ductal carcinoma in situ (DCIS) and low-grade invasive tumours. Management and practice vary greatly from country to country, although there is a trend universally for more conservative management as an alternative to open surgery [39].

13.9 Conclusion

Minimally invasive biopsy tools such as ultrasound, stereotactic biopsy, or MRI are safe, accurate, cost-effective, and widely accepted. They allow a nearly 100% reliable tissue diagnosis. FNA has lost acceptance in many Western countries but still has proven value in palpable lesions and assessment of axillary lymph nodes. Core needle biopsy is more invasive, but also more reliable than FNA, and has developed to be the most frequently used biopsy tool for assessment of ultrasound lesions. Vacuum-assisted biopsy is the method of choice for lesions that need tissue

sampling under stereotactic or MR guidance. In cases with benign histology, a re-evaluation and potentially a repeat biopsy should be discussed if findings increase at follow-up examination or if there is a mismatch between histology and imaging. In all lesions of uncertain malignant potential in the breast (B3 lesions), further tissue sampling by surgical excision or VAB and close follow-up are recommended.

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