There is more than one kind of myofibroblast: analysis of CD34 expression in benign, in situ, and invasive breast lesions

H Chauhan, A Abraham, J R A Phillips, J H Pringle, R A Walker, J L Jones

AIMS: Smooth muscle actin (SMA) positive myofibroblasts have been implicated in tumour invasion; however, acquisition of SMA is not limited to peritumorous fibroblasts and other changes in fibroblasts may be more specifically related to the malignant environment. CD34 is a sialomucin expressed by normal breast fibroblasts but lost in invasive carcinomas. The aim of this study was to establish the relation between CD34 and SMA expression in breast fibroblasts and to analyse whether loss of CD34 is specific for invasive disease.

METHODS: Immunohistochemistry for CD34 and SMA was performed on 135 cases including 10 normal, 10 fibroadenomas, 40 infiltrating ductal carcinomas, 55 cases of ductal carcinoma in situ (DCIS), and 20 radial scar/complex sclerosing lesions. The relation between staining pattern and histopathological features was recorded as positive, negative, or reduced.

RESULTS: Fibroblasts around all normal duct–lobule units and those showing epithelial hyperplasia were CD34 positive and mainly SMA negative. In fibroadenomas, fibroblasts retained CD34 but acquired SMA expression. In contrast, fibroblasts around invasive carcinoma were CD34 positive and SMA negative. In DCIS, loss of CD34 was significantly more frequent in high grade tumours than in low or intermediate grade ones (p < 0.001). The acquisition of SMA was seen more frequently than the loss of CD34, particularly in non-high grade DCIS. In all radial scars, fibroblasts were SMA positive but CD34 negative, and a similar pattern was seen in stromal cells in areas of fibrosis following core biopsy.

CONCLUSIONS: These results show that SMA positive myofibroblasts exhibit variable expression of CD34, indicating that these markers are not coordinately controlled. Loss of CD34 is strongly related to the malignant phenotype, in both invasive and preinvasive disease, but is not entirely specific because radial scar fibroblasts and fibroblasts in reactive fibrosis exhibit a similar phenotype. The functional relevance of altered CD34 expression is unclear but the very focal changes implicate local signalling mechanisms probably of epithelial origin.
inverse relation between CD34 expression and myofibroblastic differentiation.24 Whereas the normal mammary stroma comprises CD34 positive spindle cells, CD34 expression is lost on the fibroblasts surrounding invasive carcinomas,33 although it is retained by endothelial cells, making it a useful marker for studies of angiogenesis.34

The aim of our study was to examine the relation between CD34 and αSMA expression in breast fibroblasts, and to

Table 1 Summary of the pattern of expression of CD34 and α smooth muscle antigen (αSMA) in fibroblasts in relation to histopathological features

<table>
<thead>
<tr>
<th>Histology</th>
<th>CD34</th>
<th>αSMA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Normal</td>
<td>301</td>
<td>0</td>
</tr>
<tr>
<td>HUT</td>
<td>88</td>
<td>0</td>
</tr>
<tr>
<td>DCIS: low</td>
<td>28</td>
<td>21</td>
</tr>
<tr>
<td>DCIS: intermediate</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>DCIS: high</td>
<td>48</td>
<td>311</td>
</tr>
<tr>
<td>LCIS</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Invasive carcinoma</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>Microinvasion</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Radial scar</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>Fibroadenoma</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Apocrine cyst</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Postbiopsy fibrosis</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

For normal breast, ductal carcinoma in situ (DCIS), lobular carcinoma in situ (LCIS), atypical ductal hyperplasia (ADH), and hyperplasia of usual type (HUT), figures relate to individual duct-lobular units. For fibroadenomas, radial scars, postbiopsy fibrosis, and invasive carcinomas, figures relate to case numbers.

Figure 1 Fibroblasts are CD34 positive around (A) normal breast ducts and lobules and (C) hyperplasia of usual type, but are negative for α smooth muscle actin (αSMA) (B, D). Small calibre blood vessels are also CD34 positive (arrowhead in A and B). In invasive carcinomas, peritumorous fibroblasts are uniformly (E) CD34 negative and (F) αSMA positive.
investigate whether the loss of CD34 expression is a more sensitive or specific marker of malignancy in the breast than αSMA expression, with particular emphasis on expression patterns in preinvasive and at risk lesions.

**MATERIALS AND METHODS**

Immunohistochemistry for CD34 and αSMA was performed on serial sections taken from normal breast (n = 10), fibroadenoma (n = 10), infiltrating ductal carcinoma (n = 40), ductal carcinoma in situ (n = 55), and radial scar/complex sclerosing lesions (n = 20). A standard avidin biotin complex technique, without prior antigen retrieval, was used incorporating 10 minutes’ incubation in 60% H2O2 to block endogenous peroxidase. The primary antibodies were diluted in Dako antibody diluent (Qbend-10; Dako, Ely, Cambridgeshire, UK) at 1/100 for CD34 and 1/600 for αSMA. Staining of blood vessels was used as an internal positive control for CD34 and of normal myoepithelial cells for αSMA. For each case, serial sections were also stained with haematoxylin and eosin and in a proportion of cases serial sections were stained with anti-CD31 (Dako) as a further marker of endothelial cells.

**Figure 2**  In ducts displaying features of high grade DCIS, 78% were associated with (A, C) CD34 negative periductal fibroblasts and (B, D) the acquisition of α smooth muscle actin (αSMA). (C) Black arrows indicate retained CD34 on small blood vessels in contrast to the fibroblasts (white arrowhead). In low grade DCIS, (E) 47% of duct-lobular units retained CD34 on periductal fibroblasts with (f) 27% remaining αSMA negative; however, 35% of low grade DCIS ducts showed a similar expression pattern to high grade DCIS, with (G) loss of CD34 (arrows indicate CD34 positive blood vessels) and (H) gain of αSMA.
Fibroblast reactivity for CD34 and αSMA was recorded as positive, negative, and—where there was focal loss—as reduced. Because many of the sections contained ducts and lobules showing a range of histopathological features, the relation between staining pattern and pathology was interpreted for each duct–lobular unit. Thus, in addition to 40 infiltrating ductal carcinomas (IDCs) and 10 fibroadenomas, 301 normal duct–lobular units were scored, 535 ducts with ductal carcinoma in situ (DCIS; 60 low grade, 77 intermediate, and 398 high grade), six cases showing microinvasion, 88 duct–lobular units exhibiting usual type epithelial hyperplasia (HUT), six with atypical ductal hyperplasia (ADH), 12 lobular carcinoma in situ (LCIS), 11 apocrine cysts, and 24 radial scars, four of which contained areas of reactive fibrosis following preoperative core biopsy (table 1).

The relation between the staining pattern and the different histological features was compared using the χ² test, and p < 0.05 was considered significant.

RESULTS
In the normal breast, both intralobular and extralobular fibroblasts exhibited strong uniform staining for CD34 and were αSMA negative. This pattern was maintained in the presence of other pathology, including adjacent carcinoma; thus, in all 301 normal duct–lobular units fibroblasts were CD34 positive and, with the exception of 23 cases, αSMA negative (fig 1A,B). Similarly, fibroblasts around glands showing HUT, LCIS, or apocrine cyst formation were CD34 positive/αSMA negative (fig 1C,D), with the exception of focal αSMA positivity around nine of 79 ducts with epithelial hyperplasia. Fibroadenomas showed a homogeneous pattern of staining, with fibroblasts being strongly CD34 positive and αSMA positive. In contrast, all IDCs and foci of microinvasion exhibited consistent loss of CD34 expression on fibroblasts, but acquisition of αSMA (fig 1E,F). Discrete staining for CD34 was evident on small calibre blood vessels within the stroma, confirmed by their expression of the vascular antigen CD31.

The most variable pattern of expression was seen on fibroblasts surrounding ducts with DCIS; however, the loss of CD34 expression was significantly more frequent in high nuclear grade compared with low or intermediate grade samples (p < 0.001). In high grade DCIS, fibroblasts were CD34 negative in 78% cases compared with 29 of 77 (33%) intermediate and 21 of 60 (35%) cases of low grade DCIS (table 1; fig 2). In some cases, partial loss of CD34 was evident around a duct. The incidence of reduced staining was again variable between the grades; however, only 12% of cases of high grade DCIS retained normal CD34 expression compared with 22 of 77 (29%) intermediate grade and 28 of 60 (47%) low grade cases. Staining of serial sections of 20 of these cases with CD31
CD34 expression in breast

Our study has shown that fibroblast CD34 expression is consistently lost in invasive breast carcinomas that include microinvasion, and in a high proportion of cases of DCIS, particularly high grade lesions, which are thought to be more likely to progress to invasion.\(^4\) Loss of expression is also seen in a proportion of ADH, but not around glandular structures showing LCIS. This is of interest because ADH and DCIS are regarded as premalignant lesions, whereas LCIS is considered to confer an increased risk of developing carcinoma, but the risk relates to the development of carcinoma in either breast, and it also demonstrates that not all myofibroblasts associated with ADH, with a proportion of CD34 negative fibroblasts in half the cases; however, in none of the six cases was there evidence of LCIS staining.

In the radial scars, most fibroblasts were CD34 negative/αSMA positive (fig 3), although some cases displayed CD34 positive/αSMA positive fibroblasts at the periphery of the lesion. The pattern was similar in those radial scars admixed with DCIS (n = 4) and those not associated with malignant change (n = 20). Interestingly, in four cases, areas of reactive fibrosis were evident from preoperative core biopsy, and in these sites the fibroblasts were uniformly CD34 negative/αSMA positive (fig 3).

**DISCUSSION**

CD34 is a transmembrane glycoprotein that is thought to be involved in the modulation of cell adhesion and signal transduction,\(^5\) and is expressed by mesenchymal cells at several sites, including the normal mammary stroma.\(^6\,\,7\) Loss of CD34 by mesenchymal cells has been described in several situations where there is malignant transformation of the mesenchymal population. Malignant phyllodes tumours of the breast exhibit lower levels of CD34 expression than benign phyllodes or fibroadenomas,\(^8\)\(^-\)\(^10\) and CD34 is lost in sarcomas arising within CD34 positive dermatofibrosarcoma protuberans.\(^11\) Loss of fibroblast CD34 has also been described in non-neoplastic fibroblasts around epithelial tumours, such as basal cell carcinoma\(^12\) and colorectal carcinoma.\(^13\)

"Loss of CD34 may be related to invasive potential"

The importance of changes in fibroblast function in promoting tumour progression is increasingly recognised and such a tumour promoting effect is frequently attributed to the activation of fibroblasts to αSMA positive myofibroblasts. However, our study clearly demonstrates that acquisition of the myofibroblast phenotype is not indicative of malignancy in the breast, and it also demonstrates that not all myofibroblasts have the same phenotype, some being CD34 positive, as in fibroadenomas, and others being CD34 negative, as in invasive and many in situ lesions. The potential for the stromal response to tumours becoming a target for treatment is increasing, with clinical trials in place for fibroblast derived factors such as MMP\(^14\) and Tenascin.\(^15\) However, it is essential that the changes in fibroblast phenotype associated with malignancy are carefully dissected, not only to validate their use as possible diagnostic markers, but also to establish their potential as therapeutic targets.

**Take home messages**

- Smooth muscle actin positive myofibroblasts express CD34 to varying degrees, indicating that these markers are not coordinate controlled.
- The loss of CD34 is strongly related to the malignant phenotype, in both invasive and preinvasive disease, but is not entirely specific because radial scar fibroblasts and fibroblasts in reactive fibrosis exhibit a similar phenotype.
- The functional relevance of altered CD34 expression is unclear but the very focal changes implicate local signalling mechanisms, probably epithelial in origin.
- In vitro studies should be undertaken to establish the role of CD34 in the breast fibroblast.

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