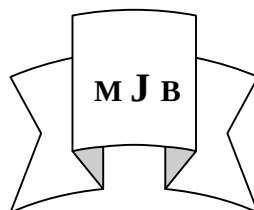


Immunohistochemical Study of Disrupted Breast Myoepithelial Cell: Implications for Tumor Metastasis

Ali Hassan Al-Timimi

Collage of Medicine, Babylon University, Babylon, Iraq,



Abstract

Previous studies detected focal disruptions in myoepithelial cell layers of several ducts with carcinoma *in situ* of breast. The cell cluster overlying each of the myoepithelial disruptions showed a marked reduction in or a total loss of immunoreactivity for the estrogen receptor (ER). This is in contrast to the adjacent cells within the same duct, which were strongly immunoreactive for the ER.

Paraffin sections from 55 patients with ER-positive intraductal breast tumors were double immunostained in the current study. Cross-sections of ducts lined by ≥ 40 epithelial cells were examined for myoepithelial cell layer disruptions and for ER expression.

Of the 55 cases with 1424 duct cross-sections examined, 24 showed disrupted myoepithelial cell layers with 101 focal disruptions. Of the 24 cases, 20 (84%) contained only ER-negative cell clusters, two (8 %) contained both ER-negative and ER-positive cell clusters, and two (8 %) contained only ER-positive cell clusters overlying disrupted myoepithelial cell layers. Of the 101 disruptions, 88 (87%) were overlain by ER-negative cell clusters and 13 (12.8 %) were overlain by ER-positive cell clusters ($P < 0.01$). It is concluded that cells overlying focally disrupted myoepithelial layers and their adjacent counterparts within the same duct displayed different immunohistochemical and molecular features. These features potentially represent an early sign of the formation of a biologically more aggressive cell clone and the myoepithelial cell layer breakdown possibly associated with tumor progression or invasion.

الخلاصة

اكتشفت الدراسات السابقة عراقيل بؤرية في طبقات من الخلايا العضلية الطلائية في عدد من القنوات المصابة بالسرطنة الموضعية للثدي. كما أن العناقيد الخلوية التي تحيط بهذه المناطق البؤرية المضطربة من الخلايا العضلية الطلائية أظهرت نقصان ملحوظ أوفقدان كامل للخاصية المناعية لمستقبلات الاستروجين بالمقارنة مع الخلايا المجاورة ضمن نفس القناة والتي كانت تظهر بقوة الامينوبيروكسيدز المناعي للاستروجين.

في بحثنا الحالي تم دراسة الشرائح النسجية المحفوظة بالبرافين من 55 مريضة مصابة بسرطنة الثدي والحاملة للدالات الاستروجينية وتم تصبغها بطريقة بالامينوبيروكسيدز المناعي المضاعف. فُحصت المقاطع العرضية من الأتنية والمحاطة بعدد من الخلايا الطلائية أقل من 40 خلية للكشف عن المناطق البؤرية المضطربة للخلايا العضلية الطلائية وللكشف عن الدالات الاستروجينية.

من مجموع الحالات الـ 55 والمتصاحبة مع 1424 مقطع قناة عرضي فُحصت، 24 حالة أظهرت اضطرابات بؤرية للخلايا العضلية الطلائية مع مصاحبة 101 عرقلة بؤرية. ومن مجموع 24 حالة، 20 منها (84 %) احتوى فقط عناقيد خلوية سلبية الاستروجين، اثنان (8 %) احتويا كلا من عناقيد خلوية سلبية الاستروجين وحاملة الاستروجين، واثنان (8 %) احتويا عناقيد خلوية حاملة الاستروجين فقط تحيط بالمناطق البؤرية المضطربة للخلايا العضلية الطلائية.

من الـ 101 منطقة بؤرية مضطربة، 88 (87 %) اعتلت من قبل عناقيد خلوية سلبية الاستروجين و 13 (12.8 %) اعتلت بعناقيد خلوية موجبة الاستروجين ($P > 0.01$). تم الاستنتاج أن الخلايا التي تحيط بالطبقات البؤرية الموضعية المضطربة للخلايا العضلية الطلائية ونظرائهم المجاور ضمن نفس القناة تظهر مواصفات بالامينوبيروكسيدز المناعي مختلف وميزات جزيئية مختلفة.

كما أن هذه الموصفات والميزات تمثل إشارة أولية لتشكيل لنسج من مستعمرات خلوية حيوية أكثر عدوانية. وإن تدمير الطبقة الخلوية العضلية الطلائية يكون من المحتمل مرتبط ارتباطاً وثيقاً بالتعاقب الخبيث للورم أو الغزو السرطاني.

Introduction

The epithelial component of normal and noninvasive breast tumor tissue is physically separated from the stroma by both the myoepithelial cells and the basement membrane (BM). Myoepithelial cells are joined by intermediate or gap junctions and a number of intercellular adhesion molecules, forming a continuous sheet or belt that encircles the epithelial cells (except at the terminal ductal-lobular unit, within which about 20% of the epithelial cells are reported to be in direct contact with the BM) [1-3]. The BM is composed of a group of fibrous proteins embedded in a hydrated polysaccharide gel, constituting a continuous lining surrounding and attaching to myoepithelial cells via hemidesmosomes and focal adhesion complexes [3-5]. Both the myoepithelial cell layer and the BM layer are permanent structural constituents, normally allowing only the passage of small molecules [1-5]. Due to this structural feature, most tumor epithelial cells have to first pass through the myoepithelial cell layer and then the BM in order to physically contact the stroma. In other words, the disruption of both the BM and the myoepithelial cell layer is an absolute prerequisite for breast tumor invasion.

Invasive and metastasized tumors, compared with *in situ* tumors, have a significantly higher mortality rate, accounting for a vast majority of breast cancer death [6]. This highlights the significance and the implications for the elucidation of the tumor invasion mechanism(s), which could potentially lead to vast benefits and advances in the field of breast cancer treatment and prevention. It has been generally

accepted that an upregulated expression of proteolytic enzymes in tumor or stromal cells is the primary, if not the only, cause for BM disruptions and tumor invasion [6,7]. This theory, however, might not reflect the intrinsic mechanism(s) of myoepithelial layer disruptions for three main reasons. First, neither the normal cellular kinetics nor dynamic alterations of myoepithelial cells during tumor invasion have been well elucidated. Also, no conclusive evidence has shown that the host's own enzymes are capable of degrading its own myoepithelial cells. Finally, the results of proteolytic inhibitor-based human clinical trials for breast cancer treatment and prevention have been very disappointing [8].

While attempting to identify the early sign of myoepithelial disruptions and the precursor of invasion, we have carried out a number of studies focusing on the physical and functional correlation between epithelial and surrounding myoepithelial cells. In one of previous studies, a double immunostaining method with antibodies to smooth muscle actin (SMA) and to the estrogen receptor (ER) was used to elucidate both epithelial cells and myoepithelial cells [9]. Several focal myoepithelial cell layer disruptions, defined as a total loss of SMA immunoreactivity and an absence of myoepithelial cells, resulting in a gap that is equal to or greater than the combined size of at least three epithelial or myoepithelial cells, were detected in several ducts that were classified as ductal carcinoma *in situ* (DCIS) based on examination on H & E stained slides. Each of the disruptions was exclusively overlain by a cluster of

cells that showed either a complete loss of or a marked reduction of ER expression, in contrast to the adjacent nondisrupted myoepithelial cell layer within the same duct, which was overlain by cells with strong ER expression [9]. Other subsequent studies further revealed that ducts with a disrupted myoepithelial cell layer had a significantly higher proliferation rate than ducts with an intact myoepithelial layer [10,11].

It has been documented that the disruption of the BM and myoepithelial cell layers is an absolute prerequisite for tumor invasion, that tumor epithelial cells and their surrounding stromal cells share a similar genetic profile [12,13], and that the progression of breast tumors is paralleled by a progressive hormonal independence [14-17]. These findings therefore appear to have several clinical implications. Focal myoepithelial cell layer disruption might represent an initial or early sign of the BM and myoepithelial cell layer breakdown and the loss of ER expression in overlying cells might be correlated events, directly triggering or signifying tumor progression or potential invasion in some cases.

Based on these speculations, the present study attempted to confirm the previous observations in a larger number of cases, to determine whether focal disruptions of myoepithelial cell layers is a prevalent event, and whether all the cell clusters overlying focally disrupted myoepithelial cell layers have the same morphological and immunostaining feature.

Materials and Methods

Formalin-fixed, paraffin-embedded breast tissue blocks harboring various grades and subtypes of ER-positive, noninvasive breast lesions from 55 female patients were studied. Serial sections of 5 μ m thickness were cut

and placed on microscopic slides for immunohistochemical and morphologic assessment. Morphologic classifications were based on our published criteria [9]. Double immunohistochemical staining with antibodies to the ER and to SMA (Vector Laboratories, USA) was carried out as previously described [9,18,19]. A micrometer was inserted into the objective of a microscope to facilitate the reviewing of the whole section and the localization of a specific lesion [20].

Cross-sections of ducts lined by ≥ 40 epithelial cells were examined under a microscope for myoepithelial cell layer disruptions and for ER expression. A focal myoepithelial layer disruption was defined as a total loss of SMA immunoreactivity and an absence of myoepithelial cells, resulting in a gap that is equal to or greater than the combined size of at least three epithelial or myoepithelial cells, or multiple such gaps in a given duct. A focal loss of ER expression was defined as a total loss or a marked reduction of ER immunostaining in cells overlying disrupted myoepithelial cell layers, compared with a strong ER immunostaining in their adjacent counterparts within the same duct overlying the nondisrupted myoepithelial cell layer. A focal positive ER expression was defined as the ER immunostaining in cells overlying focally disrupted myoepithelial cell layers being more intense than or comparable to that in their adjacent counterparts overlying the nondisrupted myoepithelial cell layer.

The profiles of ducts containing disrupted myoepithelial cell layers were photographed at a magnification of $400\times$ – $800\times$ for immunohistochemical and morphological evaluation. The frequencies of myoepithelial cell layer

disruptions associated with ER-negative and ER-positive cell clusters were statistically compared by the Student *t* test.

The adjacent sections from 10 cases with focal myoepithelial disruptions were immunostained with monoclonal antibodies to cytokeratins AE1, to cytokeratin 8 (Vector Laboratories), and to cytokeratin 19 (Vector Laboratories) in order to assess whether cells overlying disrupted myoepithelial cell layers are epithelial in nature [21]. Also, the sections in selected cases were immunostained with antibodies to major constituents of the BM-collagen IV (Dako Corporation) and laminin (Vector Laboratories) to assess the integrity of the BM underneath the disrupted myoepithelial cell layers. For molecular analyses, paired ER-negative cells and adjacent ER-positive cells within the same duct, along with clear-cut normal epithelial or stromal cells, were studied from each of five selected cases, including one mild ductal hyperplasia and four DCIS or atypical intraductal hyperplasia. The studied cells were subjected to DNA extraction as previously described [22, 23, 24].

Results

Of the 55 cases, 4(7%) contained less than three profiles and 51 (93 %) contained more than three profiles of duct cross-sections, with a total of 1424 profiles available for assessment. Of the total cases and cross-sections examined, 24 (42. %) cases contained a disrupted myoepithelial cell layer with a total of 101 (7.1%) focal disruptions. Of the 24 cases, 15(63%) contained one to four disruptions, and 9 (37%) contained five or more disruptions. Disruptions occurred in two forms: a cell-free gap between the two ends of the myoepithelial cell layer, and/or a gap filled with bud-like protrusions of epithelial cells. The size of disruptions

varied substantially among ducts, ranging from the combined size of three to more than 30 myoepithelial cells. The frequency of disruptions also varied substantially among cases. The form, size, or frequency of disruptions seemed to be independent of the size, length, architecture, and overall ER negativity of the ducts, and also of the histological grade of the lesions (Fig. 1).

The frequency and pattern of myoepithelial cell layer disruptions, however, were closely associated with the ER expression status in overlying cells. Of the 24 cases, 20 (84%) contained only ER-negative cell clusters, two (8 %) contained both ER-negative and ER-positive cell clusters, and two (8%) contained only ER-positive cell clusters overlying the disrupted myoepithelial cell layers. Of the 101 disruptions, 88 (88%) were overlain by ER-negative cell clusters and 13 (13 %) were overlain by ER-positive cell clusters (Table 1). The frequency of myoepithelial cell layer disruptions associated with ER-negative cells was significantly higher ($P < 0.01$) than that associated with ER-positive cells. The number of ER-negative cells overlying the disrupted myoepithelial cell layer varied markedly, ranging from three to more than 100 cells. These cells were generally distributed as clusters, and cells of the same cluster were morphologically similar. A vast majority ($> 90\%$) of the ER-negative cell clusters were small (< 15 cells) and not easily appreciable on H & E stained sections (Fig. 2). The ER-negative cells in some of the larger clusters (> 15 cells), however, showed noticeable alterations in shape and density, morphologically distinct from their adjacent ER-positive counterparts within the same duct (Fig. 3). More than 95% of the ducts contained only one or two disruptions, while a few of

the ducts displayed multiple disruptions in the myoepithelial cell layer. The stromal tissues surrounding ducts with myoepithelial cell layer disruptions were often more vascular and contained more leukocyte aggregates, compared with stromal tissues surrounding ducts with an intact myoepithelial cell layer.

Although more than 84% of the myoepithelial cell layer disruptions were overlain by ER-negative cell clusters, nearly 14% of the disruptions were subjacent to ER-positive cell clusters. These ER-positive clusters were generally distinct from ER-negative cell clusters in three aspects: most of the clusters occurred in ducts with markedly attenuated myoepithelial cell layers, they usually showed no alterations in cell shape, density, or polarity, and the surrounding stromal tissues displayed no distinct morphological alterations.

The myoepithelial cell layer disruptions and their associated ER-negative cell clusters occurred in ducts with DCIS or atypical intraductal hyperplasia in 90% of the cases. In 10% of the cases, however, myoepithelial cell layer disruptions and associated ER-negative cell clusters were seen in hyperplastic, and even normal appearing, ducts (Fig. 4).

All the ER-negative cell clusters overlying the disrupted myoepithelial cell layer and their adjacent ER-positive counterparts in all 10 cases showed distinct immunoreactivity to cytokeratin 8, cytokeratin 19, and cytokeratins AE1/AE3, suggesting that they are epithelial in nature. Immunostaining with antibodies to collagen IV and laminin revealed no distinct immunoreactivity surrounding disrupted myoepithelial cell layers, suggesting that the basement membrane was also disrupted. The ER-negative cell clusters were either in or

protruded from the epithelial component.

Molecular analyses on cells from the five selected cases revealed distinct LOH and MI in both ER-negative cells and adjacent ER-positive cells within the same duct at each of the markers. The frequency of LOH and MI among the DNA markers, however, varied from 12% to more than 70%. The ER-negative and ER-positive cells showed a different frequency or pattern of LOH and MI. Figure 4 shows examples of the LOH pattern in ER-negative cells and adjacent ER-positive cells from a selected case. Subsequently, and currently, additional cases with ER-negative cell clusters overlying disrupted myoepithelial cell layers were selected for a larger scale comparison at a wider spectrum. The preliminary results are in agreement with those seen in the five previously selected cases.

Discussion

The myoepithelial cell layer has been traditionally regarded as a structural barrier for separating mammary epithelial cells from the surrounding stroma and for contracting ductal and lobular spaces assisting milk secretion [25,26]. Recent studies, however, have revealed several lines of evidence suggesting that myoepithelial cells may play active roles in preventing *in situ* tumors from invasion, and in regulating the functions of the epithelial cells.

Normal myoepithelial cells secrete several cell growth inhibitors, including maspin, which inhibit tumor cell growth in both tissue cultures and in animal models [27-29]. Normal myoepithelial cells can also convert precursor hormones into active steroid hormones within the mammary epithelial tissue [30]. The protein of a tumor suppressor gene, , is colocalized with maspin exclusively in

myoepithelial cells, and the expression of these two proteins is linearly decreased with tumor progression in a vast majority of the cases assessed [10,11]. The loss of maspin and Wilms' tumor 1 expression or the disruption of myoepithelial cell layers leads to a significantly higher epithelial cell proliferation [10,11].

On the other hand, recent studies have suggested that myoepithelial cells could be the specific target of external and internal insults and could be subject to a variety of normal and pathologic changes. The exposure to lambda carrageenan could specifically result in the filament disassembly and loss of the mammary myoepithelial cells, whereas exposure to oxytocin could markedly enhance the myoepithelial cell differentiation and proliferation [31,32,33].

Despite this recent progress in myoepithelial cell research, the cell kinetics of myoepithelial cells has not been elucidated, and the mechanism of myoepithelial cell layer disruptions remains elusive.

Based on these findings, it is hypothesized that disruptions of the BM and myoepithelial cell layers and tumor invasion may be initiated or mediated by myoepithelial cells. The hypothesized mechanism and the involved processes are as follows. Normal myoepithelial cells frequently undergo proliferation and differentiation to replace aged or injured cells. An external or internal insult then disrupts the normal replacement process, resulting in a cluster of dying myoepithelial cells. Following this, degraded products of dead myoepithelial cells attract lymphocyte infiltration that physically disrupts the BM. A focal disruption in the myoepithelial cell layer and the BM layer then results in an increased permeability for metabolism-and growth-related molecules. The altered

microenvironment results in the changes of the gene expression pattern and the behavior of the adjacent epithelial cells, facilitating the formation of a biologically more aggressive cell clone. Epithelial cells overlying disrupted myoepithelial cell layers then undergo a localized epithelial cell proliferation, which may occur in two forms: stem cell mediated proliferation that gives rise to ER-negative cell clusters, and differentiated cell mediated proliferation that produces ER-positive cells. Finally, cells overlying disrupted myoepithelial cell layers undergo cytodifferentiation, releasing stage-restricted and invasion-associated molecules, which trigger angiogenesis, tissue remodeling, and increasing production of growth factors in the stroma, providing a favorable environment for epithelial cell growth [34-36]. These interactive changes between epithelial and stromal cells lead to further degradation of the BM and myoepithelial cell layers, and a clonal expansion and stromal invasion of cells overlying disrupted myoepithelial cell layers.

These hypotheses appear to be supported by the results of two recent studies showing that the frequency of white blood cell infiltration into the tumor tissues seems to linearly increase with tumor progression [37,38]. They are also in an agreement with the results of most recent study, which reveals that ducts with focally disrupted myoepithelial cell layers have a significantly higher rate of white blood cell infiltration and more clusters of multiple proliferating cells compared with morphologically comparable ducts without myoepithelial disruptions.

The mechanism for the loss or diminution of ER expression in cells overlying a disrupted myoepithelial cell layer is unknown, but could result

from several reasons. A previous immunohistochemical study in human breasts has shown that none of the epithelial cells with ER expression and progesterone receptor expression was proliferating, and none of the proliferating cells showed either ER or progesterone receptor expression [39]. The ER gene in these cells might have been inactivated by methylation during tumor progression. Previous studies have shown that the progression of breast tumors is paralleled by a progressive hormonal independence [14-17]. A recent study has revealed that α -ER and β -ER are separately localized in a subset of breast tumors and appear to have different functions [40]. These cells might be derived from the myoepithelial lineage. A number of previous studies have shown that myoepithelial cells can express partial myodifferentiation in human breast cancer [41-43]. Finally, these cells are newly formed through a stem cell mediated clonal proliferation and are not mature enough to express the ER protein. Previous studies have demonstrated that the ER expression status is related to the age or

differentiation status of the cells [25,44,45].

Conclusions

A total of 101 focal disruptions in the myoepithelial cell layers were detected from 1424 duct cross-sections of 24 patients with DCIS. Of the 101 disruptions, 88 (87 %) were overlain by ER-negative cell clusters and 13(12.8%) were overlain by ER-positive cell clusters ($P < 0.01$). The microdissected ER-negative and ER-positive cells within the same duct from all five selected cases showed a different frequency or pattern of LOH and/or MI. The loss or reduction of ER expression, along with a different pattern of genetic alterations, suggests that the ER-negative cell clusters and their adjacent ER-positive counterparts might have substantially different genetic and biochemical profiles.

Abbreviations

BM = basement membrane; DCIS = ductal carcinoma *in situ*; ER = estrogen receptor; H & E = hematoxylin and eosin; LOH = loss of heterozygosity; MI = microsatellite instability; SMA = smooth muscle actin.

Table 1. Frequency of myoepithelial cell layer disruptions and the status of estrogen receptor expression

Total cross-sections	Total disruptions	Focal loss of estrogen receptor	Estrogen receptor-positive	P
1424	101 (7. %)	88 (87 %)	13 (12.8%)	< 0.01

References

1. Tsubura, A, Shikata, N, Inui, T, Morii, S, Hatano, T, & Oikawa, T: Virchows Arch 1988, 413:133–139.
2. Jolicoeur, F, Seemayer, TA, Gabbiani, G, Robidoux, A, Gaboury, L, Oligny, LL, & Schurch, W: Int J Surg Pathol 2002, 10:281–291.
3. Slade, MJ, Coope, RC, Gomm, JJ, & Coombes, RC: Exp Cell Res 1999, 247:267–278.
4. Miosge, N: Histol Histopathol 2001, 16:1239–1248.
5. Nerlich, A: Veroff Pathol 1995, 145:1–139.
6. Pasqualini, JR: Breast Cancer – Prognosis, Treatment, and Prevention (New York: Marcel Dekker)2002.
7. Goldfarb, RH & Liotta, LA: Semin Thromb Hemost 1986, 12:294–307.

8. Coussens, LM, Fingleton, B, & Matrisian, LM: Science 2002, 295:2387–2392.
9. Tavassoli, FA & Man, YG: Breast J 1995, 1:155–162.
10. Man, YG, Saenger, JS, Strauss, BL, Vang, RS, Bratthauer, GL, Chen, PY, & Tavassoli, FA: Proceedings of Department of Defense Breast Cancer Research Program Meeting: September 25–28 2002; Orlando, FL, Fort Detrick, MD: US Army Medical Research and Material Command 2002, 1:Poster section 9:14.
11. Man, YG, Vang, RS, Saenger, JS, Strauss, BL, Bratthauer, GL, Chen, PY, & Tavassoli, FA: Proceedings of Department of Defense Breast Cancer Research Program Meeting: September 25–28 2002; Orlando, FL, Fort Detrick, MD: US Army Medical Research and Material Command 2002, 1:Poster section 9:16.
12. Moinfar, F, Man, YG, Arnould, L, Bratthauer, GL, Ratschek, M, & Tavassoli, FA: Cancer Res 2000, 60:2562–2566.
13. Man, YG, Mannion, C, Albores-Saavedra, J, Bratthauer, GL, Kuhls, E, & Tavassoli, FA: Appl Immunohistochem Mol Morphology 2001, 9:340–345.
14. Schmitt, FC: Eur J Cancer 1995, 31A:2049–2052.
15. Clarke, R, Brunner, N, & Katzenellenbogen, BS: Proc Natl Acad Sci USA 1989, 86:3649–3653.
16. Murphy, LC: In vivo 1998, 2:95–106.
17. Sheikh, MS, Garcia, M, Pujol, P, Fontana, JA, & Rochefort, H: Invasion Metastasis 1994, 14:329–336.
18. Man, YG & Tavassoli, FA: Appl Immunohistochem 1996, 4:139–141.
19. Man, YG, Ball, WD, Culp, AJ, Hand, AR, & Moreira, JE: J Histochem Cytochem 1995, 43:1203–1215.
20. Man, YG, Schammel, DP, & Tavassoli, FA: [abstract] Cell Vision 1998, 5:84–85.
21. Moinfar, F, Man, YG, Lininger, RA, & Tavassoli, FA: Am J Surg Pathol 1999, 23:1048–1058.
22. Man, YG, Moinfar, F, Bratthauer, GL, Kuhls, E, & Tavassoli, FA: Pathol Res Prac 2001, 197:635–642.
23. Man, YG, Moinfar, F, Bratthauer, GL, & Tavassoli, FA: Diag Mol Pathol 2000, 9:84–90.
24. Man, YG, Kuhls, E, Bratthauer, GL, Moinfar, F, & Tavassoli, FA: Electrophoresis 2001, 22:1915–1919.
25. Robinson, GW, McKnight, RA, Smith, GH, & Hennighausen, L: Development (Camb) 1995, 121:2079–2090.
26. Chodosh, LA, Cruz, CMD, & Gardner, HP: Cancer Res 1999, 59:1765s–1772s.
27. Sternlight, MD & Barsky, SH: Med Hypotheses 1997, 48:37–46.
28. Sternlight, MD, Safarians, S, Rivera, SP, & Barsky, SH: Lab Invest 1996, 74:781–796.
29. Shao, ZM, Nguyen, M, Alpaugh, ML, O'Connell, JT, & Barsky, SH: Exp Cell Res 1998, 241:394–403.
30. Tobacman, JK, Hinkhouse, M, & Khalkhali-Ellis, Z: J Steroid Biochem Mol Biol 2002, 81:65–68.
31. Tobacman, JK: Cancer Res 1997, 57:2823–2826.
32. Sapino, A, Macri, L, Tonda, L, & Bussolati, G: Endocrinology 1993, 133:838–842.
33. Zhang, R, Man, YG, Vang, RS, Saenger, JS, Barner, R, Wheeler, DT, Liang, CY, Vinh, TN, & Bratthauer, GL: Breast Cancer Res 2003, 5:R151–R156.
34. Bissell, MJ, Radisky, DC, Rizki, A, Weaver, VM, & Petersen, OW: Differentiation 2002, 70:537–546.
35. Muschler, J, Levy, D, Boudreau, R, Henry, M, Campbell, K, & Bissell, MJ: Cancer Res 2002, 62:7102–7109.
36. Gudjonsson, T, Ronnov-Jessen, L, Villadsen, R, Rank, F, Bissell, MJ, & Petersen, OW: J Cell Sci 2002, 115:39–50.

37. Ben-Hur, H, Cohen, O, Schneider, D, Gyrevich, P, Halperin, R, Bala, U, Mozes, M, & Zusman, I: Anticancer Res 2002, 22:1231–1238.
38. Gannot, G, Gannot, I, Vered, H, Buchner, A, & Keisari, Y: Br J Cancer 2002, 86:1444–1448.
39. Russo, J, Ao, X, Grill, C, & Russo, IH: Breast Cancer Res Treat 1999, 53:217–227.
40. Fuqua, SA, Schiff, R, Parra, I, Moore, JT, Mohsin, SK, Osborne, CK, Clark, GM, & Allred, DC: Cancer Res 2003, 63:2434–2439.
41. Malzahn, K, Mitze, M, Thoenes, M, & Moll, R: Vir Arch 1998, 433:119–129.
42. Petersen, OW, Nielsen, HL, Gudjonsson, T, Villadsen, , Ronnov-Jessen, L, & Bissell, MJ: Breast Cancer Res 2001, 3:213–217.
43. Petersen, OW, Hoyer, PE, & van Deurs, B: Cancer Res 1987, 47:5748–5751.
44. Chen, CM, Martin, LA, Johnston, SR, Ali, S, & Dowsett, M: J Steroid Biochem Mol Biol 2002, 81:333–341.
45. Ponder, BA: Nature 2001, 411:336–341.

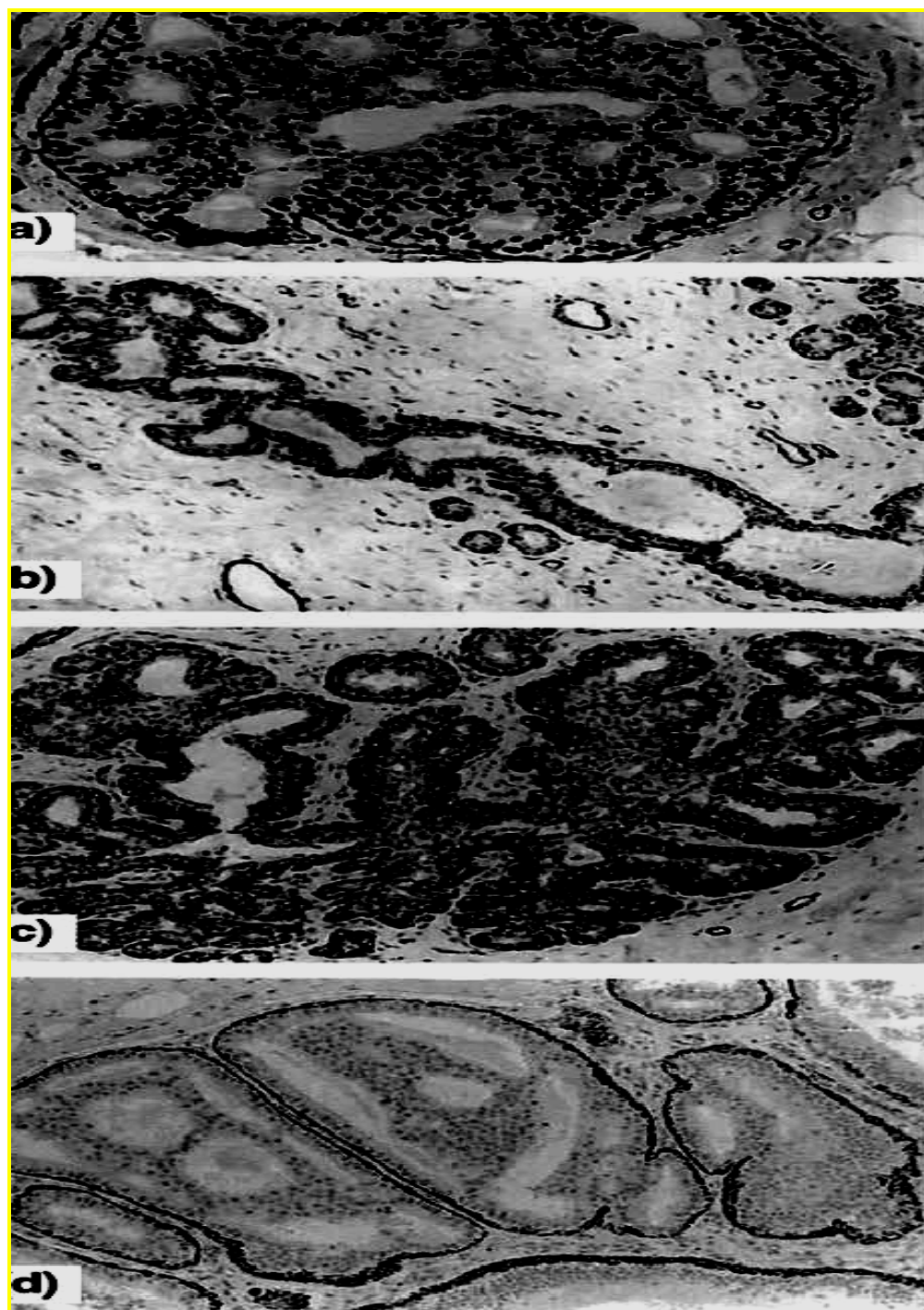


Figure 1 Disruptions of myoepithelial cell layers are independent of the size, length, architecture, and overall estrogen receptor (ER) negativity of the ducts. Paraffin-embedded breast tissue sections were double immunostained with antibodies to ER and smooth muscle actin, and were developed with 3,3'-diaminobenzidine (DAB; black or brown) and 3-amino-9-ethylcarbazole (AEC; red) chromogens, respectively. Distinct myoepithelial cell layers are seen in the following structures: **(a)** a large duct with ductal carcinoma *in situ* (DCIS), 100×; **(b)** a long normal duct, 40×; **(c)** a duct with intraductal hyperplasia, 100×; **(d)** intermediate grade ER-negative DCIS, 100×.

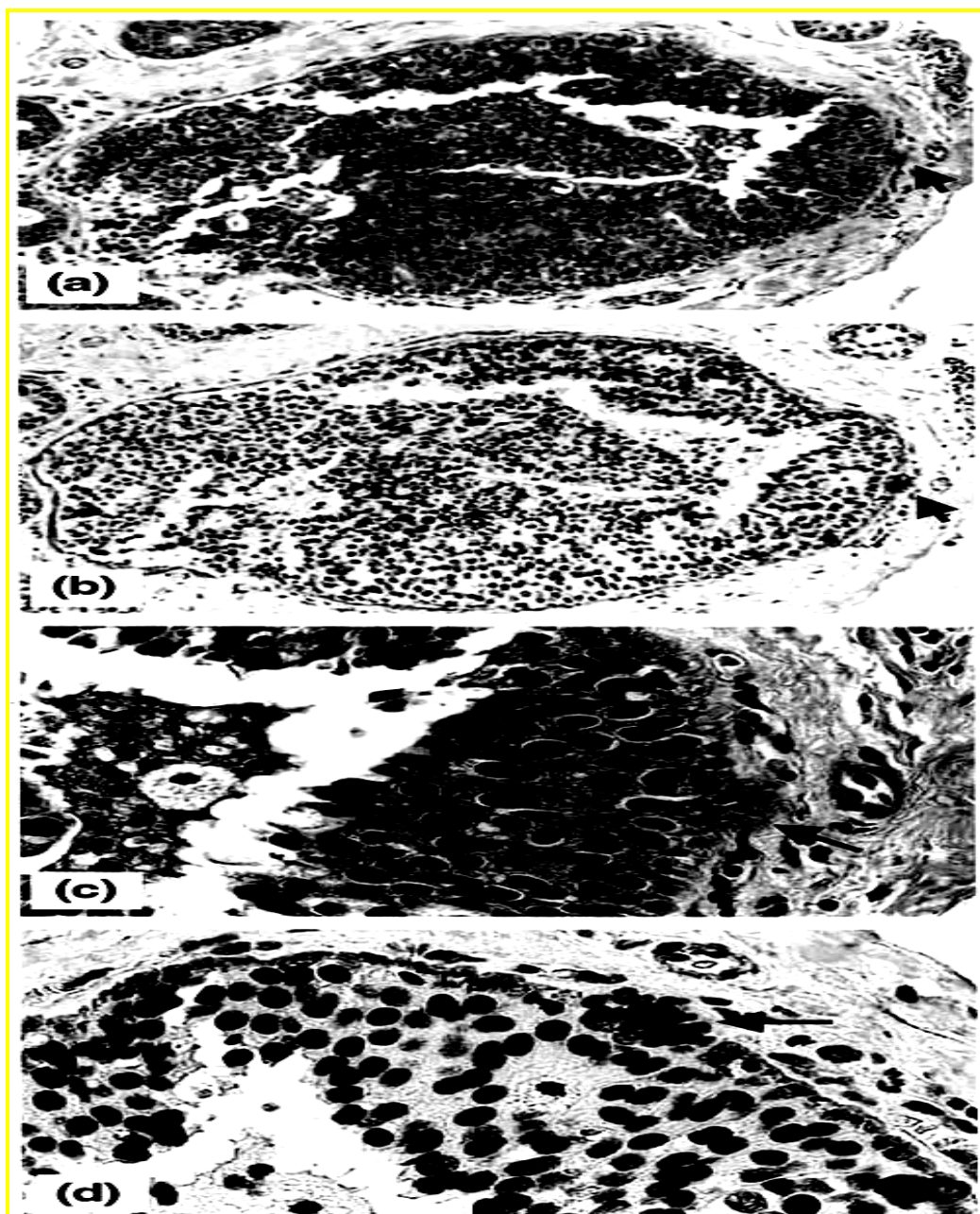


Figure 2 Myoepithelial cell layer disruptions and overlying small estrogen receptor (ER)-negative cell clusters (< 15 cells) in ER-positive ductal carcinoma *in situ* (DCIS). **(a)** H & E staining of a large duct with DCIS, 100×; **(b)** the adjacent section of (a) immunostained, 100×; **(c)** a higher magnification of (a); **(d)** a higher magnification of (b). The myoepithelial cell layer disruption and the overlying ER-negative cells are identified with an arrow.

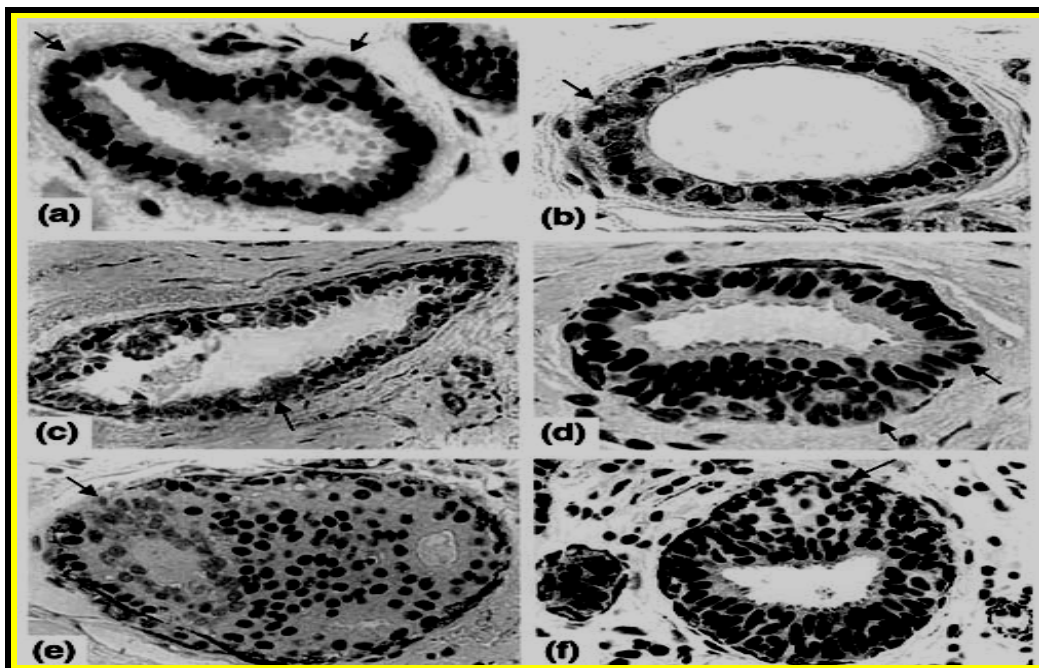


Figure 3 Myoepithelial cell layer disruptions and overlying estrogen receptor (ER)-negative cell clusters in normal and hyperplastic appearing ducts. All sections were immunostained for ER (brown) and smooth muscle actin (red). (a)–(c) Normal appearing ducts, 400×; (d)–(f) hyperplastic ducts, 400×. Myoepithelial cell layer disruptions and ER-negative cell clusters are identified with arrows.

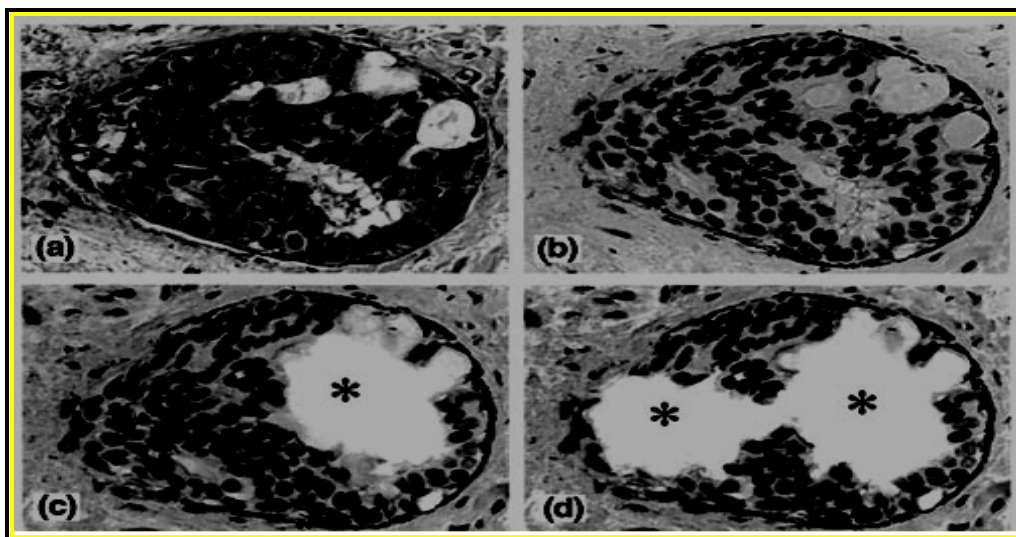


Figure 4 Comparison of the loss of heterozygosity (LOH) pattern in estrogen receptor (ER)-negative cells and adjacent ER-positive cells within the same duct. (a) H & E staining of a duct with atypical intraductal hyperplasia, 200×; (b) the adjacent section of (a) immunostained for ER, 200×; (c) ER-positive cells; (d) ER-negative cells. Asterisks indicate the ER-negative cells and the ER-positive cells; arrows identify LOH.