

WJCO 5th Anniversary Special Issues (2): Breast cancer**Significance of immunohistochemistry in breast cancer**

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Abstract

The biological characteristics of the tumour are used to estimate prognosis and select appropriate systemic therapy for patients with (breast) cancer. The advent of molecular technology has incorporated new biomarkers along with immunohistochemical and serum biomarkers. Immunohistochemical markers are often used to guide treatment decisions, to classify breast cancer into subtypes that are biologically distinct and behave differently, and both as prognostic and predictive factors. Steroid hormone receptors, markers of tumour proliferation, and factors involved in angiogenesis and apoptosis are of scientific interest. In this review we will provide information on the immunohistochemical markers used in the management of breast cancer patients using available data from the literature. We consider the utility of established immunohistochemical markers, and discuss the challenges involved in integrating novel molecular markers into clinical practice.

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Key words: Breast cancer; Immunohistochemistry; Markers

Core tip: Immunohistochemistry has an important role in the pathology of breast disease, as well as in other benign or malignant tumours. There is a growing list of avail-

able products (antibodies) or antigen retrieval techniques, which all contribute to the broader utility of immunohistochemistry for solving diagnostic problems or for determining prognosis and response to therapy in breast pathology. Myoepithelial markers are useful in helping to distinguish benign lesions from malignant lesions. The most common immunohistochemical breast cancer prognostic and therapeutic markers used include: estrogen receptor, human epidermal growth factor receptor-2, Ki-67, progesterone receptor, and p53. In addition, markers of angiogenesis and apoptosis are also important.

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INTRODUCTION

Immunohistochemistry (IHC) is used to characterize intracellular proteins or various cell surfaces in all tissues. Individual markers or more often panels of various marker proteins can be used to characterize various tumour subtypes, confirm tissue of origin, distinguish metastatic from primary tumour and provide additional information which may be important for prognosis, predicting response to therapy or evaluating residual tumour post-treatment. There is a growing list of available products (antibodies) or antigen retrieval techniques, which all contribute to the broader utility of immunohistochemistry for solving diagnostic problems or for determining prognosis and response to therapy in breast pathology. Diagnostic and prognostic markers are described although some of them can be included in both.

DIAGNOSTIC MARKERS

The most important diagnostic problems that occur in

Table 1 Diagnostic markers

Marker	Staining pattern	Useful for
Smooth muscle actin	Cytoplasmic staining	Myoepithelial differentiation
Calponin	Cytoplasmic staining	Myoepithelial differentiation
p63	Nuclear	Myoepithelial differentiation
Smooth muscle myosin heavy chain	Cytoplasmic	Myoepithelial differentiation
CD10	Membranous staining	Myoepithelial differentiation
S100	Cytoplasmic	Myoepithelial differentiation
High-molecular-weight cytokeratins (14 and 5/6)	Cytoplasmic	To distinguish invasive carcinoma from benign proliferations; expressed by lobular carcinomas
Cytokeratin 8	Peripheral cytoplasmic	Ductal carcinoma cells
Cytokeratin 8	Perinuclear staining	Lobular carcinoma cells
CK 7 and 20		Mammary origin of a metastatic carcinoma
E-cadherin	Membranous staining	Usual ductal carcinomas
Hormone receptors estrogen receptor, progesterone receptor	Nuclear	Identified subtypes, mammary origin
HER2 neu	Membranous staining	Identified subtypes
Gross cystic disease fluid protein 15	Cytoplasmic	Mammary origin of a metastatic carcinoma
Mammaglobin A	Cytoplasmic	Mammary origin of a metastatic carcinoma
Carcinoembryonic antigen, CEAD-14 clone	Cytoplasmic	Evaluation of metastatic mammary carcinoma

mammary gland tumor pathology are: the differential diagnosis of various types of benign lesions and carcinoma; differentiating between carcinoma *in situ* and invasive carcinoma, diagnosis and differentiation of microinvasion and its imitating lesions and confirming the breast as the primary site in metastatic carcinoma. In the absence of advanced molecular biological techniques, IHC can be used to identify histologic subtype or molecular phenotype. Some of these problems can be solved using IHC markers (Table 1). It is well known that normal glandular breast tissue is composed of three cell types which express different subsets of proteins: luminal, basal and myoepithelial. The luminal cells express cytokeratins (CK 7, 8, 18, 19), epithelial membrane antigen (EMA), milk fat globule membrane antigen (MFGM), α -lactalbumin, estrogen receptor (ER), and progesterone receptor (PR). Myoepithelial cells express basal cell type CKs and specific markers: smooth muscle actin, calponin, S100 and p63, while basal cell types express different cytokeratins (5/6, 14, 17)^[1-3].

Myoepithelial markers: SMA, Calponin, p63, SMMHC

Myoepithelial markers are useful in helping to distinguish invasive carcinoma from benign proliferations with a similar morphological appearance, benign proliferative lesions and most preinvasive lesions with an intact myoepithelium. Invasive carcinomas lack the myoepithelial cell layer that normally surrounds benign breast glands. There is an exception, microglandular adenosis, a benign proliferative lesion which lacks the myoepithelial cell layer^[3-5]. In the same context, to assess intraductal proliferative lesions, high-molecular-weight cytokeratins (cytokeratin 14 and cytokeratin 5/6) can be helpful in distinguishing ductal hyperplasia from low-grade ductal carcinoma *in situ* (DCIS). Atypical ductal hyperplasia or *in situ* carcinoma can arise in otherwise benign papillary lesions and is defined as a type of ductal hyperplasia that morphologically simulates DCIS. Characteristically, atypical ductal hyperplasia has a uniform population of cells and most lesions

are small and focal, involving only a portion of a duct or only a few small ducts measuring less than 2 mm. Using IHC, positive myoepithelial staining is seen in the benign area with attenuated or absent staining in areas of atypia or *in situ* carcinoma. It is possible that the area of atypia or *in situ* carcinoma may not even be represented in the limited sample from a core needle biopsy.

Smooth muscle actin (SMA) has long been used as a myoepithelial marker in breast pathology diagnosis as a sensitive marker of myoepithelial differentiation, even if it is not specific, because any cell with substantial expression of actin is positive for SMA (myofibroblasts and blood vessels are positive for SMA).

This becomes problematic in lesions where there are either myofibroblasts or blood vessels in close proximity to the epithelial lesion. One pitfall is the presence of myofibroblasts within desmoplastic stroma adjacent to nests/glands of invasive carcinoma being misinterpreted as myoepithelial cells, resulting in a false-negative diagnosis. This is why the use of a panel of markers (p63, calponin, smooth muscle myosin, CD10, S100) or a more specific marker such as p63 are recommended.

One option is calponin, a protein belonging to the contractile apparatus in smooth muscle cells, which is considered to have the same sensitivity as SMA, however, similar to SMA, staining of myofibroblasts and smooth muscle in blood vessels can be obtained. As with SMA, cytoplasmic staining of myoepithelial cells tends to encircle the nucleus as opposed to the staining pattern of myofibroblasts. Compared to other markers (p63 or smooth muscle myosin heavy chain (SMMHC)), it tends to show more complete staining of the myoepithelial layer.

p63 is a homolog of p53, and has been shown to be expressed exclusively in myoepithelial cells in normal breast and can be very useful in differential diagnosis involving benign lesions such as sclerosing adenosis, radial scars and papillary lesions. The advantage of using p63 is its nuclear localization and absence of staining in smooth

muscle cells, such as myofibroblasts and blood vessels. Thus, it provides almost 100% specificity, however, its sensitivity has been reported to be approximately 90%. This is demonstrated by the so-called “focal gaps” in staining in the myoepithelial layer, partly due to the plane of section. In addition, it has now been shown that about 10% to 15% of invasive tumors, particularly high-grade and metaplastic carcinomas, express p63, although the staining is usually weaker than that seen in myoepithelial cells. Similarly, foci of squamous differentiation stain positively.

Like other smooth muscle markers, SMMHC is associated with contractile elements and is present in all cells with such properties. It is expressed primarily in myoepithelial cells, but is also expressed in blood vessels. An advantage of SMMHC is that it demonstrates less cross-reactivity in myofibroblasts than calponin and SMA. Overall, the studies so far suggest that among smooth muscle markers, SMMHC provides the best results, in terms of both sensitivity and specificity.

When inflammation or reactive fibrosis obscure the interface between involved ducts and adjacent stroma in some cases of DCIS, IHC can help to clarify the integrity of the duct wall. Usually ductal carcinoma cells are negative for myoepithelial cells markers: S100, SMA, SMMHC, calponin, CK5, CK14, CK17, CD10, and p63^[3,6-14]. The specific markers among these are SMMHC, calponin, and p63, these as well as some basal CKs have an advantage in that they do not stain myofibroblasts. Is this correct?

In most laboratories, however, the choice between these markers depends on individual experience, preference or financial resources. A combined approach, a nuclear and a cytoplasmic myoepithelial marker is the best option to increase the diagnostic utility of these markers. Pitfalls in the use of myoepithelial markers include those related to interpretation, fixation and technical aspects, and possible biological effects. Interpretative issues include the possibility of mistaking myofibroblasts for myoepithelial cells due to cross-reactivity of cytoplasmic epitopes (in particular, SMA and calponin). Fixation and technical issues include underfixed tissue not immunostaining optimally; in such situations, entrapped benign glands may be mistaken for invasive carcinoma due to lack of staining of myoepithelial cells, resulting in a false-positive diagnosis of carcinoma. The key to solving these issues is to include adequate internal controls.

Lobular or ductal carcinoma: E-cadherin, CK8

Determining whether an *in situ* lesion is lobular carcinoma or ductal carcinoma has clinical management implications and is another situation in which IHC proves its worth. Generally, ductal and lobular carcinomas, either invasive or *in situ* can be distinguished in hematoxylin-eosin-stained sections. In cases with non-specific morphologic characteristics, categorization can be performed through IHC, and E-cadherin is currently used to differentiate

between the two. The majority of ductal carcinomas express cytoplasmic E-cadherin, whereas most lobular carcinomas lack expression of E-cadherin^[3,15,16]. In addition, the differences in CKs expression may be used: high-molecular-weight CK (clone 34βE12) is usually expressed by lobular carcinomas, but is absent or expressed at low levels in most cases of DCIS^[3,17,18]. In the same context, CK 8 is stained in ductal carcinoma cells in the peripheral cytoplasm, while perinuclear staining is characteristic of lobular carcinoma^[19].

Identification of subtypes of breast cancer

Analysis of both adjuvant and neoadjuvant trials has shown that not all chemotherapeutics have equal effects on breast cancer patients, therefore, further individualization of chemotherapy may be required. Data on differences in chemotherapy sensitivity to taxanes and anthracyclines suggest that there are significant differences across disease subtypes, which if further validated, could be used to guide the best decision-making in patient treatment^[20]. The St Gallen expert panel which met at the 12th International Breast Cancer Conference held at St Gallen (Switzerland) in March 2011, identified four subtypes of breast cancer according to oestrogen and progesterone receptors, and overexpression and/or amplification of the human epidermal growth factor receptor 2 (HER2) oncogene. The four subtypes were luminal A, luminal B, Erb-B2 overexpression and basal-like. The expert panel provided systemic treatment recommendations for the subtypes including endocrine therapy alone for luminal A, endocrine ± cytotoxic therapy for luminal B (HER2 negative); cytotoxics + anti-HER2 + endocrine therapy for luminal B (HER2 positive); cytotoxics + anti-HER2 for HER2 positive (non luminal); and cytotoxics for triple negative.

Markers for mammary origin in metastatic carcinoma: GCDFP15, mamaglobin, CEA

In the case of small metastasis of infiltrating lobular carcinomas, false negative results are far more frequent than those in infiltrating ductal carcinoma^[21]. Medullary carcinoma metastasis or other subtypes of mammary carcinoma (lobular, sarcomatoid) can often be mistaken for malignant lymphoma (with “signet ring” cells, clear cells, with carcinoma pattern, sarcomatoids). In these situations, a positive reaction for CK and lack of reactivity for lymph markers suggest a diagnosis of metastasis. In as many as 24% of lymph nodes reported metastasis-free by standard histological examination, various authors found metastasis when multiple or serial sections were cut. Immunohistochemical markers also improve the specificity and accuracy of cell detection; therefore it is important to evaluate their utility in improving standard histological procedures. In the case of large metastasis in the axillary lymph nodes, IHC can demonstrate by a positive reaction for epithelial markers the carcinomatous nature of cells, difficult to appreciate as epithelial, in particular, in

the case of axillary metastasis of infiltrating lobular carcinoma (relatively uniform appearance of tumor cells and low mitotic activity). For small metastasis of infiltrating lobular carcinoma, false negative results are much more common than in infiltrating ductal carcinoma^[21]. In addition, medullary carcinoma metastasis or other subtypes of breast carcinoma can sometimes be confused with malignant lymphoma (cells in the so-called “signet ring”, clear cell); in these situations, a positive reaction for CK and lack of reactivity for lymphoma markers suggest a diagnosis of metastasis.

The identification of metastatic carcinoma of the breast may be difficult in the absence of a previous history of breast cancer. Various immunophenotypic markers have been introduced to aid in this process. Markers for mammary origin include receptors for hormones, such as androgen receptors (ARs) and gross cystic disease fluid protein 15 (GCDFP-15)^[3]. GCDFP-15 is present in the liquid of breast cysts and any apocrine cells: mammary glands, salivary glands, sweat, Paget’s disease, *etc.* Therefore, carcinoma of the breast and others show reactivity to GCDFP-15. Even in these conditions, the positive predictive value and specificity for the detection of breast cancer is 98%-99%^[22], but moderately sensitive (50%-74% for breast carcinoma), which is why it is important to add other markers to the diagnostic panel such as ER, PR, AR, and HER-2/*neu*, mammaglobin, and CKs (7 and 20). In this context, ARs and/or HER-2/*neu* are given additional value in a great number of ER-negative high-grade ductal carcinomas^[3].

Lately, mammaglobin has been described as a breast cancer-specific gene, and its utility as a novel breast cancer marker has been confirmed^[3,23,24]. Mammaglobin A and B identified in breast cells are overexpressed in breast cancer. Mammaglobin A is more specific for breast and gynecologic organs, while mammaglobin B may be found in a number of other tumors, especially gastrointestinal malignancies. Many studies have suggested that elevated mammaglobin levels in breast cancer are associated with clinical and biological features defining a less aggressive tumor phenotype. Mammaglobin expression is not changed at the metastatic or lymph node site. It can help, in combination with other markers, to establish the correct diagnosis of metastatic breast carcinoma. Although many carcinomas would not be included in the differential diagnosis of breast carcinoma, the specificity of this marker was 92%^[25].

In the same study, when the immunohistochemical staining pattern of mammaglobin was compared with GCDFP-15 in the breast carcinomas, mammaglobin had higher sensitivity than GCDFP-15. In addition, the mammaglobin antibody cocktail stained deeper than GCDFP-15, and among positive cases, the number of cells stained with mammaglobin was higher than with GCDFP-15. Despite some non-specificity of the mammaglobin antibody, these data provide convincing evidence for the inclusion of mammaglobin in a panel for the workup of carcinoma of an unknown primary site.

During the diagnosis of breast carcinoma, it should be taken into consideration that the sensitivity of mammaglobin is better than that of GCDFP-15^[25-27].

Carcinoembryonic antigen (CEA) is a well-known tumour marker glycoprotein of 180 kDa. The polyclonal antibody reacts strongly and diffusely with ductal mammary carcinomas, lung and large intestine carcinomas; CEAD-14 clone reacts with a small subset of mammary carcinomas, usually high grade, which is useful in the evaluation of metastatic mammary carcinoma in the lung, liver, brain and lymph nodes; 13% of breast carcinomas are positive for CEAD-14, with a focal reaction, but diffuse in high-grade carcinomas. A negative CEAD-14 pulmonary tumour is more likely to be a metastasis and not a primitive lung tumour, which is positive for other specific markers (such as thyroid transcription factor-1, TTF1)^[28].

MARKERS OF PROGNOSIS AND RESPONSE TO THERAPY

The most common immunohistochemical breast cancer prognostic and therapeutic markers used include: ER, HER2, Ki-67, PR, and p53. In addition markers of angiogenesis and apoptosis are used.

Hormone receptors

Nowadays, immunohistochemical detection of ER and PR is part of the routine work-up of breast cancer, and in some cases of DCIS the presence of ERs is an indication for tamoxifen therapy. There are many scoring systems and many studies have compared their ability to predict treatment response and correlations with outcome. The first scoring system counted the percentage of positive cells and ignored staining intensity^[29,30]. When we determine the proportion of positive stained cells, at least 1% is considered a hormonally treatable state. According to the International Breast Cancer Study Group scheme which is the basis of the most recent St Gallen treatment guidelines, breast cancer is divided into three groups based on the percentage of positive cells: responsive (10%), response uncertain (1%-9%), and nonresponsive (0%). In other words, a threshold of 1% positive cells indicates the option for hormonal therapy. These guidelines are widely followed in many countries from Europe and the United States, but they seem to be insufficient.

Many users report results as an Allred score, which comprises both the percentage of positive cells and staining intensity^[31]. A total score of 3 or more, corresponding to 1% to 10% positive cells, characterises the lowest positive result and corresponds to the St Gallen endocrine response uncertain category in which case adjuvant hormone treatment can be recommended, but has an uncertain benefit^[3,32,33]. Immunohistochemical staining for ER in DCIS, without associated invasive lesions has a role in estimating the potential positive effect of tamoxifen. The National Surgical Adjuvant Breast and Bowel Project

Protocol B-24, in patients with DCIS treated with partial mastectomy and then irradiation, who received placebo or tamoxifen for five years showed a conclusive reduction in both ipsilateral and contralateral breast cancer in the adjuvant tamoxifen group^[3,34,35].

HER-2/Neu expression

HER-2/neu was one of the first oncogenes studied in samples of invasive breast cancer and it is identified in 10%-20% of breast cancer patients. It is a marker for sensitivity to Herceptin (trastuzumab), and resistance to tamoxifen^[36]. Although Her-2/neu can be detected using many methods, only two are currently approved and recommended for its detection: IHC and fluorescence *in situ* hybridization (FISH). Standardized immunohistochemical techniques exhibit a very good correlation with FISH methods. Such standardization requires the use of 10% neutral-buffered formalin as a fixative allowing at least 6-8 h of tissue fixation, and not more than 48 h. IHC evaluates overexpression of the receptor protein at the surface of the cells, while FISH evaluates the status of the *HER2* gene in the nucleus. In the majority of *HER2*-positive cancers, *HER2* protein overexpression is the result of gene amplification, thus both methods should be highly correlated.

Immunohistochemistry reactions for HER-2 are scored by HercepTest where 0 and 1+ scores are negative, 2+ is weakly positive and 3+ is positive. A positive HER-2 result consists of a uniform and intense membrane staining of more than 30% of tumour cells and further evaluation is unnecessary for invasive cancers that stain definitely positive or negative. Weakly positive or equivocal or 2+ cases should be tested for gene amplification by FISH. A positive result using this method indicates more than 6 HER-2 gene copies per tumour cell nucleus or a HER-2 gene to chromosome 17 ratio of more than 2.2^[3,36-38].

Selection of the best treatment, especially if the patient is a candidate for HER2-targeted therapy, depends on accurate laboratory results of the assessment of HER2 status. All aspects of the test are performed in a highly standardized fashion with good quality control and the quality controls must be continuously monitored. The standardization includes aspects of pre-analytical sample tissue handling, the type and duration of fixation, tissue processing, assay performance, interpretation, and reporting^[37].

Due to the intrinsic subjectivity of the results of the two techniques (IHC and FISH), the identification of new methods with less subjectivity is necessary. Recently, the chemiluminescent technique has been used as a quantitative assay^[39,40]. It has many benefits such as high sensitivity and accuracy, stability of reagents, easy-to-use protocols, non-photodegradable products, and a good correlation between IHC and immunohistochemiluminescence results.

Markers of apoptosis and cell proliferation: Ki-67 proliferation index, BCI-2, p53

Ki-67, a non-histone protein, involved in the early steps of polymerase I-dependent ribosomal RNA synthesis is a predictive and prognostic marker in cancers and has been extensively studied. When Ki-67 level is above 10%-14%, breast cancer patients are defined as high-risk^[41,42]. According to the St. Gallen Consensus (2009), the Ki-67 index is useful for selecting patients with hormone receptor-positive breast cancers for the addition of chemotherapy to endocrine therapy. Thus, breast tumours are classified as low, intermediate, and highly proliferating according to a Ki-67 labelling index of under 15%, 16%-30%, and over 30%, respectively. Data from the Clinical Cancer Registry Regensburg showed that Ki-67 expression was associated with common histopathological parameters, especially grading and survival, but is an additional independent prognostic parameter for disease-free survival and overall survival in breast cancer patients^[43].

The neoadjuvant setting is useful for analyzing the value of Ki67 as a predictive and prognostic tool. The majority of studies investigating complete pathological response have identified a high Ki67 proliferation rate as a predictive factor for a higher rate of complete pathological response^[44,45]. However, it was found that patients in whom progression occurred had a higher proliferation rate than those who responded to neoadjuvant chemotherapy. This suggests a nonlinear effect of Ki67 on treatment response and probably on prognosis as well^[44,45].

Ki-67 expression has been used to determine the effects of different doses of tamoxifen on breast cancer proliferation^[42,46]. The change in Ki-67 expression induced by lower doses of tamoxifen was comparable to that achieved with the standard dose, indicating that tamoxifen retains antiproliferative activity at low doses^[46,47]. Dowsett *et al*^[48], in a small study, showed that a higher Ki-67 labelling index after two weeks of neoadjuvant therapy with tamoxifen was associated with shorter recurrence-free survival, whereas higher Ki67 expression at baseline was not. According to Ellis *et al*^[49], a significant reduction in the Ki-67 index after a short period (a few weeks) of hormonal treatment may be a simple and affordable way to select patients with ER-positive breast cancer who may not benefit from adjuvant chemotherapy.

Another proliferation marker in tumour tissue is the Ki-S2 antibody. This antibody recognises a proliferation-specific nuclear protein expressed exclusively in the cell cycle phase S, G₂, and M. Therefore, actively proliferating cells that constitute a subset of the population recognised by Ki-67 were specifically labelled. The cycling ratio was defined as the ratio of the Ki-S2 labelling index to the Ki-67 labelling index and represents the relative fraction of cells in proliferation. Alterations in cell cycle regulation at the G₁-S transition strongly influence breast can-

cer progression^[42,50]. Prognosis is probably indicated by the percentage of cells in S through M phases of the cell cycle and measurement of the Ki-S2 index may also improve to allow an accurate prognosis and to identify patients with a low risk of recurrence who may not require adjuvant therapy^[42,51].

With regard to the molecular breast cancers, high Ki-67 proliferation index can be used to classify triple negative breast cancer into subtypes with different prognoses or responses to treatment. For this purpose, the number of Ki-67 positive cells among the total number of counted tumour cells was determined and the high expression of Ki-67 was defined as $\geq 10\%$. It is known that patients with triple negative breast cancer have a poor survival, despite their high response rate to neoadjuvant chemotherapy, and those with high Ki-67 have more aggressive clinical features^[52].

The use of adjuvant chemotherapy in early breast carcinoma is controversial, with many advocating its use in high-risk patients as defined by specific pathologic parameters. Both BCL2 and p53, which are involved in apoptosis and cell proliferation, play an important role in determining tumour growth and may help to define high-risk patients more accurately. In breast cancer patients, BCL2 expression is significantly associated with hormone receptor status and p53 is an important prognostic marker in early breast cancer^[53].

BCL2 belongs to a group of protein key regulators of apoptosis or programmed cell death. The tumorigenic potential of inappropriate BCL2 protein expression associated with an adverse outcome was first described in subsets of non-Hodgkin's lymphoma as a result of the chromosomal translocation [t(14,18)]^[54,63].

Overexpression of BCL2 protein has been identified in a variety of solid organ malignancies, but in contrast to non-Hodgkin's lymphoma, BCL2 protein expression in breast cancer is associated with a nonaggressive phenotype of low-grade, slowly proliferative ER+ breast tumours^[55-57]. This favourable prognostic effect of BCL2 in breast cancer is explained by its non-apoptotic functions^[55,58]. BCL2 is expressed in normal breast glandular epithelium and is upregulated by oestrogen, possibly as a direct result of transcriptional induction^[55,59]. Its amplification or copy number gain is a rare condition and correlation between transcript and protein levels in breast cancer is nonlinear, involving post-transcriptional regulation^[55,60]. Moreover, many studies have demonstrated that expression of BCL2 is associated with improved survival in breast cancer, however, this was attributed to its correlation with ER status^[55,61,62]. If we compare patients with ER⁺/BCL2⁻ disease to those with ER⁻/BCL2⁺ disease, the former have been found to have a worse prognosis than the latter^[61,62].

The prognostic value of BCL2 is present across molecular subtypes, and is independent of parameters such as stage, grade and tumour size. BCL2 can be used to prevent patients undergoing unnecessary cytotoxic therapy and provides additional prognostic information^[55].

The other marker, p53 is well studied in cancers, but its value in predicting clinical outcome in breast cancer is debatable. The p53 gene is located on the short arm of chromosome 17 and encodes a 375 amino acid nuclear phosphoprotein that prevents propagation of genetically modified cells^[64]. Wild-type p53 is a tumour suppressor protein and plays an essential role in regulating genomic stability by controlling the cell cycle and inducing apoptosis when cell damage cannot be repaired^[65-67]. In normal cells, p53 has a very short half-life due to ubiquitylation and proteasome degradation^[68,69]. IHC can be used, as wild-type p53 protein is rapidly degraded, while TP53 mutations (18%-25% of primary breast carcinomas) are often associated with the production of a stable protein. In addition, sequencing of the p53 gene in all breast cancers would be expensive and time-consuming for routine practice^[70,71,73]. A higher tumour grade, negative ER and PR status, and the more aggressive basal subtype were associated with abnormal p53 immunohistochemical expression or p53-positive status^[70,72,73]. With regard to early breast cancers, some scientists have reported that a p53 mutation has no influence on the outcome and therefore, the value of p53 status is too weak to be recommended as a routine marker in clinical practice^[74].

Angiogenesis markers

Tumour growth and metastasis are dependent on tumour angiogenesis and this complex process involves a delicate balance between angiogenic and antiangiogenic factors. Numerous studies have investigated the relationship between tumour angiogenesis, prognosis and response to antiangiogenic drugs. Analysis of these factors in tumour or serum of breast cancer patients by IHC or multiplex protein assay (FASTQuant[®] Microspot Assays) can improve diagnosis and prognosis of the disease. There is a large list regarding angiogenesis markers: Angiogenin, Ang2, keratinocyte growth factor (KGF), fibroblast growth factor basic, intercellular adhesion molecule (ICAM)-1, platelet-derived growth factor-BB and the vascular endothelial growth factor family. With regard to these markers, it has been observed that patients with breast cancer exhibited high levels, as well as high serum levels when compared to patients with benign breast diseases. When some of these markers were evaluated either in tumour or serum in breast cancer patients, they showed an association with standard clinical parameters, ER status and intratumoural microvessel density of tumours^[75].

The commonly used method to determine angiogenesis is counting intratumoral blood vessels (MVD) stained with factor VIII related antigen or anti CD31 or CD34 using light microscopy. The main difficulty is the significant variability in density between different areas of tumor and among observers. Counting newly formed stained microvessels is a useful tool in the early detection of metastatic potential and in the selection of patients for whom anti-angiogenesis drugs might be beneficial. The reactivity level of CD34 antigen was assessed by IHC

in all types of invasive ductal breast cancer and its level seems to be a useful predictor for the development of local lymph node metastasis and can indicate the benefit of antiangiogenic treatment^[76,77].

Anti-angiogenic drugs have been approved recently for the therapy of advanced cancers, including breast cancers. These drugs, alone or in combination with chemotherapy, are able to improve overall or progression-free survival in cancer patients. Unfortunately, the lack of validated biomarkers to allow the selection of patients who are most likely to benefit from targeted drugs such as bevacizumab, sunitinib, sorafenib and pazopanib, limits the rational use of these drugs and the ability to determine optimal dose and scheduling of these drugs^[78].

Most of the biological and clinical activity of the anti-angiogenic drugs currently approved for cancer therapy is against the VEGF-related pathways. The VEGF system is part of the platelet-derived growth factor gene family, and interacts with its specific receptors; VEGFR-1 (flt-1) and VEGFR-2 (flt-2) for VEGF-A, a very potent angiogenic growth factor. VEGF-B, interacting with VEGFR-1, seems to have an important role in the maintenance of existing vessels, but this protein is not well studied. VEGF A and B, their receptors VEGFR-1 and 2 are expressed in a variety of normal cells, and overexpression has been described in malignant tumors^[79-82].

There are different techniques used to assess VEGF-A, IHC being the most convenient in routine diagnosis as well as research, as it allows single cell analysis combined with morphology. The results are currently based on visual examination of IHC-stained tissue slides and several different scoring systems have been used^[79,83,84]. Some of these scoring systems evaluate the intensity of immunoreactivity, while others combine the examination of intensity score with the percentage of cells stained resulting in a semiquantitative scoring system. Unfortunately, such scoring is defined by subjectivity and debatable intra- and interobserver reproducibility. Therefore, using the same tumour sections, some laboratories also introduced an automated method for analyzing VEGF expression and obtained the AI score. Methods for computer-assisted image analysis of VEGF-A improved reproducibility by reducing some of the variation between measurements^[79,85,86].

The prognostic importance of VEGF in invasive breast cancer is associated with tumour stage and ER status, and inversely correlated with tumour grade and measurement of tumour VEGF, as an indicator of angiogenesis, which is more reliable prognostically than measurement of microvessel density or serum VEGF^[87,88]. In addition, tamoxifen treatment was associated with higher circulating and platelet-derived VEGF levels^[88].

CONCLUSION

IHC has become an integral part of the pathology laboratory. It is a more mature technology and accessible to the majority of pathology laboratories. IHC can be used

for diagnostic issues, estimating prognosis or predicting response to therapy. The best approach in the use of immunohistochemical markers is to combine them with the examination of standard hematoxylin-eosin slides and use panels of markers. Once the potential value of a new immunohistochemical method is appreciated, the burden will be to ensure standardization of the test protocol to maintain conformity and minimize interlaboratory variation. Results may vary widely depending on the choice of fixative, choice of antibody manufacturer, and the type of immunostaining methods. A scoring system for test results should be regularly adopted and properly reported. IHC testing is cost-effective and can be carried out in parallel with other tests. In the event of equivocal results, a back-up test using multigene assays or others methods should be made available. Once these parameters are standardized, IHC will assume a better and well-defined role in the management of patients with cancer.

It is clear that the role of IHC in detecting biomarker expression in pathology largely depends on research studies which demonstrate differential immunohistochemical expression and other studies that show good correlation between positive expression and response to new therapy. Although a gene study is a sensitive technique, it lacks specificity in distinguishing different cells, and may be contaminated by other cells. In addition, gene profile analysis is complex and inconvenient for routine clinical use.

With regard to subtypes, while the majority of scientists were against the requirement of multi-gene expression array profiling for subtype definition, approximately half the panel of St. Gallen 2013 opted for the use of a clinic-pathologic definition as sufficient for subtype definition. In conclusion, only ER, PR, Ki-67 and Her-2/neu are recommended for clinical use.

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