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Advances in Breast Ultrasound

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1. Introduction

Breast ultrasound was introduced as a clinical method in breast imaging in the seventies of the 20th century (Jellins, 1971; Kobayashi, 1974). In the Anglo-Saxon countries breast ultrasound was employed mainly by radiologists, by gynecologists predominantly in Germany.

In the early period the indication for breast ultrasound was the differentiation between the cystic or solid nature of palpable lumps (Figs. 1, 2). To make this distinction is easier in ultrasound than in mammography. On this way ultrasound became an accepted method as an adjunct to mammography for further analysis of equivocal mammographic lesions.

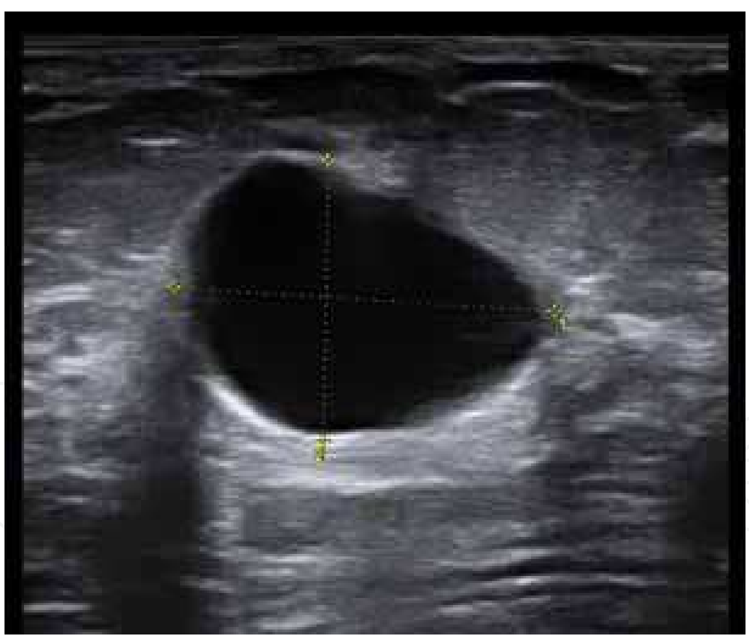


Fig. 1. Typical cyst: anechoic with distinct and smooth margins, benign

Though till now in guide lines of early detection of breast carcinoma indications for breast ultrasound are restricted in this sense, already in the eighties of the 20th century, the capability of breast ultrasound went far beyond this limits (Hackelöer et al., 1986). In contrast to mammography ultrasound is able to generate a detailed map of the anatomic structure of the breast. Because of this ability sonography is qualified to diagnose many benign and malign diseases of the breast by its own (Teboul & Halliwell, 1995).

Fig. 2. Typical fibroadenoma: solid, isodens, distinct and smooth margins (pseudocapsule), benign

2. Contemporary principles of breast ultrasound

Breast ultrasound is a dynamic (live) examination, the diagnostic procedure is performed by scanning systematically the whole breast in perpendicular planes. Though not unusual in Anglo-Saxon countries, it´s not sufficient to make a diagnosis on the basis mainly of printed or frozen digital pictures like in mammography. It is necessary to scan both whole breasts in real time. Only in this way is it possible to get a true impression of the architecture of the individual breast. Only with this background structural and architectural distortions as well as differences in the architecture of both sides will be remarkable. To classify the margins of a lesion in detail the dynamic examination is basically as well.

During whole breast scanning there are several steps to absolve:

What kind of breast parenchyma exists in respect of density (that is the relation of glandular to fatty tissue), echogenicity, homogeneus or inhomogeneous structure?

Are there any distinct lesions or masses?

In case of a lesion: the sophisticated description of the lesion related to standardized terms with final submission in BI-RADS categories with recommendation which way to follow up, is mandatory (ACR, 2003; Madjar et al. 2006).

Are there non mass like structural distortions requesting further analysis or complementary imaging modalities?

Principles of the description and the classifying of a discovered lesion are described in known textbooks and publications of breast ultrasound (Madjar & Mendelson, 2008; Stavros, 2004).

Examples and illustrations of cases with *typical sonographic appearance*, see below (Fig. 3, 4, 5, 6).

Fig. 3. Typical carcinoma: Architectural distortion, hypoechoic and echoinhomogeneous, margins ill-defined with echogenic halo, spiculae, acoustic shadow, vertical orientation

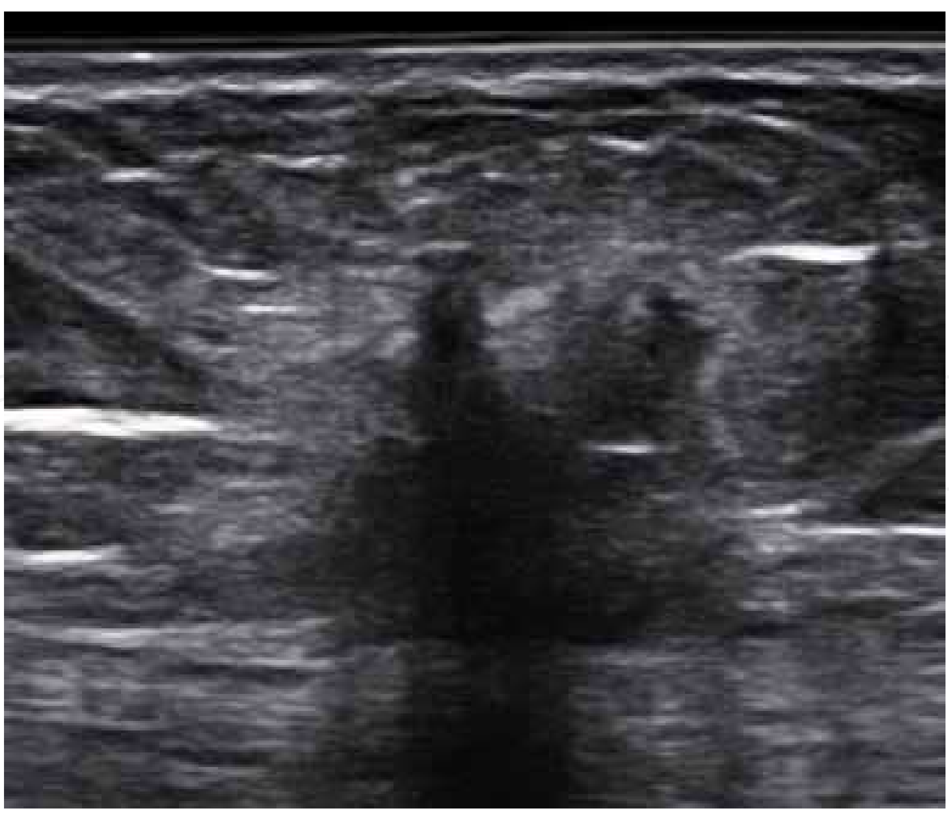


Fig. 4. Another carcinoma with typical architectural distortion, hypoechoic, acoustic shadow, desmoplastic reaction (echogenic halo)

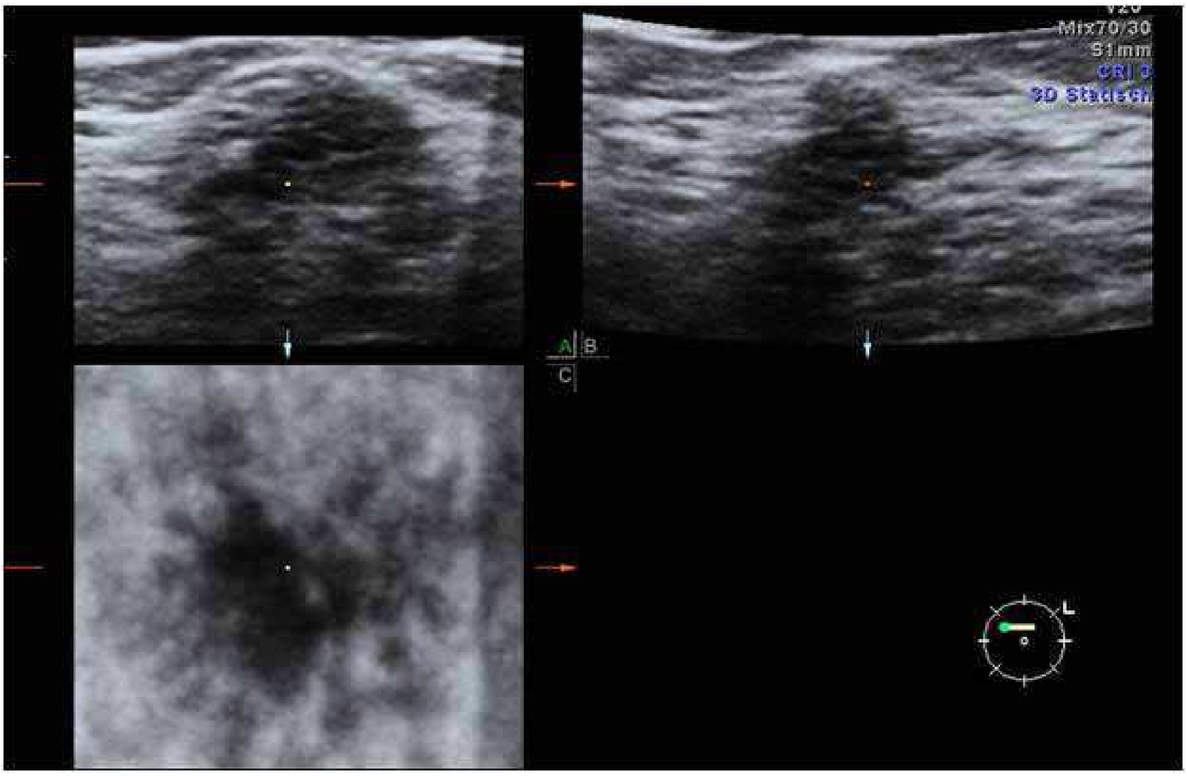


Fig. 5. Palpable lump: DCIS (ductal-in-situ-carcinoma): hypoechoic with indistinct margins, retraction pattern in the C-plane

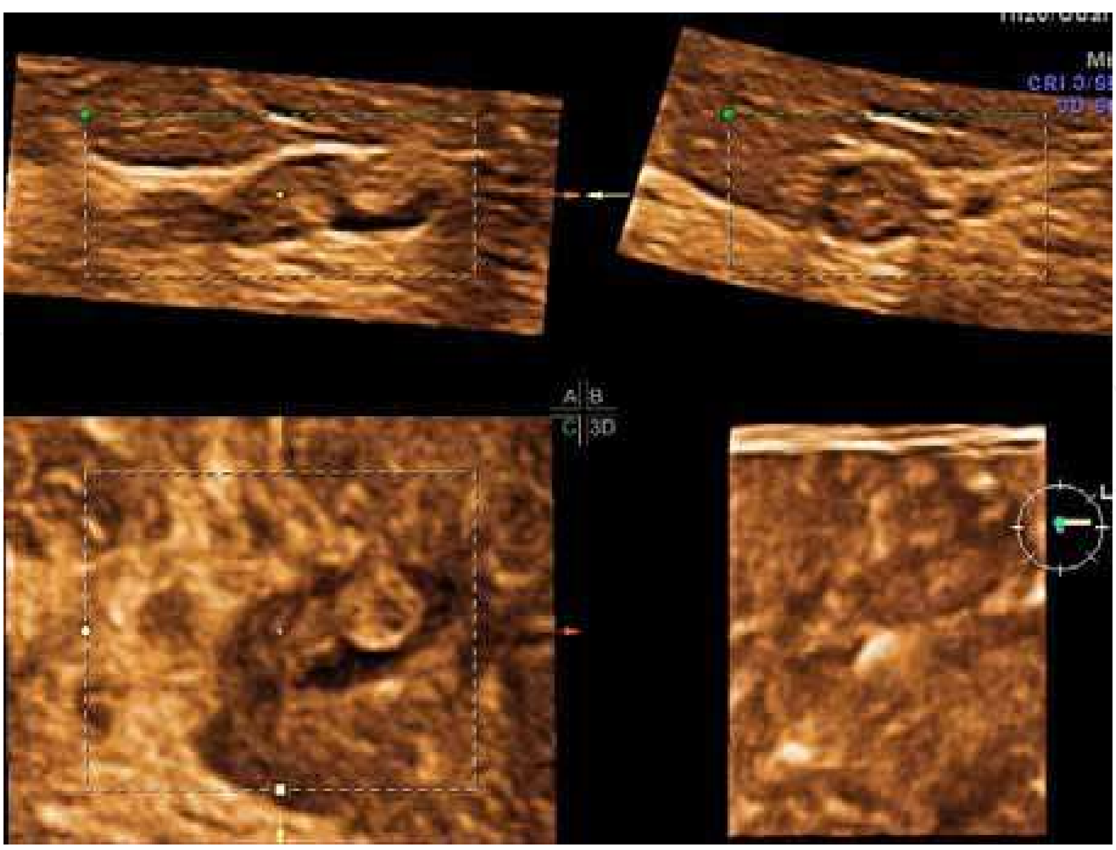


Fig. 6. Intraductal papilloma in 3-D technique: intraductal solid mass in a delated milkduct

3. New insights in breast ultrasound

To make the distinction between a benign and a malign or between a probably benign and a probably malign lesion, the differentiation of the margins and the echogenicity is essential. But with developing technology and experience some classical criteria like sound transmissing - shadowing versus enhancement - and the direction of growing - horizontal versus vertical - lose relevance. Enhancement is no longer a distinguishing marker for a benign lesion nor is this the horizontal growing pattern. By use of contemporary technology (Compound Scanning, Tissue Harmonic) enhancement can be observed in malign lesions as well and the growing pattern of ductal carcinomas often starts horizontal. Figs. 7, 8, 9 demonstrate not well known, but not rare characteristics of malign breast lesions.

With progress in resolution of the machines not smooth and not distinct circumscribed margins of fibroadenomas become more visible. Especially in the C-plane of the 3-D mode often fingerlike continuities are remarkable. That means that the finding of non smooth oval or round margins alone is no longer conclusive to submit this lesion to BI-RADS 4 (suspect) (Fig. 10, 11, 12).

On the other hand circumscribed margins are not rare – not only in special forms of carcinoma like medullary or mucinous carcinoma - but even in ductal carcinoma (Figs. 8, 15).

In this sense breast ultrasound with contemporary high definition ultrasound has become not easier, but more sophisticated.

Additional technical modules like color Doppler and 3-D therefore gain on relevance.

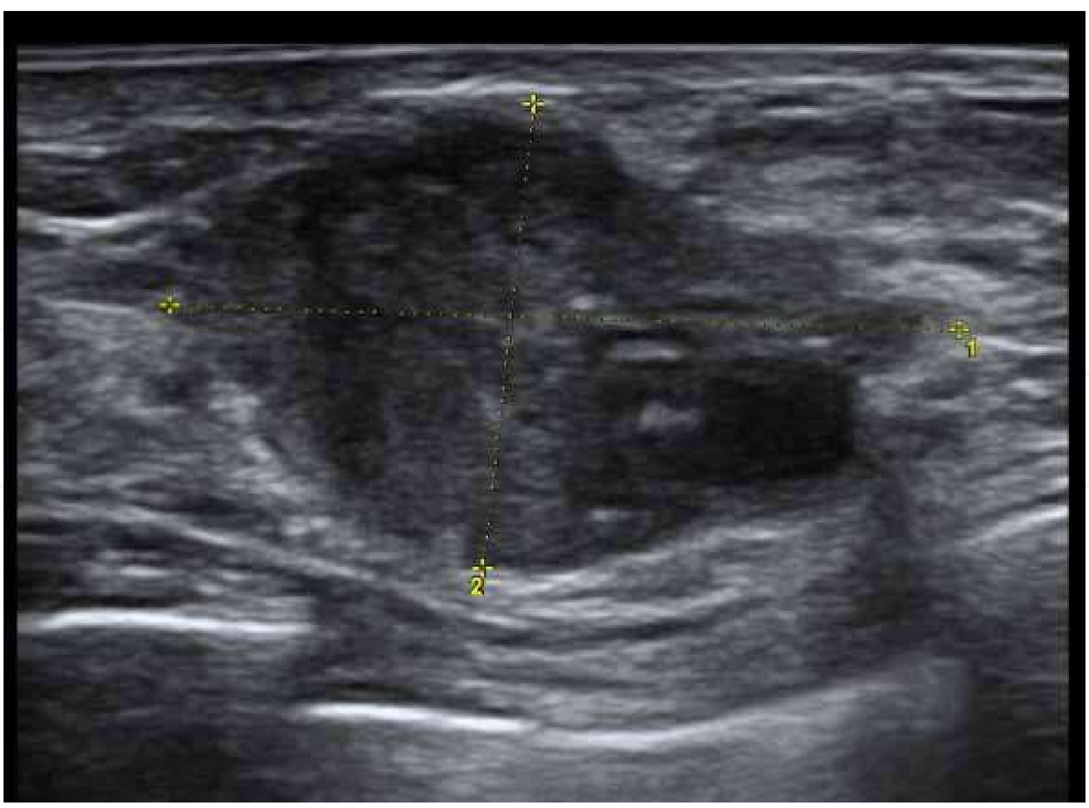


Fig. 7. A more horizontal orientation of a carcinoma, sound transmission attenuated only marginal, but predominantly enhanced

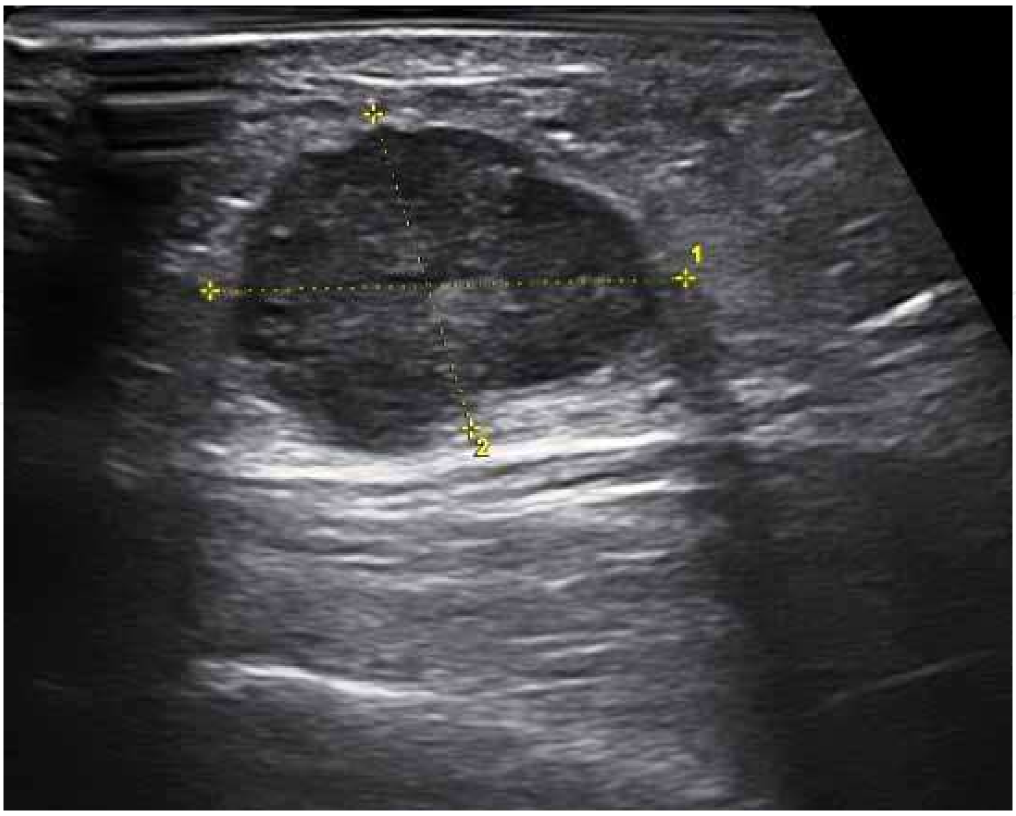


Fig. 8. Ductal carcinoma, smooth surrounded with sound - enhancement

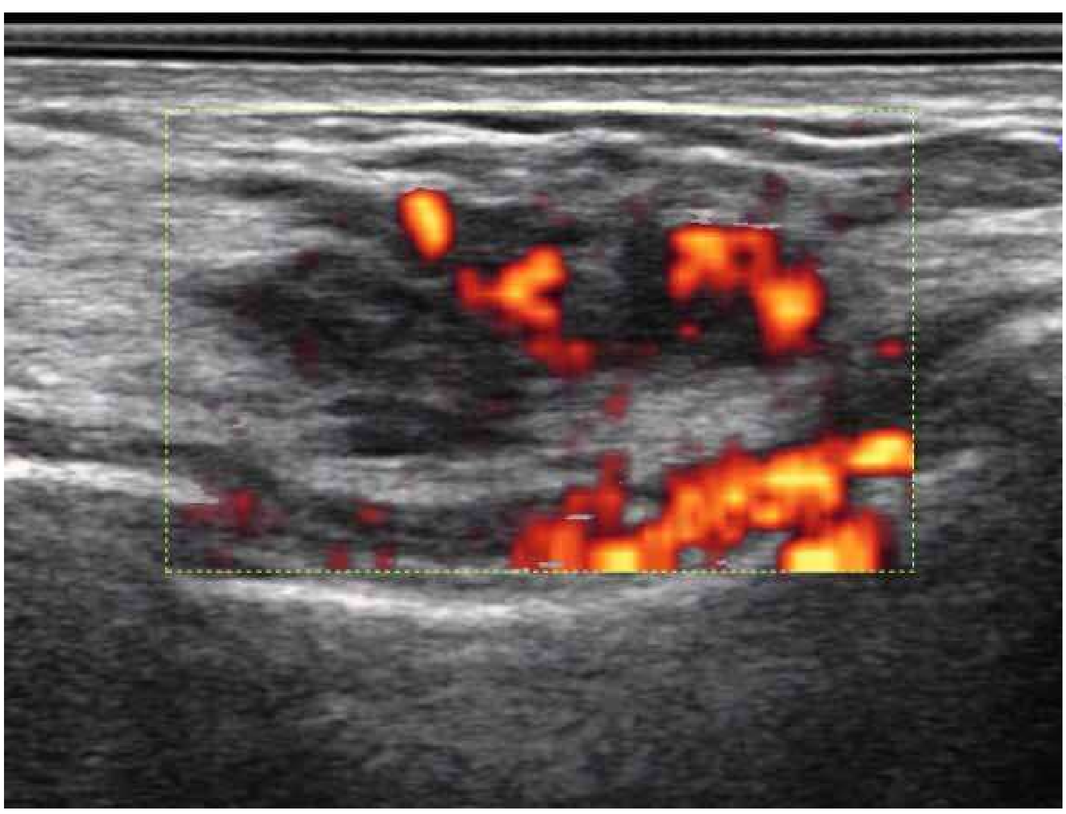


Fig. 9. DCIS: Horizontal growing pattern of a DCIS with microinvasion, clear vascularization in color Doppler

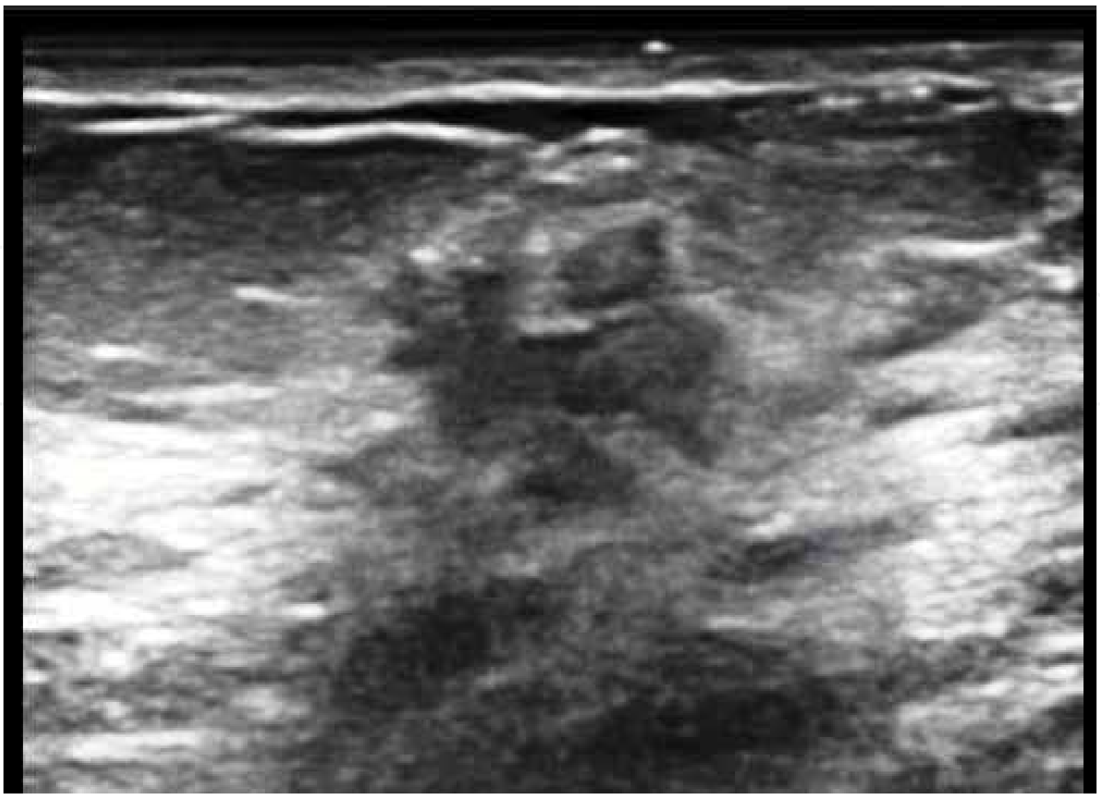


Fig. 10. Fibroadenoma: indistinct and not smooth margins (by this way not distinguishable from a carcinoma)

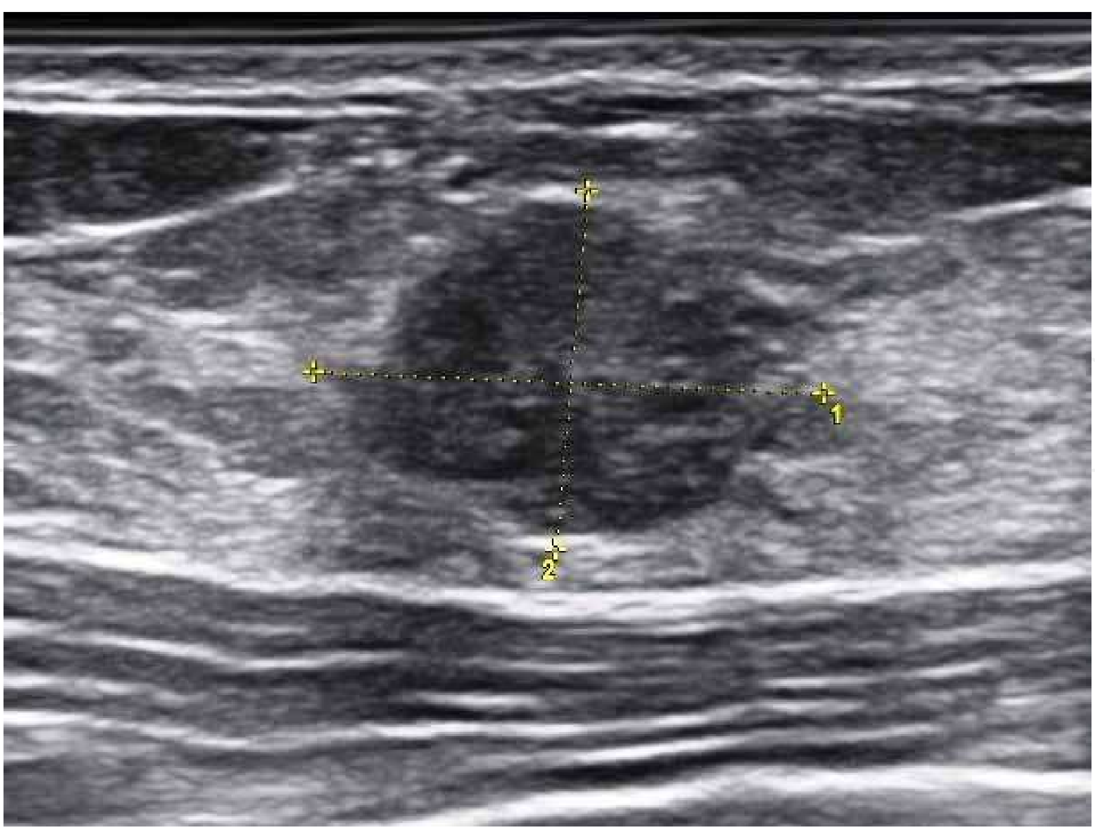


Fig. 11. Fibroadenoma: fingerlike continuities (not rare)

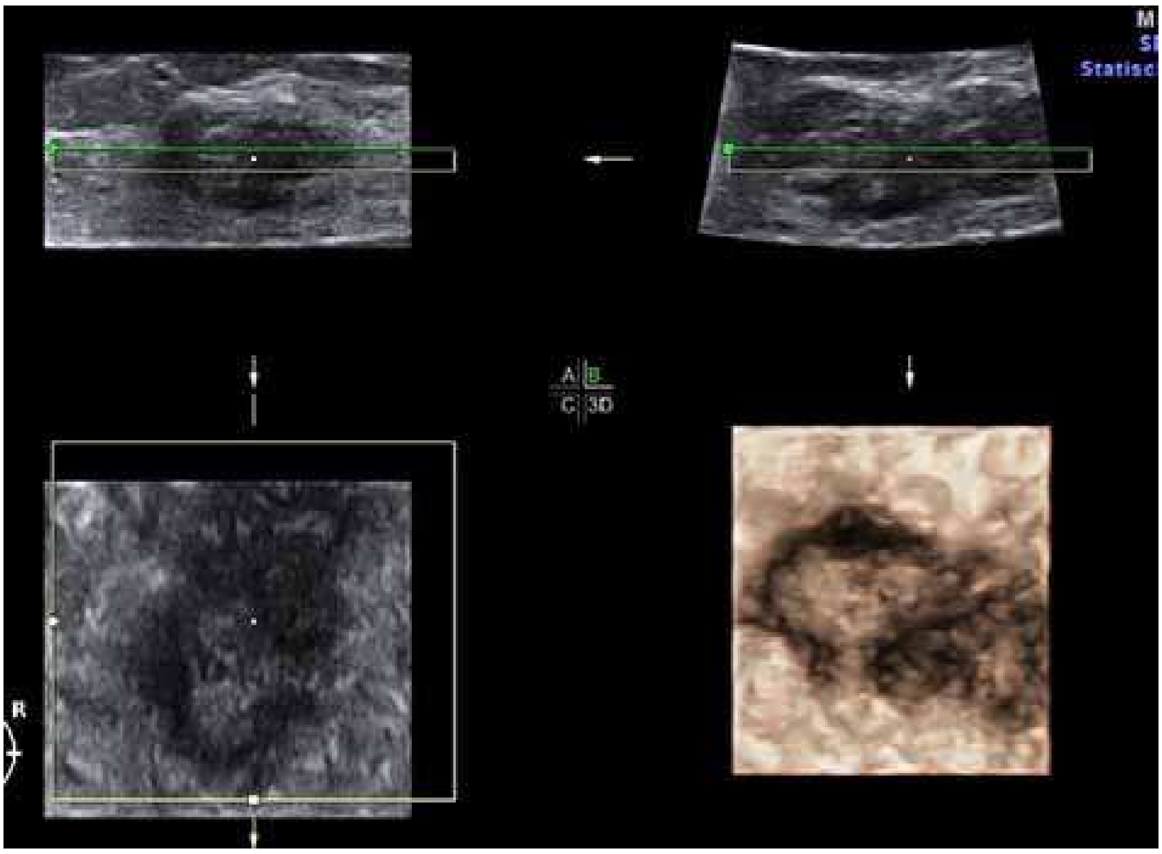


Fig. 12. The same lesion of Fig. 11 in 3-D mode

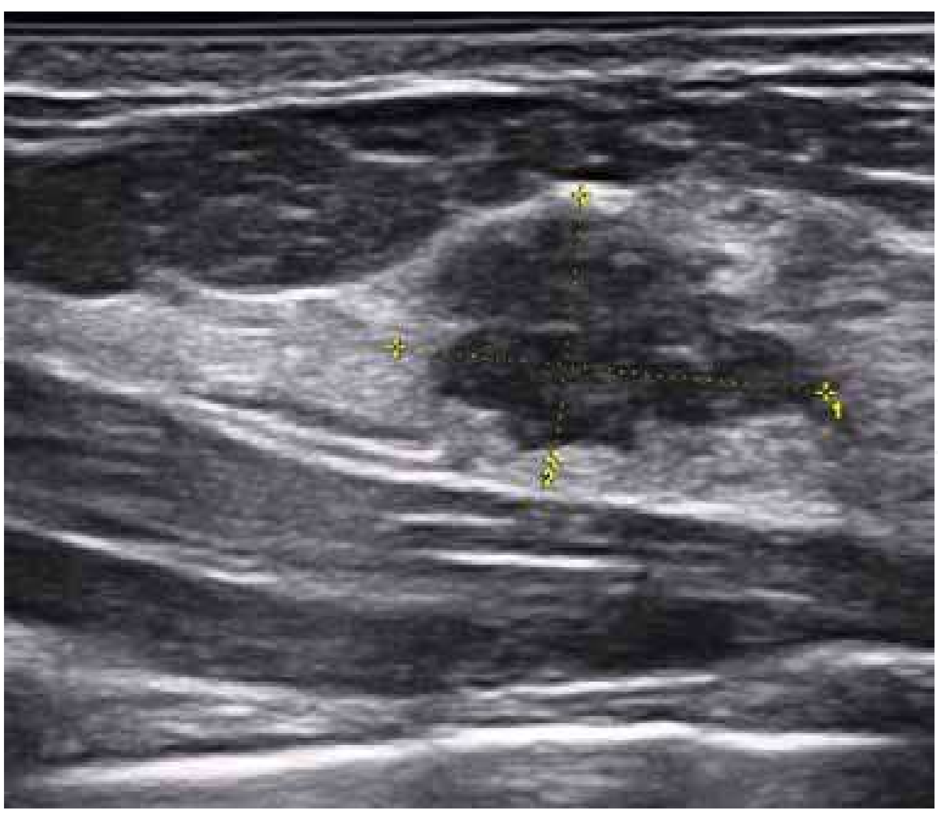


Fig. 13. Fibroadenoma with not smooth margins

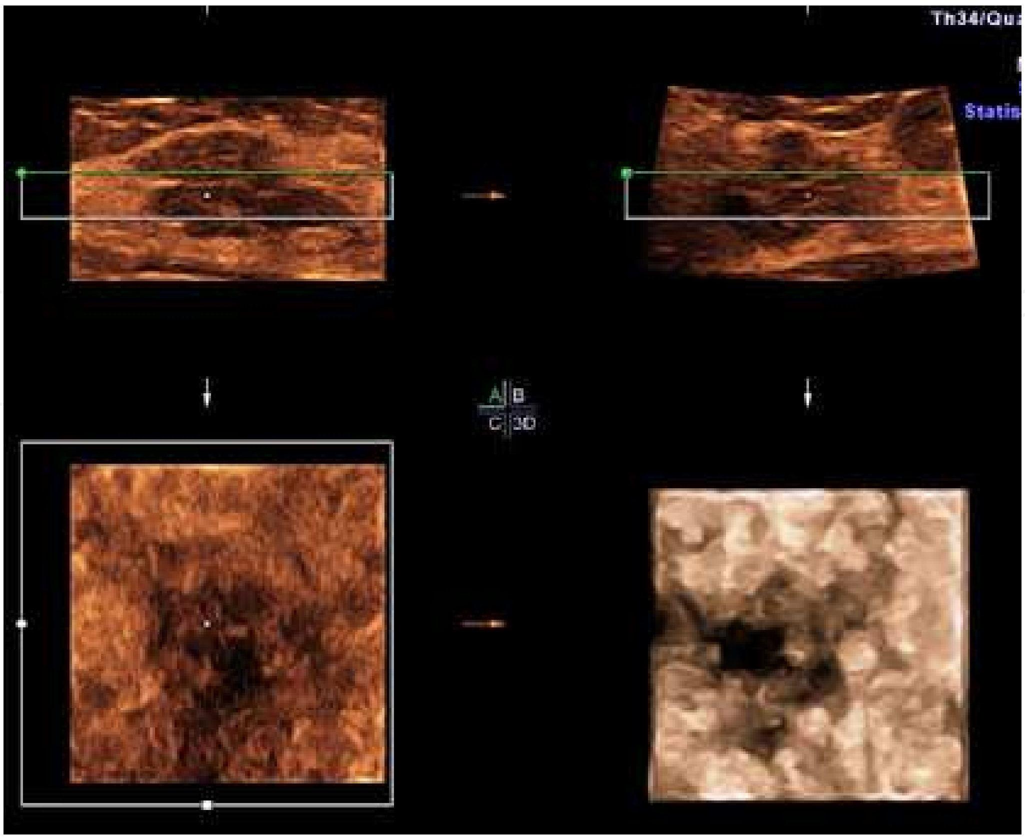


Fig. 14. Fibroadenoma of Figure 12 in 3-D mode with a canyon-like impression

Fig. 15. Inflammatory, invasive ductal carcinoma with smooth and distinct margins, at first misinterpreted as mastitis

4. Color Doppler

Though color Doppler is not routinely used in all institutions performing breast ultrasound, in our view color Doppler is fundamental as an additional criterion in discriminating malign from benign lesions (Weismann, 2006). But as it is with other marker: the fact of a proven vascularity generates not for itself a definite submission to a suspect cluster. It is important to observe the type of vascularization: color signals running straight into the lesion are a hint of malignancy, whereas angiogenesis round the border of a lesion is not. Of course the degree of vascularization is relevant. Vascularization within the lesion stresses suspicion of malignancy, but is not a verification of malignancy. The missing of vascularization on the other hand is not a proof of benignancy (Figs. 16, 17).

The detection of significant vascularization within a lesion shifts an otherwise benign looking lesion from BI-RADS 3 (probably benign) to BI-RADS 4 (suspect), proposing it to core biopsy.

Quantitative spectral Doppler has not proven to be of relevance.

5. 3-D ultrasound

3-D technique, now available in breast ultrasound by different manufacturer, is a valuable tool to obtain a detailed impression of the margins and the surroundings of a lesion in a view from above (the so called C-plane). Necessary is a special probe with automated acquisition of different planes. The option of Volume Rendering strengthens the spacious impression of the lesion with its relationship to the neighborhood. By use of 3-D technique additional criteria for lesion submission could be applied. Pattern of retraction or compression in the near surroundings of a lesion are of importance. Star-like retraction

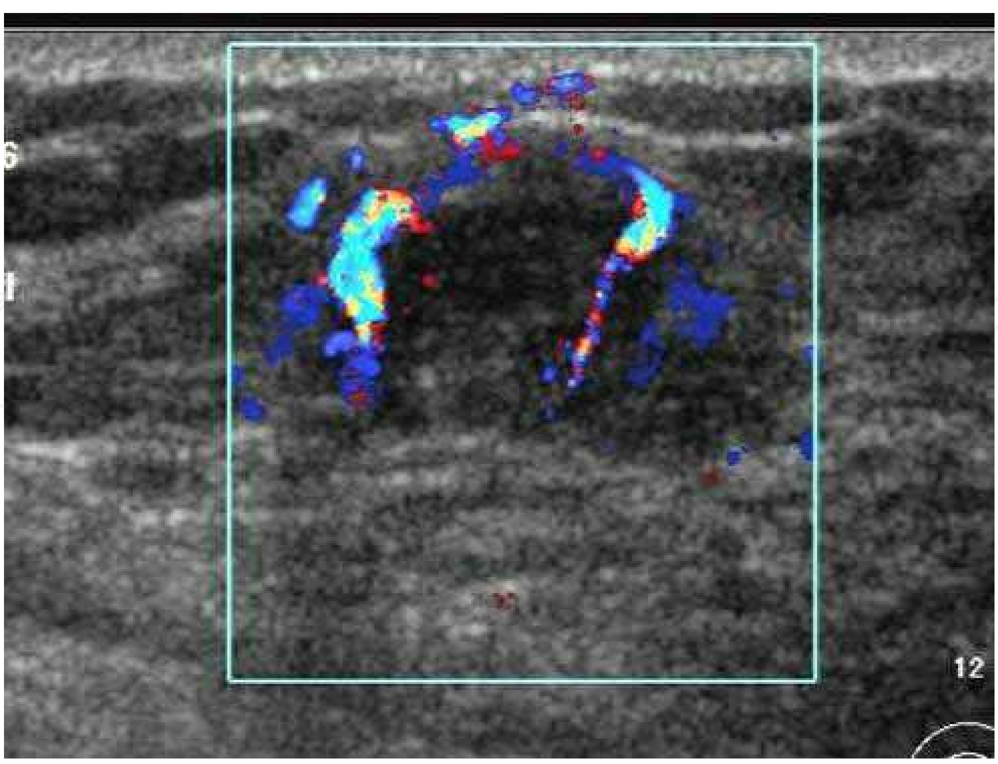


Fig. 16. DCIS (in pregnancy) with powerful vascularization

pattern is a hard marker for malignancy, whereas a compression pattern hints to benignancy (Fig. 19). With retraction pattern in the C-plane otherwise (in the A- and B-Plane) benign looking lesions are to subordinate to BI-RADS 4 (suspect) (Figs. 5, 17, 18).

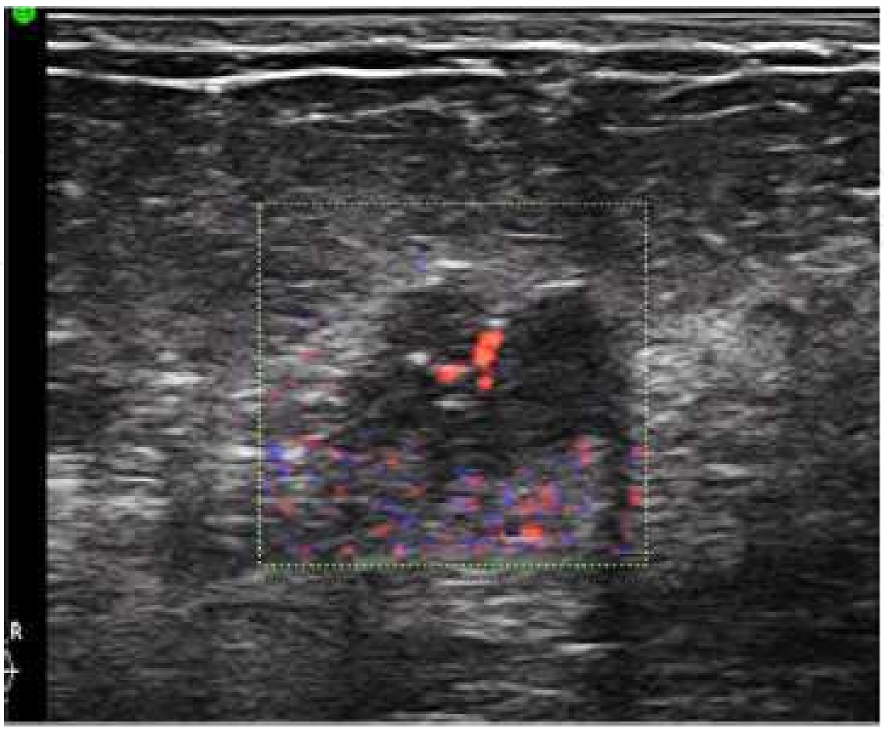


Fig. 17. Carcinoma: not easy detectable. Suspicion was strengthened by color Doppler

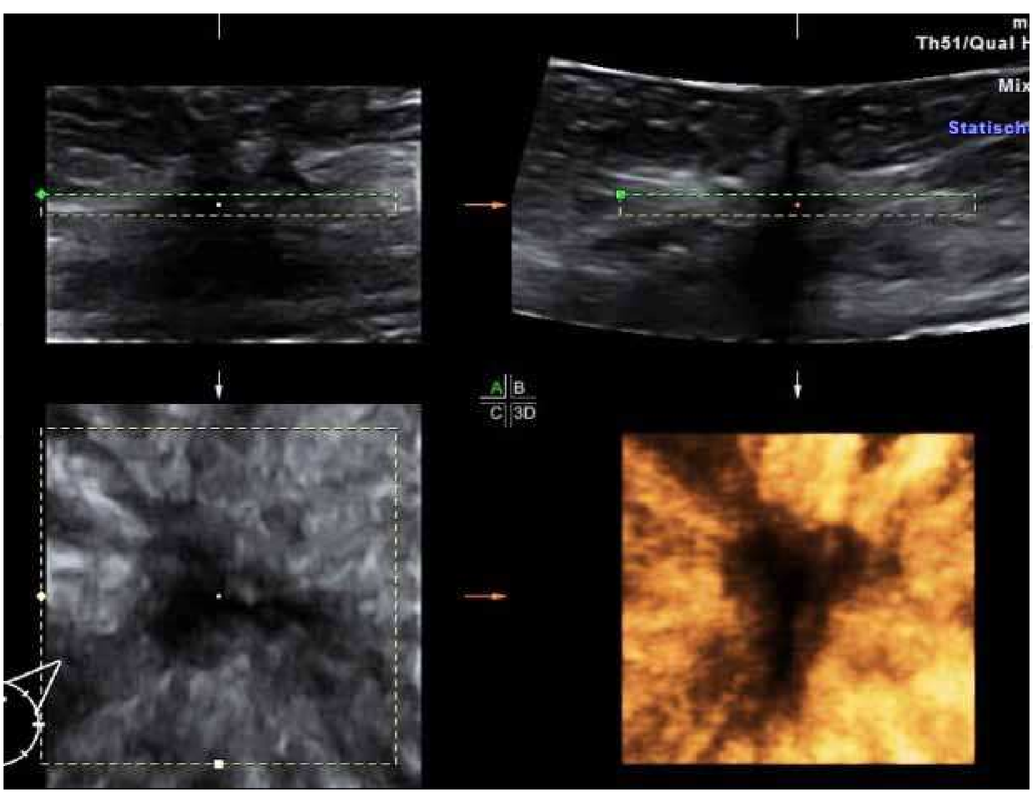


Fig. 18. Carcinoma of Fig. 17 in 3-D mode: suspicious retraction pattern

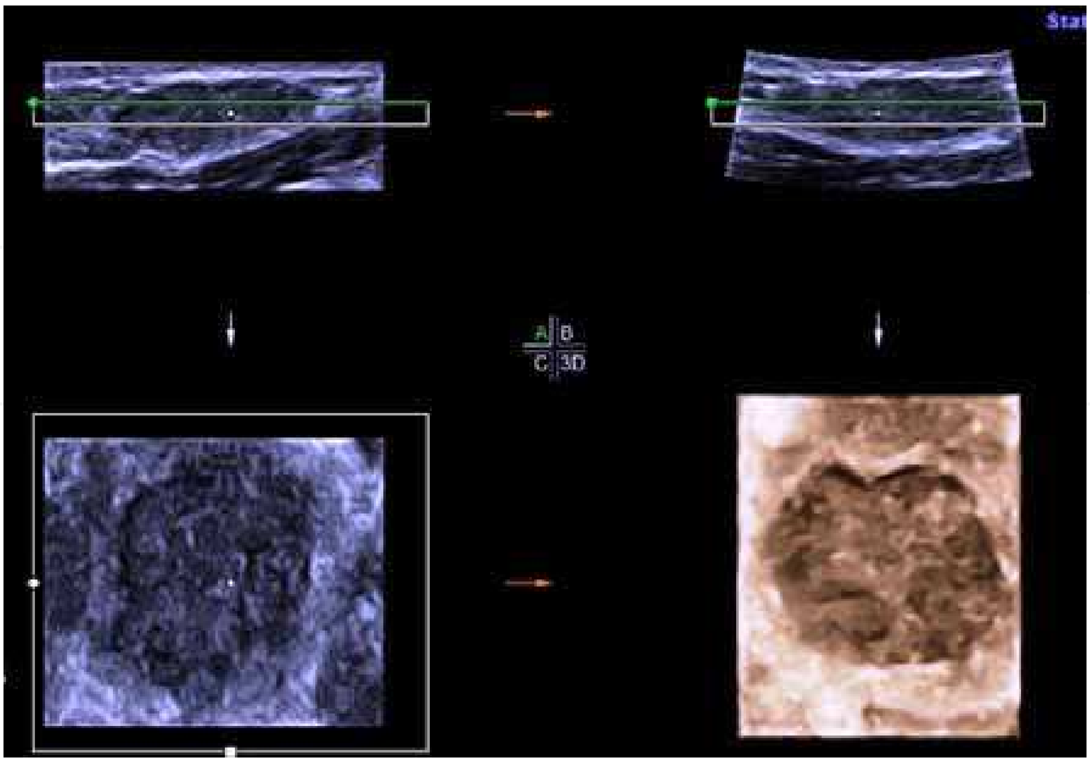


Fig. 19. Compression pattern of a benign fibroadenoma

However, carcinomas often may show indeterminate surrounding in the C-plane (not definite retraction phenomenon) as well. 3-D seems to be of similar value to color Doppler in differentiating masses further, detected previous in B-Mode (Weismann & Hergan, 2007).

The basic principle of sonographic diagnosis in breast ultrasound is to put all criteria in a synopsis or a mosaic, not to make a scarce diagnosis on one or two single signs.

6. Architectural distortion and structural disturbance

Architectural distortion is a term primary used in mammography and then became familiar in breast ultrasound too. In breast ultrasound it describes a well known hard marker for a malign lesion: the continuity of the glandular structure of the parenchyma is interrupted by an anechoic or hypoechoic irregular surrounded lesion (Figs. 3, 4).

What here is called "structural disturbance" is a far less obviously and more diffuse change in the echotexture of the gland of different extension. Echogenicity in local disturbances is somewhat more sonolucent, surroundings are not striking but poorly defined. It may correspond to a local discreet irregular course of the milk ducts. Such regions may represent only local mastopathic changes or preinvasive lesions like DCIS or so called "radial scars". In other cases even invasive carcinomas, i.e. triple negative (often mammographic occult) carcinomas may be present (Figs. 20, 21, 22, 23, 25).

To discover local "structural disturbances" whole breast scanning of each side is mandatory. It is necessary to take notice of the difference of a local disturbed region to the normal structure and echotexture of the individual breast and the difference to the other side. Specificity of breast ultrasound of such a lesion is not high, but this corresponds to the complexity of breast parenchyma in the sense of an extreme variable biological substrate.

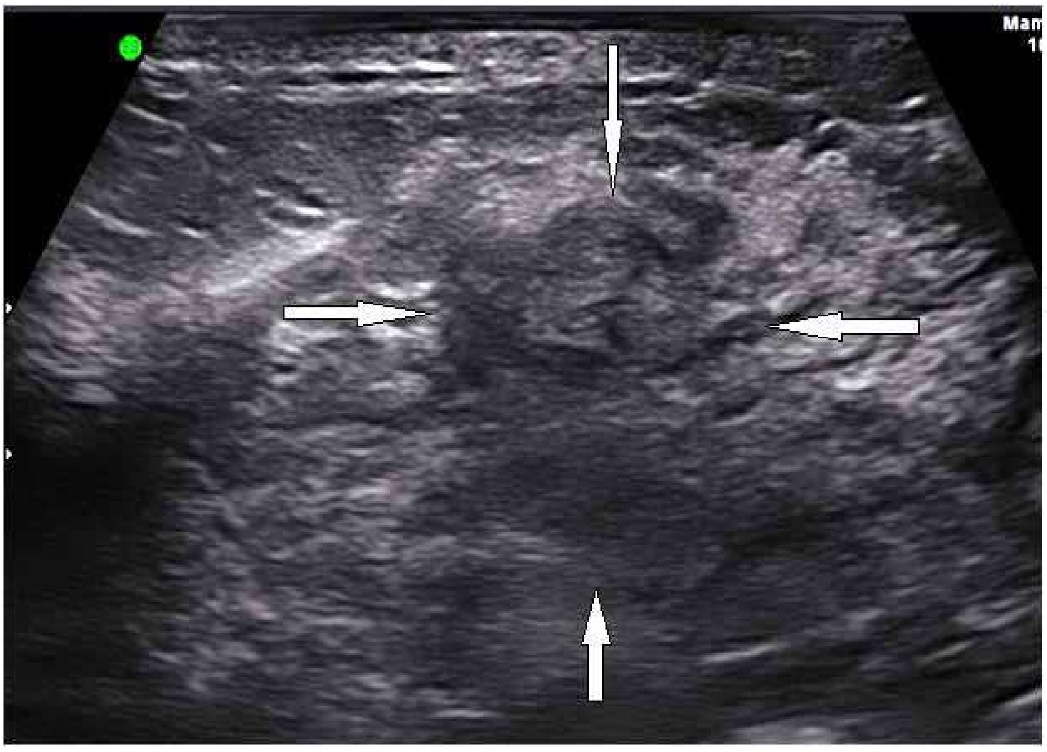


Fig. 20. Structural distortion: indistinct and ill defined, discreet sonolucent region in the center of the gland. The regular architecture of the gland-parenchyma is somewhat disturbed, but not disrupted: DCIS, in a dynamic examination better detectable than in a frozen picture

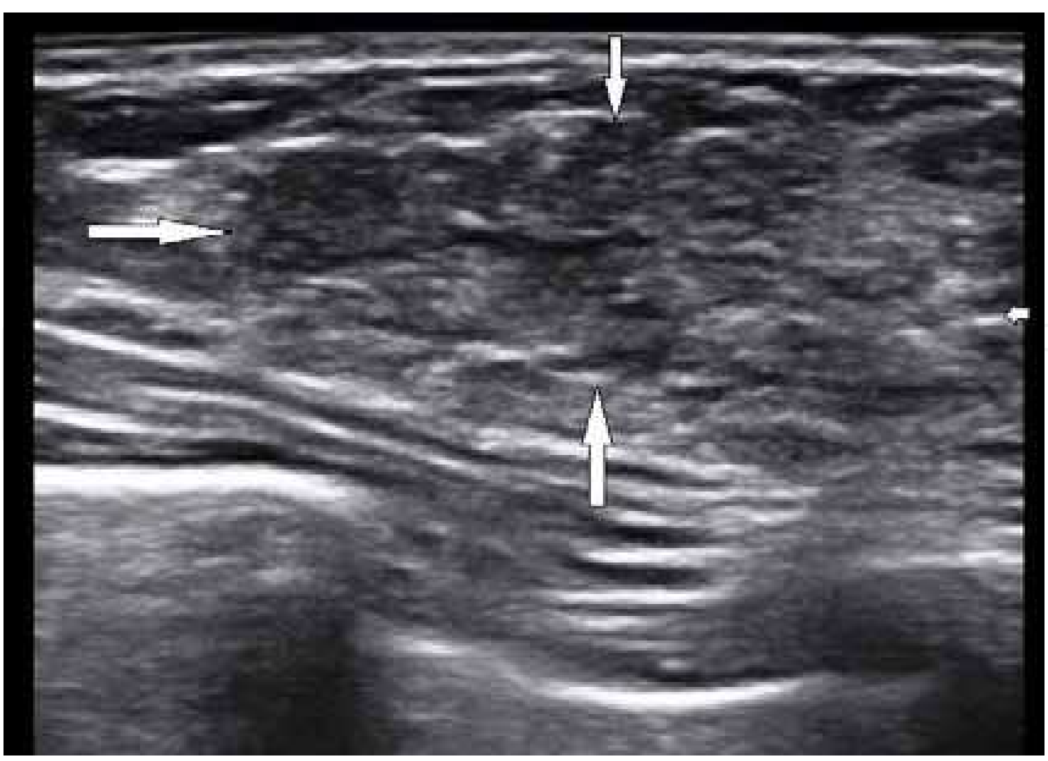


Fig. 21. DCIS in the outer upper region of the breast: not well defined extended region with lobulation and disturbed architecture

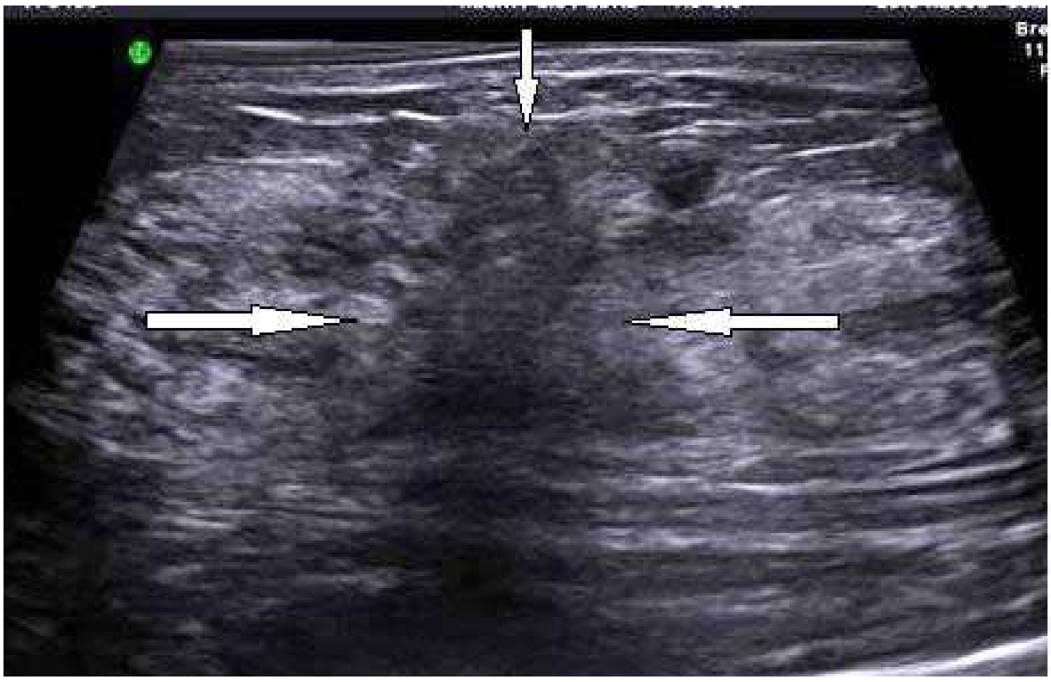


Fig. 22. A region with sonolucent structural disturbance

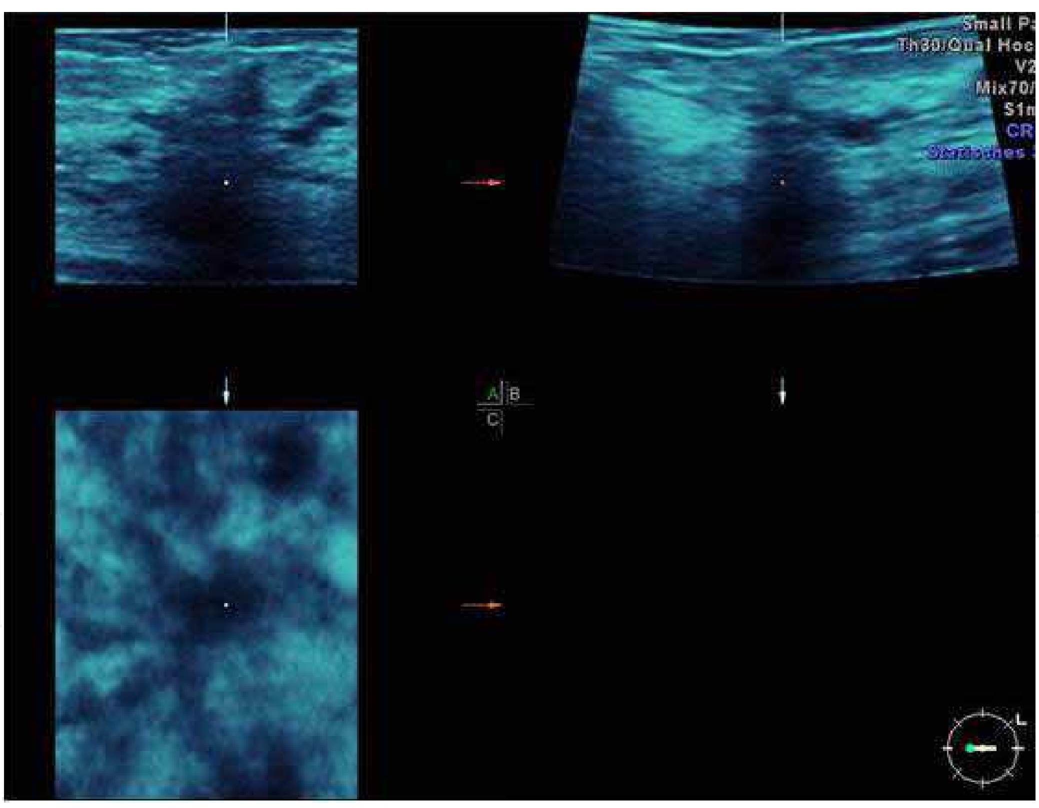


Fig. 23. Same lesion like Fig. 22: Suspicious retraction pattern in 3-D: “radial scar” with DCIS

Diagnosing and describing such local disturbances requires best technological equipment and some years of experience. However, this seems to be the most important field of progress in breast ultrasound: to become able to distinguish fine differences in the echotexture, not only to detect distinct striking masses.

It may be difficult and controversial to submit "structural disturbances" in BI-RADS 3 (probably benign) or 4 (suspect). At minimum such regions are to expose to complementary image modalities, i.e. mammography, perhaps MRI too and they are recommended for follow up. In more striking cases and high risk patients core biopsy should be preferred.

There is a need for further evaluation of the relevance of this type of ultrasound findings.

7. Ultrasound and DCIS (ductal carcinoma in situ)

In general ultrasound is thought to be not competent in detecting DCIS in comparison to mammography. That this is not true in some regards has been shown in the last decade. Breast ultrasound is especial important in detecting DCIS without microcalcifications. Today we do not know the real biological proportion of DCIS with and without microcalcifications (Hille et al., 2007).

The second entity is DCIS as a palpable lump, i.e. symptomatic DCIS. It could be shown that sonography is superior to mammography in detecting theses lesions (Yang et al., 2004), (Figs. 5, 16, 21).

Revealing "structural disturbances" seems to be of relevance to remove shortages of breast ultrasound in respect of diagnosing DCIS and to discover lesions that are otherwise, i.e. in mammography, occult (Figs. 9, 20, 22).

In a study evaluating the diagnostic competence of imaging methods in respect of breast carcinomas, which were operated, the sensitivity of sonography for DCIS was not far behind mammography (Berg et al., 2004)

Nevertheless, microcalcifications as a hint for DCIS is not reliable seen in ultrasound, when presenting without a mass (that means without sonolucent surroundings). This is the reason that - especially in a screening setting – sonography does not match mammography in diagnosing DCIS (Fig. 24).

8. Is breast ultrasound a screening tool?

The most controversial debate is going on about this topic. Most radiologists accept breast ultrasound mainly as an adjunct to mammography: mammography always first and then after - in cases of mammographical equivocal lesions or very dense breasts - ultrasound complementary. But that seems a traditional point of view and connected to specific interests. Ultrasound is time consuming, when performed by the physician in comparison to other modalities and is not well granted by insurances.

Under scientific and healthcare aspects the main point should be: What is the capacity of breast ultrasound in detecting early breast carcinoma in asymptomatic women? What we can say now: Breast ultrasound performed with high technology and in experienced hands at least has an equal, probably higher sensitivity for invasive carcinomas in comparison to mammography (Benson et al., 2004; Berg et al., 2008; Kolb et al., 2002) In respect to DCIS sensitivity is lower in published studies, but in this field there is evolvement, see above. Breast ultrasound can play an important role in detecting aggressive breast carcinoma not presenting microcalcifications like cases of "triple negative" types, often arising in younger women in dense breasts (Fig. 25). Recently investigations discovered that these cancers represent an important proportion of so called "interval cancers" in mammographic screening (Haakinson et al., 2010).

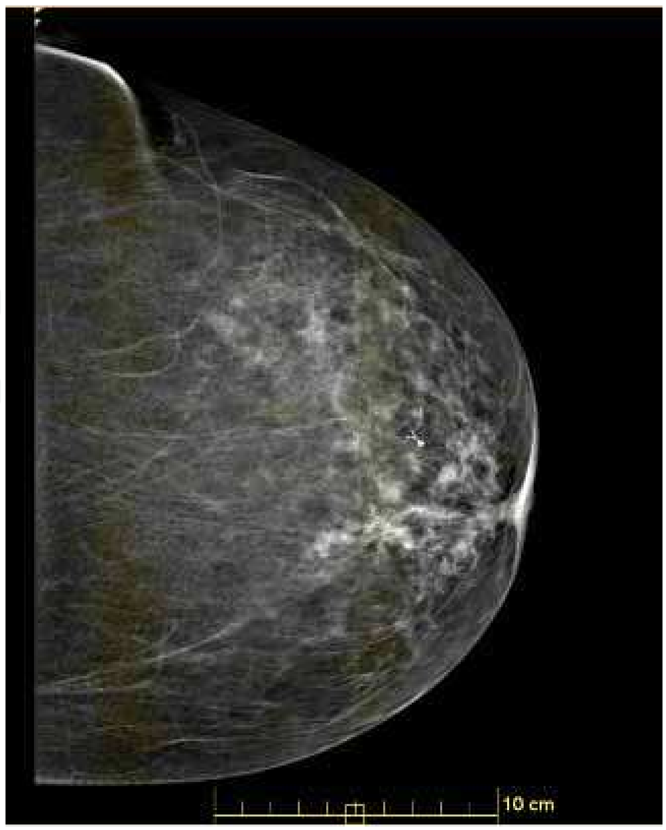


Fig. 24. Extended DCIS with microcalcifications in mammography, not visible in ultrasound

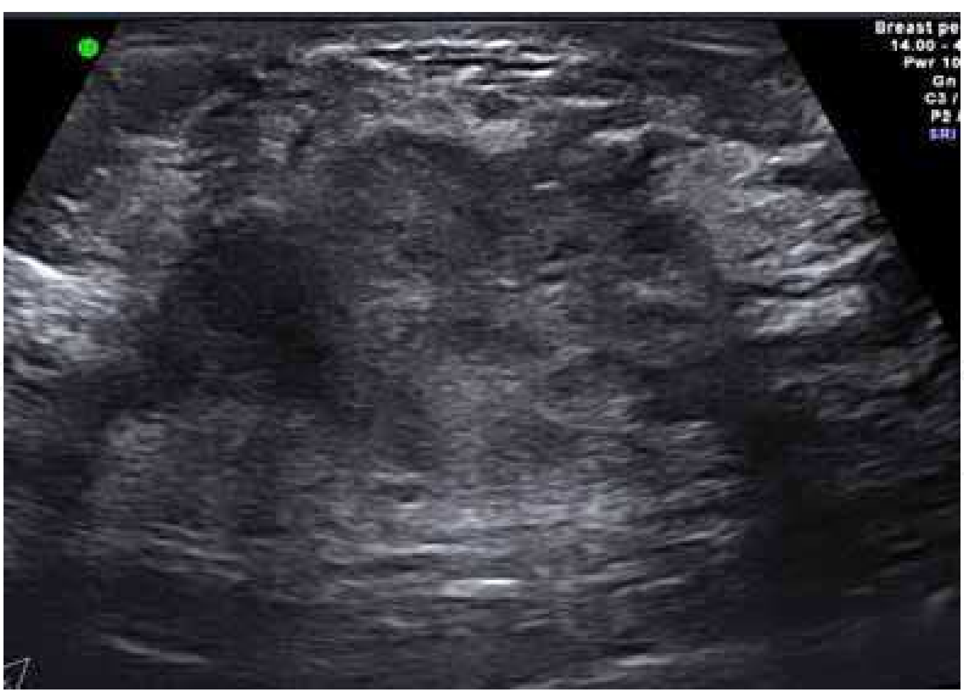


Fig. 25. “Triple-negative” carcinoma: extended, but not so obvious and with discreet structural changes

One important advantage of breast ultrasound is the absence of ionization. Sonography could be repeated without restriction.

Compared to mammography and MRI, ultrasound-machines are cheap. Special laboratories and assistants are not necessary.

But there are open questions and disadvantages of breast ultrasound. First, breast ultrasound is extremely dependant on the expertise of the physician and on the used technology. Second, handheld breast ultrasound does not produces an image document of the whole breast, that could be examined outside the laboratory. Therefore problems of quality control exist. New technologies of automated aquired 3-D volumes may remove these shortages in future. Third, there is a lack of randomizised trials comparing ultrasound versus other modalities.

Recently published studies demonstrate the feasibility of breast ultrasound as a preventive medical check-up in gynecological offices (Lenz, 2011; Madjar et al., 2010).

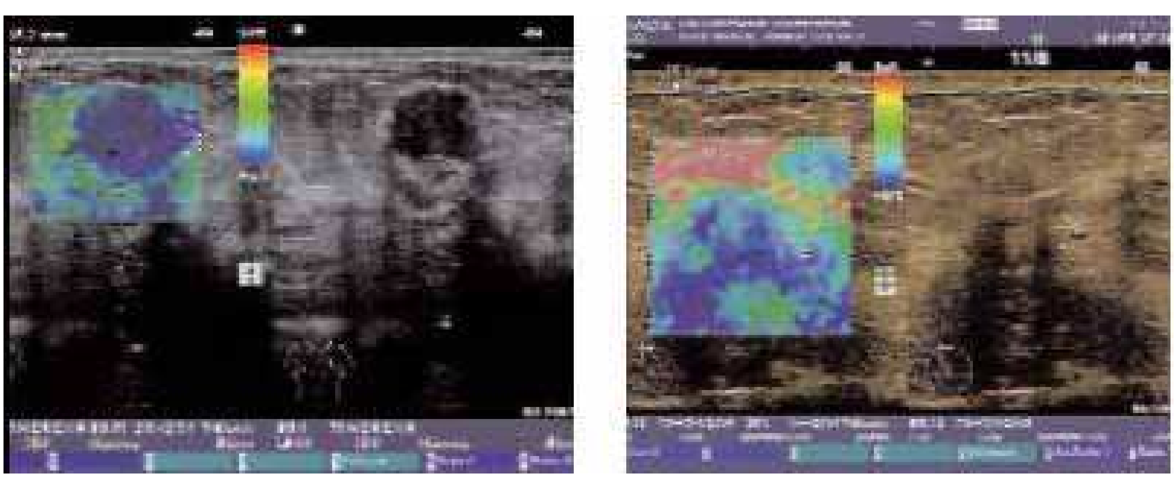
9. Areas of progress in breast ultrasound

9.1 Contrast- enhanced breast ultrasound

Contrast agents, intravenous applied, to improve sensitivity and specificity in breast ultrasound in detecting vascularization had been researched over a decade. Till now this - in sonography of the liver established – expanded procedure has not become a method of standard in breast ultrasound. The main reasons may be, that the procedure is more expensive and time consuming and is not suitable for breast-screening. A lesion which is to examine further with contrast agents is to detect in conventional B-Mode first. But there might be clinical indications for contrast agents instead of radioactive agents in future to test sentinel lymph nodes (Goldberg et al., 2011; Sever et al., 2011).

9.2 Elastography

At time manufacturer are equipping machines with elastography modules and some study groups are researching the potential role of this method. In conventional B-mode detected lesions were additionally examined in respect of the characteristics of stiffness. Different techniques, color coded or shear-wave techniques are used (Figs. 26a,b). Elastography is



(a) (b)

Fig. 26. (a) (b) Elastography of carcinoma, coded in blue. (Figures by courtesy of R. Ohlinger, center of breast diseases, university of Greifswald, Germany)

extremely observer dependent in applying pressure by the handheld probe. Results are different and today it remains unclear, if specificity of breast ultrasound in discriminating benign from malign lesions can increase with elastography in a reliable way, so that invasive biopsies could be spared (Baldwin, 2011).

Fig. 27. Automated 3-D system (ABVS), figure with license by courtesy of SIEMENS AG

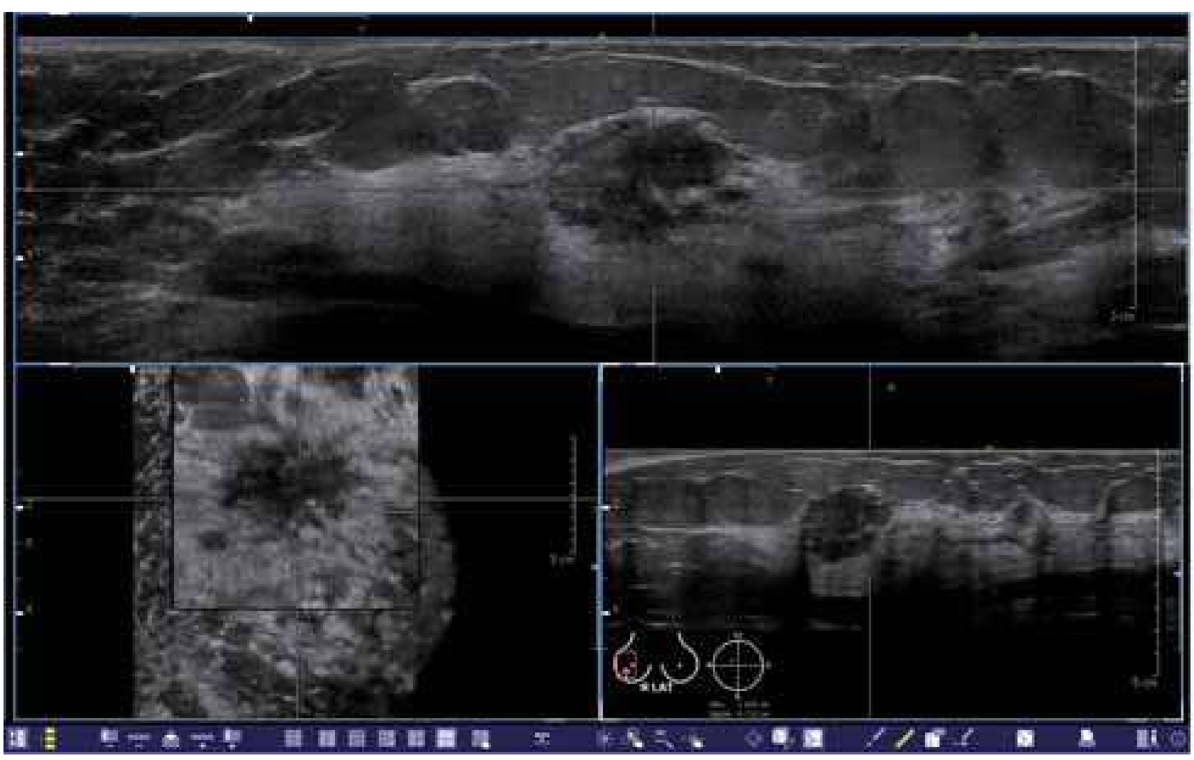


Fig. 28. Carcinoma in 3 planes bei ABVS, with license by courtesy of SIEMENS AG

9.3 Automated 3-D

Today a system is available, which acquires 3-D volumes of the whole breast (Fig. 27, 28). The resolution of the system is sufficient. The volume of the breast is acquired from different directions with a special probe by means of a large contact area. Than after the observer has to go through the whole volume to detect suspicious regions at the computer. The rendered C-Plane and the A- and B-plane could be presented in parallel on the screen. In future this step may be done by help of CAD (Computer Aided Detection). The acquisition itself could be done by assistant persons (sonographers).

Till now it is unclear, if an automated system can match traditional handheld breast ultrasound in accuracy performed by an expert and if the duration of the examination could be reduced. If suspect findings in the acquired volume are to check in handheld ultrasound afterwards, additional examination time would be required. There is a need for bigger trials (Chang et al., 2011; Moon et al., 2011)).

Advantages are the repeatability and the independence of the diagnostic procedure from patient´s presence. In aspects of a possible ultrasound screening this advantage may be helpful.

10. Conclusion

Breast ultrasound is a valuable tool for diagnosing breast carcinoma as well as benign diseases of the breast. Breast ultrasound could not only used as an adjunct to mammography and in symptomatic cases, but could probably used as a screening tool in asymptomatic women. Especially in women with dense breasts sonography will overcome mammography with a higher detection rate for invasive carcinomas.

Of special importance will be the capacity for detecting local “structural disturbances” as a hint for hidden malignancies.

Color Doppler and 3-D mode had proven to be of importance. Elastography has to demonstrate this in future.

A high technological standard and a very good experience of the examiner are prerequisites.

11. References

American College of Radiology (ACR) (2003). *ACR-BI-RADS® - Breast Imaging Reporting and Data System (BI-RADS™)*. Breast Imaging Atlas. 3rd ed. Reston (VA): ©America College of Radiology

Baldwin, P. (2011). Breast ultrasound elastography. *Radiologic Technology*, 82: 347M-365M

Benson S.R.; Blue J.; Judd K.; et al. (2004) Ultrasound is now better than mammography in detection of invasive breast cancer. *Am J Surg,* 188: 381-385

Berg, W.A.; Gutierrez, L.; Ness Aiver, M.S.; Carter, W.B.; Bhargavan, M.; Lewis, R.S.; Ioffe, O.B. (2004). Diagnostic accuracy of mammography, clinical examination, US, and MR imaging in preoperative assessment of breast cancer. *Radiology,* 233: 830-849

Berg, W.A.; Blume, J.D.; Cormack, J.B. et al. (2008). Combined screening with ultrasound and mammography vs. mammography alone in women at elevated risk of breast cancer. *JAMA,* 299: 2151-2163

Chang, J, M.; Moon, W., K.; Cho, N.; Park, J, S.; Kim, S. J. (2011). Breast cancers initially detected by hand-held ultrasound: detection performance of radiologists using automated breast ultrasound data. *Acta Radiol,* 52: 8-14

Goldberg, B., B.; Merton, D., A.; Liu, J., B.; Forsberg, F.; Zhang, K.; Thakur, M.; Schulz, S.; Schanche, R.; Murphy, G.,F.; Waldman, S., A. (2011). Contrast-enhanced ultrasound imaging of sentinel lymph nodes after peritumal administration of Sonazoid in a melanoma tumor animal model. *J Ultrasound Med,* 30: 441-453

Haakinson D., J.; Stucky, C., C.; Dueck, A., C.; Gray, R. J.; Wasif, N.; Apsey, H., A.; Pockaj, B. (2010). A significant number of women present with palpable breast cancer even with a normal mammogram within 1 year. *Am J Surg,* 200: 712-717

Hackelöer, B.J, Duda V. & Lauth G. (1986). *Ultraschall-Mammographie*. Springer, ISBN 3-540-16233-X, Berlin

Hille, H.; Vetter, M.; Hackelöer, B., J. (2007). The Suitability of High-Resolution Ultrasound for the Detection of DCIS. *Ultraschall in Med,* 28: 307-312

Jellins, J.; Kossof, G.; Buddee F.,W.; Reeve T., S. (1971). Ultrasonic visualization of the breast. *Med Journ of Australia,* 1: 305-307

Kobayashi, T. (1974). Clinical evaluation of Ultrasound techniques in breast tumors and malignant abdominal tumors. *Excerpta medica,* 191-198

Kolb, T.; M.; Lichy, J.; Jeffrey, H. (2002). Comparison of the performance of screening mammography, physical examination, and breast ultrasound and evaluation of factors that influence them: An analysis of 27.825 patient evaluations. *Radiology,* 225: 165-175

Lenz, S. (2011). Breast ultrasound in office gynecology –Ten years of experience. *Ultraschall in Med,* 32: S3-S7

Madjar, H.; Ohlinger, R.; Mundinger, A.; Watermann, D.; Frenz, J. P.; Bader, W.; Schulz-Wendtland, R.; Degenhardt, F. (2006). BI-RADS-Analogue DEGUM Criteria for Findings in Breast Ultrasound - Consensus of the DEGUM Committee on Breast Ultrasound. *Ultraschall in Med* 27: 374-379

Madjar H., Mendelson E., B. (2008). *The practice of breast ultrasound.* 2nd revised edition. Thieme, ISBN 10-313124342, Stuttgart

Madjar, H.; Becker, S.; Doubek, K.; Horchler, T.; Mendoza, M.; Moisidis-Tesch, C.; Näther, B.; Niebling, K.; Pröls, U.; Schardt, A.-R.; Ulrich, S.; Zahn, U. (2010). Impact of Breast Ultrasound Screening in Gynecological Practice. *Ultraschall in Med,* 31: 289-295

Moon, W., K.; Shen, Y., W.; Huang, C., S.; Chiang, L., R.; Chang, R., F. (2011). Computer-aided diagnosis for the classification of breast masses in automated whole breast ultrasound images. *Ultrasound Med Biol,* 376: 539-548

Sever, A., R.; Mills, P.; Jones, S., E.; Cox, K.; Weeks, J.; Fish, D.; Jones, P., A. (2011). Preoperative sentinel node identification with ultrasound using microbubbles in patients with breast cancer. *AJR,* 2: 251-256

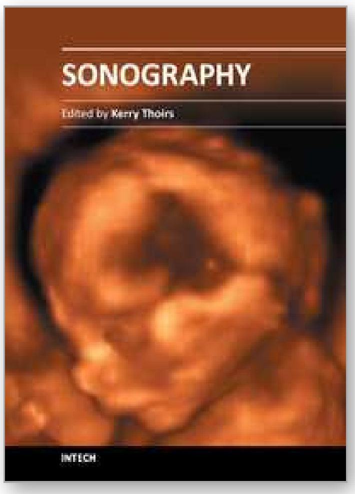
Stavros A., T. (2004). *Breast ultrasound.* Lippincott, Williams & Wilkins. ISBN 0-397-51624-X, Philadelphia

Teboul, M.; Halliwell, M. (1995). *Atlas of ultrasound and ductal echography of the breast*. Blackwell, ISBN 0-632-03329-0, London

Weismann C. (2006). Role of colour Doppler ultrasound in breast imaging. *EJC Supplements,* 4:41-42

Weismann C., Hergan K. (2007). Current status of 3D/ 4D volume ultrasound of the breast. *Ultraschall in Med* 28: 273-282

Yang, W.T.; Tse, G.M.K. (2004). Sonographic, mammographic and histopathologic correlation of symptomatic ductal carcinoma in situ. *AJR,* 182: 101-110



Sonography

Edited by Dr. Kerry Thoirs

ISBN 978-953-307-947-9
Hard cover, 346 pages
Publisher InTech
Published online 03, February, 2012
Published in print edition February, 2012

Medical sonography is a medical imaging modality used across many medical disciplines. Its use is growing, probably due to its relative low cost and easy accessibility. There are now many high quality ultrasound imaging systems available that are easily transportable, making it a diagnostic tool amenable for bedside and office scanning. This book includes applications of sonography that can be used across a number of medical disciplines including radiology, thoracic medicine, urology, rheumatology, obstetrics and fetal medicine and neurology. The book revisits established applications in medical sonography such as biliary, testicular and breast sonography and sonography in early pregnancy, and also outlines some interesting new and advanced applications of sonography.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Heino Hille (2012). Advances in Breast Ultrasound, Sonography, Dr. Kerry Thoirs (Ed.), ISBN: 978-953-307-947-9, InTech, Available from: http://www.intechopen.com/books/sonography/advances-in-breast-ultrasound

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