Improvements of the US BI-RADS Assessment – A Necessity for a Non-Invasive Positive and Differential Diagnosis of Breast Cancer. Application of the New Full Breast Ultrasonography Concept

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ABSTRACT

Objective: Despite the engineering progress, the diagnosis of breast cancer (BC) is unsatisfactory due to less specific descriptors and non-anatomical scanning and interpretation, proving that physicians lag behind technology. We aimed to improve the noninvasive positive and differential diagnosis of BC using modern technology applied to the new integrative concept of Full Breast Ultrasonography (FBU): anatomical radial scanning, color Doppler and Strain Sonoelastography (SE).

Methods: We analyzed retrospectively 1841 consecutive FBUs in 1333 patients from screening, diagnosis, or follow-up, in two centers. We searched three descriptors: the ductal connection of the lesions, the incident angle of the plunging artery, and the SE (Ueno score). We compared the initial BI-RADS assessment with pathological reports or follow-up examinations of benign findings.

Results: Radial scanning and ductal connection provided a standardized examination of the entire breast, with 100% sensitivity, early detection, precise location, and easy follow-up. We found no correlation BC-Density-Age, but a significant association BC-Benign pathology. The benign lesions, usually multiple, associated the proliferative and secretory types. The incident angle of the plunging artery was the best descriptor for the BC mass-type and associated with a score 4 or 5 Ueno led to PPV of 97.01%, specificity of 99.67%, and accuracy of 99.69%. Inflammatory BC illustrated high glandular strain and diffuse hyperemia.

Conclusion: FBU had optimal accuracy, independent of the mammographic model, in screening and diagnosis. The vascular angle correlated with strain SE (adapted to the breast heterogeneity) raised the specificity and is recommended for inclusion in US BI-RADS.

Keywords: breast cancer; color Doppler; Strain Sonoelastography; Ultrasonography.

I. INTRODUCTION

Diagnosis and treatment of common diseases in conditions of disruptive events of large populations, such as epidemic or pandemic diseases, natural disasters or extensive wars, can suffer significant restrictions and difficulties. In quiet times, medical resources are still limited for many underdeveloped countries and for significant population groups in the advanced ones. Thus, extensive medical examinations are not available for everyone, always and everywhere. However, most examinations have significant limitations and some additional diagnostic techniques are required for the final diagnosis, increasing the final costs and further restricting availability. This is the case with the diagnosis of breast cancer (BC), which ranks first among all woman cancers, with an incidence of 25.4% in 2018 [1].

The radiological-imaging methods used in the positive and differential diagnosis of BC are expensive, not available for all, and must be followed by breast biopsies. All techniques, including mammography with its modern developments (iodinated intravenous contrast agents, Tomosynthesis), breast Magnetic Resonance Imaging (MRI) with controversial paramagnetic contrast agents or their replacement by diffusion-weighted imaging (DWI), ultrasound (US) with or without contrast enhancement (CEUS) or Automatic Breast Volume Scanner (ABVS) and, finally, different types of Sonoelastography (SE), have significant limitations:

1. Non-anatomical examination techniques, with breasts distortions, and scanning in orthogonal planes similar to the regional examinations in computed tomography or MRI (chest, abdomen, spine, limbs), but useless for specific organs (breast, heart, thyroid, uterus, kidneys, etc.);

2. Incomplete organ exploration, resulting in low sensitivity, because of partial volume omissions for large breasts in mammography, frequent omissions in classical US
due to slipping of the short linear transducer on the convex and sometimes large surface of the breast and distortions with under-examination in MRI due to pronation and breast coils, fixed or variable with arbitrary geometry;

3. Neglect of breast anatomy represented by radially oriented mammary lobes, which may overlap but rarely communicate, and are covered and mixed with various amounts of fatty tissue, as demonstrated Sir Cooper since 1840 [2]. Indeed, a mammary lobe is structured by a ductal-lobular tree representing the parenchyma that is surrounded by specific glandular stromal tissue containing stromal cells, connecting fibers, vessels and nerves. In fact, in routine MRI or US, only the central peri-areolar ducts are mentioned if they are enlarged, neglecting the terminal ductal-lobular units (TDLUs), the sites of initiation of most benign and malignant breast lesions, actually clearly illustrated by the radial and antiradial US scans using high-frequency linear transducers. Mammography cannot demonstrate either the normal breast parenchyma due to its low absorption of low-energy X-rays, nor premalignant and malignant findings that do not develop microcalcifications or stromal spicules. The mammographic descriptor “fibro-glandular structure” borrowed by the US and MRI is vague and without anatomical significance. Shear Wave Elastography (SWE) completely ignores both the anatomy of the breast and the pathological composition of breast cancer, emphasizing the value of the peripheral stiff ring sign representing the stromal reaction and underestimating the importance and size of the central softer area given by the malignant focus, with importance in targeted biopsy. Therefore, the sensitivity and specificity are low for all these breast diagnostic techniques used worldwide.

4. A radiological lexicon based on X-ray absorption and flat projection of an entire breast volume in mammography, illogically borrowed and applied to sectional techniques in US and MRI, which are based on different physics, the reflection of the ultrasonic waves or the precession of the excited protons in a magnetic field, respectively. Thus, the descriptors are not related to the anatomical and pathological findings of each technique, which implies less specificity and, consequently, the suspicious findings require complementary methods and additional biopsies before the final evaluation, according to Breast Imaging Reporting and Data System (BI-RADS) per the ACR recommendations [3]. Because not all cancers enhance rapidly in breast MRI, the types of curves have moderate specificity, while breast architecture is described with nonspecific descriptors: “breast composition”, “fibro-glandular tissue”, “background parenchymal enhancement” etc.

In short, after using complementary radiological and imaging techniques, the suspicious findings require the mandatory biopsy, with its high costs and risks; in the U.S. alone there are an estimated 800,000 unnecessary benign/1,000,000 annual breast biopsies [4], with increased anxiety and morbidity in patients, increased health care costs - $ 8 billion spent annually on breast diagnostic procedures [5], and an unchanged future risk of BC after all negative examinations.

The US BI-RADS system [6] is actually the best standardized diagnostic and reporting tool, however, it has significant inconsistencies:

• “completely fatty composition” of the breast in women is never possible, even for advanced glandular atrophy, because the thin channels and the remaining lobules represent the basis of BC in such cases;
• the descriptor “fibro-glandular” is vague, because the mammary parenchyma is not illustrated and the stroma is reduced to a fibrous component;
• “architectural distortion” and “radial scars” are not similar in the projection of a compressed breast of mammography and in a sectional view in US or MRI, etc.

Other limitations of the current BI-RADS system are some underestimations for the US technique: “calcifications” are classified according to their location “in mass, out of mass and intraductal”, but the mass itself is not located intralobar (of mammary origin, connected with the ductal-lobular tree) or outside the mammary lobe (of non-mammary etiology, such as lipomas, cytosteatonecrosis, neuromas, lymphomas, foreign bodies, hematomas). Moreover, the vascular evaluation, briefly classified as “absent, internal, in the rim”, actually has a major value in the differential diagnosis in both contrast MRI and color Doppler, as we will describe below. The new SE is not standardized, it is wrongly applied as an independent or optional technique and with different mechanical procedures, either strain SE or Share Wave Elastography (SWE), so its value is not related to the main group of descriptors, well specified by Stavros before the US BI-RADS system [7].

Consequently, the specificity of the findings is low and the differential radiological-imaging diagnosis of breast diseases has been neglected, the physicians remaining behind the modern developments of technical engineering. Thus, official courses state the sensitivity of mammography between 48% and 75% depending on breast density, while ABVS has increased the recalls number. All authors agree with low sensitivity and PPV for the main descriptors of breast sonomorphology, as benign and malignant findings overlap.

This study is justified by the followings:
• High incidence of BC: In 2020, it was estimated that 276,480 new cases of invasive BC will be diagnosed in U.S. women, along with 48,530 new cases of BC in situ. Approximately 1 in 8 women [12.4%] will develop invasive BC during their lifetime [8].
• Extension and overall relative survival rate of 5 years are considered 99% for localized, 85% for regional and 27% for distant disease [9], so early detection is mandatory.
• Malpractice suits: the breast is listed as the first organ for malpractice claims [10].
• Cost-effectiveness high rate for screening and diagnosis of BC.

II. PURPOSE

We aimed to improve the non-invasive radiological-imaging positive and differential diagnosis of BC, using the US modern technology and the US BI-RADS system according to the Vth Edition [6], but applying the new integrative concept of Full Breast Ultrasonography (FBU), represented by the anatomical radial and antiradial ductal scanning of the whole breast and of the satellite lymph nodes, completed with color Doppler detailed analysis and Strain SE [11].
III. METHOD

This study was approved by our institutional review board who granted a waiver of consent. All patients provided a signed informed consent, and no special funding or any conflict of interest involved this study.

A retrospective research implied 1841 consecutive FBU in 1333 patients, referred as screening, diagnostic or follow-up examination performed in two imaging centers, between January 2016 and March 2020, using ultrasound equipments of different manufacturers, with linear transducers of 5cm length and a possibility of virtual convex/trapezoidal scans (ML 6-15MHz, Voluson E8 Expert, GE Healthcare, Tiefenbach, Austria and, respectively, EUP-L74M 3-15 MHz, Hitachi HI VISION Avius ®, Germany).

The gender distribution included 1312 female and 21 male patients, aged between 1 and 85 years. The FBU was used as first-intention examination or as secondary independent technique, for the whole breasts and the satellite lymph nodes (axillary, supra- and sub clavicular, internal mammary, thoracic lateral), and the results were further compared with the other examinations provided. The radial and antiradial scanning and interpreting was implemented after the “Ductal Echography” of Teboul [12]: each main duct with its branching tree was evaluated from the nipple to the periphery, inside the anatomical limits of the breast, and a general assessment of the fatty amount, breast parenchyma (galactophorous ducts and lobules) surrounded by glandular stroma and the salient vasculature was mentioned at the beginning of the examination report. The Doppler and Strain SE were applied using the largest limits of the field-of-view, for better discrimination of abnormal findings from the background appearance. The panoramic views (sie-scape technique) or 4D acquisitions were sometimes acquired as illustrations for the clinicians.

We used the US BI-RADS assessment supplemented by three main descriptors for the positive and the differential diagnosis of any findings:

1. The ductal connection of the abnormal finding upon Teboul [12], justified by the ductal origin of 80% BC and lobular type of 15% cases: present for breast lesions or absent in extramammary masses;

2. The incident angle of the plunging artery for any focal lesion/mass, according to Kajirakoaka et al. [13], present only in malignancies and absent in the benign masses, which may have a peripheral vasculature, in rim, with an acute angle of penetration; for the non-mass-like BC the relative increased vasculature in the glandular pathological area was considered positive criterion [14];

3. The Strain SE with the Ueno (Tsukuba) scoring [15], [16]. The cut-off value of the strain ratio/ fat-to-lesion ratio (FLR) was 4.70, based on previous studies, the most benign lesions presenting less ratio value, and the malignant ones a higher value. However, SE itself cannot specify malignancy, but was correlated with the US BI-RADS descriptors and completed with the color Doppler evaluation. The Strain SE scoring was extended in our practice with the blue-green-red (BGR)-summation score for the pseudo-nodular fibro-microcystic dysplasia, complex cysts, postsurgical or posttraumatic heterogeneous fluid collections.

The statistical analysis was based on the comparison of the initial US BI-RADS assessment with the pathological reports after surgical excisional biopsies for the small, infra-centimetric suspect findings or, respectively, after core needle biopsies for the larger, palpable or mammographic centimetric lesions, and for the extended diseases (multifocal and multicentric cancers). The benign findings had routine follow-up examinations, while the small, of less 10mm findings with incomplete suspect characterization assessed categories 4A, 4B or 4C, had short-term follow-up FBU of 3-6-month as the preferred option (Fig. 1a).

![Image](552x477)

Fig. 1. Case distribution in the US BI-RADS assessment supplemented with the three descriptors: ductal connection, incident angle of the plunging artery, and Strain SE (a). The age distribution of suspected and confirmed cases of BC demonstrated the natural course of the disease, with incomplete descriptors in patients under 40 years of age (BI-RADS 4A and 4B) and more pronounced descriptors for malignancy after 41 years (BI-RADS 4C, 5 and 6) (b).

IV. RESULTS

From all FBU, 77% represented single examination, and 23% two or multiple US follow-up. The age-related distributions of BC by FBU was according with the literature, but with good detection in dense breasts in young women or after hormonal treatments (Fig. 1b).

From all 1841 FBU, 11 examinations were assessed US BI-RADS category 6, representing follow-up for confirmed BC before surgical treatment (9 patients) or for oncological evaluation in two patients with metastases following palliative treatment. 7 examinations were assessed US BI-RADS category 0 (0.38%). From the rest of 1823 FBU, 134 were classified as suspect of various risk (US BI-RADS categories 4A, B, C and 5) and the rest of 1689 FBU were
assessed benign findings (BI RADS categories 1, 2, 3) (Fig. 2).

From the total of 1333 patients, a pathological report was available for 134 patients assessed with the categories 4 and 5 BI RADS after the FBU examination, and for 86 patients assessed in the benign categories with surgical treatment for large fibroadenomas, large/symptomatic cystic dysplasia, hamartomas (3 cases) or benign phyllodes tumors (2 cases).

The rest of patients with normal or typical benign findings had no suspect evolution after at least 12 months interval. For all patients examined by FBU, the sensitivity was 100%, all lesions visible on mammography, MRI or clinically detected being independently described by US.

Inversely, some cancers were detected only by FBU, such as small less 8mm cancers with unipolar vessel of incident angle and SE with score 3 or 4 Ueno (4 cases), or small multifocal invasive ductal or lobular cancers with distant metastases (2 cases) and malignant mastitis (2 cases, including a patient with physiological lactation and satellite lymphadenopathy).

The attitude for the unpalpable less 8mm cancers was either a short interval follow-up of 3-6 months, and if proved imaging evolution (increased vasculature, strain, size), a skin mark under US guidance was made followed by surgical excision biopsy, or the initial exam was accompanied by a skin mark if other signs of extension were present (lymphadenopathies, distant metastases salient on US, including sternal-costal joint, pleural or subpleural lung changes), followed by core biopsy.

The specificity was 99.67%, the accuracy 99.69%, with a PPV of 97.01% and NPV of 100%. The results seem unbelievable as compared with other techniques, but are appropriated to other previous multi-operator studies based on the new concept of the FBU, and with the previous publications of the inventor Teboul; his technique, with a United States Patent in 1998 [17], reported an accuracy over 97% before the integration of the SE, and was developed by his promoters, synchronously with the engineering technical development [18]. Moreover, the three descriptors presented above added to the US BI-RADS assessment allowed a better differential diagnosis. The combined criteria of FBU were useful, but the incident angle of the plunging artery was the most important for the malignant assessment; the tumor size correlated with the number of vascular poles, the vessels diameter and the presence of aliasing. Some hypo vascular the cancers had small vessels that were difficult to detect, except for menus such as “Superficial” or “Nearfield”; when salient, the new-formation vessels always had an incident angle, useful for the differential diagnosis with a solid benign mass. Similarly, peripheral nodal pericapsular new formation vasculature with increased strain was more significant for the lymph nodes metastases than the cortical thickness or the nodal transverse diameter recommended in the worldwide practice.

We found 40% cases of multifocal, multicentric or extended malignancies, some undetected with other techniques; the multifocal cancers were considered when issued in the same mammary lobe, with proved ductal connection, the secondary and tertiary foci following the smallest intraductal pressure upon Teboul, and corresponding to the thick lobe theory related to the large section in pathology according to Tot [19], [20]; the size of the tumor foci was proportional with their new-formation vasculature (Fig. 3).

The multicentric cancers were considered if present in different mammary lobes, because they usually demonstrate pathologically different malignant type, different genomic profile, unrelated to quadrants. The BI-RADS classification of multiple cancers by quadrants is arbitrary and may induce inappropriate surgical treatment, unnecessary segmental excision of healthy lobes and remnants of diseased lobes, explaining the recurrence in 5-10% of cases [21].

The diffuse cancers involving one or more lobes such as malignant mastitis/ inflammatory BC and DCIS demonstrated diffuse hyper vasculature and increased lobar strain, associated or not with increased shadow of the Cooper ligaments or abnormal hypo echogenicity of the surrounding stroma; the differential diagnosis was made with the benign mastitis that presented higher strain of the pre-mammary fatty tissue than of the mammary lobe and with the breastfeeding aspect that illustrated diffuse hyperemia with normal global breast SE (Fig. 4).

Strain SE differentiated the inspissated cysts from the solid masses, or inspissated ducts from duct hyperplasia, papilloma and DCIS; the BGR score demonstrated the presence of fluid of any consistency. The benign hyperplastic scars (keloids) could mimic recidivate in SE, but the absence of Doppler signal offered the differential diagnosis. The great mimickers were the fibro-microcystic dysplasia and the sclerosing adenosis, suggesting malignancies in all techniques (mammography, US, MRI), but FBU illustrated benign-type vascularity and complex summation-type BGR score at strain SE (advantage over SWE) (Fig. 5).

The rare malignancies, type mucinous or medullary cancer, with pseudo-benign descriptors in the classical US, presented new formation vasculature, usually multipolar and with incident angle, a scoring 4/5 Ueno, according to the reduced stromal reaction (with/without shading and halo) (Fig. 6).

We found a significant association BC-benign pathology, proving that BC rarely develops in a normal breast, justifying the characterization and location of all lesions; FBU avoided unnecessary, otherwise mandatory biopsies in all suspected multicenter and multifocal lesions. Moreover, no significant correlation was found for BC-Density-Age, due to the
regional geographical specificity of the population and to previous hormone therapy, either birth control pills, assisted fertility, or menopausal hormone replacement therapy, which increased breast density.

The BI-RADS 3 category in 458 FBUs included 110 follow-up examinations after BC surgery, either radical or conservative, because of the risk of second or recurrent BC; we illustrated the remnant benign mammary lesions, or the postsurgical suture granulomas, seromas, remnant lobar structures in radical mastectomy, remnant satellite lymph nodes with benign aspect, in one patient a lost axillary drain migrated under the great pectoral muscle. The follow-up exams that demonstrated remnant BC or remnant lymphadenopathy were assessed category 6 US BI-RADS.

From a total number of 57 patients with BC examined (categories 5 and 6 BI-RADS), 46/1333 (3.45%) represented new cases diagnosed by FBU as independent examination, assessed US BI-RADS 5 category, and 11 patients were assessed category 6 after confirmed biopsy or incomplete surgical excision and were checked during the oncologic therapy.

Fig. 3. 50-year-old patient: FBU, R: 10:00: bifocal cancer: the radial scan illustrates the main tumor with an incident angle of the plunging artery (a), undetectable in the smaller secondary lesion visible with ductal connection on the antiradial scan (b), but Strain SE with 4 Ueno score and high FLR for both is conclusive (c). Satellite lymphadenopathy shows new-formation cortical vascularization and increased strain (d). US BI-RADS 5 – invasive duct carcinoma (IDC).

Fig. 4. 46-year-old patient, FBU in malignant mastitis / inflammatory BC: skin thickening, hyper echogenicity of the skin and pre-mammary fatty tissue, salient lymphatic spaces, and hyperemia (explaining the sign of orange peel), two aspects from the periphery R:9:00 (a) to the center of the pathological changes R: 3:00 (b). The characteristic sign of the increased stiffness of the glandular area under the preserved fatty elasticity (c) includes some micronodular parenchymal foci that demonstrate the highest strain. Type of diffuse cancer - US BI-RADS 5 category.
Fig. 5. 43-year-old patient: 3D volume rendering MRI demonstrates the breasts distortion due to the pronation and the shape of the breast coil (a, b); multifocal and multicentric enhancements with a suspicious MRI curve for a macronodular lesion in the left breast (c, d); mammography is inconclusive for this dense breast (e), and FBU illustrates pseudo-nodular fibro-microcystic dysplasia with BGR-summation score (f) - US BI-RADS category 3.

Fig. 6. 54-year-old patient: FBU, L: 1:00, radial and antiradial scans in multifocal BC, rare type, no shading: low vasculature of 2D scans might suggest benignity (a), but heterogeneous stiffness of 5 Ueno score with posterior stromal infiltration raises suspicions (b); 4D Doppler acquisitions (c, d) demonstrate multipolar incident vessels running to the center of the pathological volume, leading to the correct evaluation of US BI-RADS category 5.

The 88 patients assessed US BI-RADS 4 category were differentiated according to the risk of BC in the three subcategories A, B and C; in addition to the US BI-RADS fifth Edition, we developed the criteria of Doppler and strain SE: when the intensity of new formation vasculature and the incident angle of the plunging artery (°-ies) were barely visible, and the strain SE was around the cut-off interval (4.70-5.00), we accorded the assessment 4A category (47 patients -3.52%), with a peak of incidence between 51-60-year-old; a short-interval follow-up of 6 months was preferred to an immediate biopsy, because many cases did not develop a malignant lesion and the breast involution during the progression of the menopause may reduce the parenchymal abnormal proliferation, with decrease of the vasculature and of the strain.

The US BI-RADS 4B assessment (17 patients) was accorded in more advanced cases, but we avoided this category because of high grade of subjectivity and incertitude delivered to the patient and to the clinician; we found such cases of any adult age, but with a plateau of higher incidence between 40-60-year-old.

The US BI-RADS 4C assessment (24 patients -1.83%) was
present for any adult group, but with a peak between 51-60-year-old, similar to the 4A, 5 and 6 categories. That suggests by one hand the malignancy had the higher incidence in perimenopausal and postmenopausal age, and by the other one it was preceded and accompanied by abnormal proliferative findings, possible premalignant, as the pathological reports demonstrated additionally to BC (atypical hyperplasia, sclerosing adenosis, metaplasia, etc.).

Case: patient of 50-year-old diagnosed with sclerosing adenosis and less 5mm suspect nodule, assessed US BI-RADS 4A, presented a fluctuated evolution at repeated 6 month follow-up during 2 years: stable (assessed 4A), partially regressed (3 category), aggravated (4C category); after surgical excisional biopsy the sclerosing adenosis was confirmed and the following examination demonstrated postmenopausal parenchymal atrophy with minimal remnant dysplasia (final BI-RADS 3 category). The 4C assessment was overestimated thus we considered false-positive diagnosis; however, due to the apparent evolution and to the higher risk of BC in the presence of sclerosing adenosis, the conservative surgery offered in the meantime both the pathological diagnostic and the cure of the small lesion.

Case: patient of 51-year-old, with FBU aspect of dense breast with fibro-microcystic dysplasia and a less 5mm nodule with ductal connection, irregular shape, suspect unipolar incident vasculature, but score 3 Ueno and normal satellite lymph nodes, assessed 4C; the 6 months follow-up examination demonstrated not significant increasing of the lesion’s size, but increased number of vascular poles with incident angle and partial involvement of the cortical of the satellite axillary nodes, and was correctly assessed BI-RADS 5 category, proved an IDC.

Case: patient of 55-year-old presented background breast parenchymal atrophy, associated with a secreting galactophoritis (duct ectasia) and fibro-microcystic dysplasia extended of lobar type, with diffuse salient vasculature; the initial assessment of US BI-RADS 5 category was overestimated due the strain SE of score 4 Ueno and because of the mimicking of the lobar-type BC; the conservative surgery was performed and a secretory dysplasia associated with ductal hyperplasia with metaplasia, periductal fibrosis and lymphocyte infiltration was found by the pathologists (false-positive).

In our experience, the fibro-cystic dysplasia, usually associated with duct ectasia represented the most frequent pathology in all patients, thus the relative incidence in BC cases was inevitable high, but we do not consider this a premalignant finding. Sometimes fibro-microcystic dysplasia, especially the pseudo-nodular type, could mimic malignancies on mammography and gray-scale US; it demonstrated a raised strain SE with score 4 Ueno or a BGR-summation score, but the absence of a salient vasculature sustained the differential diagnosis and the evolution was stable or regressive.

The differential diagnosis in benign masses was accurate by FBU and did not require diagnostic biopsies. The pseudo-solid inpsissated cysts, ductal papilloma, hamartoma, cystosteatonecrosis, duct hyperplasia, benign breast edema, were easily demonstrated by the radial and antiradial scanning of FBU.

V. DISCUSSIONS

The historical evolution of the medical ultrasound had an unfortunate implementation of the most important tools of diagnosis, the analysis of the vasculature by Doppler and the assessment of the elasticity by SE: the new technical achievements were used independently, due to their consecutive development, with unsatisfactory results; this is correct for any examination of the body part, but especially for the breast and thus resulted their underestimation by US BI-RADS. Some authors tried to use Doppler and the incident angle combined with Sonoelastography in the positive and differential diagnosis of BC, but the promising results were limited by the wrong technique of classical gray scale Ultrasound, performed in orthogonal scans, without anatomical lobar analysis, with reduced sensitivity and specificity [22].

The Doppler technique is still underused, there is usually a limited application with a small region-of-interest (ROI) around a suspect lesion; but for the breast, the assessment of the whole vasculature is important, both for assessing the sensitivity of the equipment and choosing the best menu, and for establishing the background breast vasculature, which is increased in lactation breast, mastitis, inflammatory breast cancer, congestive heart failure. Only after breast background vasculature is illustrated, we can detect and interpret the localized pathological Doppler signal. The incident angle of the plunging artery, oriented towards the center of the cancer, represents an important descriptor for the malignancy, better than the number of poles and the aliasing, which have their value, too, but depend on the tumor size. The incident angle demonstrates the high rate of tumor proliferation, while the acute angle, described as vasculature “in rim”, signifies a slow tumor development, with benign appearance, without infiltration but with a slow progressive compression of the surroundings. Moreover, the aliasing representing the high, turbulent velocities could be related to the “wash-out” curve of contrast enhancement in MRI. It is illogical to consider valuable the study of the tumor vasculature in breast contrast MRI, contrast subtraction mammography, or CEUS, and to neglect the possibility of color Doppler analysis, cheaper and without risks. Moreover, the 3D Doppler could localize the pathological area when no-mass like BC is suspect, useful for the guided biopsy (Fig. 6).

We consider the Strain SE more adapted to the breast glandular lobar radial architecture, associated with the pre-and retromammary fatty tissue, resulting a heterogeneous scanning slice: the fatty and the lobar tissues overlap and their distribution is different for any woman and for the same woman is different for any radius of each breast quadrants; we can compare different tissues from the skin to the ribs with full range of elasticities. Strain SE differentiates the solid findings from fluids (inspissated ducts and cysts, fibro-microcystic dysplasia, hematomas, seromas); the pressure of acquisition is controlled and the semiquantitative FLR diminishes the subjectivity; there is a correlation between the elasticity of the ROI (B area) compared with the softest tissue, represented by the fat (A area), similar to the assessment of the echogenicity of the findings (hypo-, iso- or hyperechoic relative to the fat); Ueno (Tsukuba) score is more analytical than SWE interpretation and is appropriate for US BI-RADS.
categories [15], [16].

These aspects are not possible with good accuracy in SWE, which is based on the horizontal transmission of US shared waves. In SWE the strain of the mass is not directly correlated with the fat (the softest) and the ribs (the hardest), but with the speed of those shared waves that is related to the elasticity of the tissues traversed horizontally, of lobar, fatty, or mixed structure; the benign features appear with the same blue picture, without differentiation between solid and fluid, fat or lobar structures, while the malignancy is proved by the stiff ring sign, or diffuse heterogeneous increased stiffness, resulted when stromal fibrous reaction and microcalcifications are present. However, about 30% breast cancers are missing calcifications and peripheral desmoplastic reaction (small cancers, in situ, or rare types such as mucinuous, papillary, medullary), and SWE rise the false-negative results. The sensitivity of the SWE is better in fatty breasts, similar to the mammography, but the dense breasts may reduce its accuracy, with difficulty in the assessment of the size and extension of the BC.

VI. CONCLUSION

FBU allowed an accurate positive and differential diagnosis of breast pathology, with low costs and fewer unnecessary biopsies. We recommend it as an available and valuable tool for the present and future breast imaging diagnostic centers who made these examinations.

The value of US BI-RADS for standardizing practice should be improved in the next likely edition with a more precise examination technique and a new hierarchy of descriptors, and the above are an example. ABVS, useful for the artificial intelligence, should be adapted to the radial reconstructions, with a precise clock-vise location of the findings, and with possibility to demonstrate the ductal connection of the pathological findings, either benign or malignant; the overrated “plan C” is less useful, because the breast architecture is based on lobes with radial orientation around the nipple as proved by galactography and by consequence the physiology and pathology of breast is of lobar type; the nipple with the emergent ducts and their relationship with the skin and the thoracic wall are mandatory for the staging of BC. The breast MRI scanning could be improved upon a radial model, similar to the cholangiopancreatography (MRCP).

This study is a signal, and some multicenter assessments need to be conducted for the implementation of FBU in medical practice worldwide.

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