Advances in digital mammography

Gisella Gennaro
Veneto Institute of Oncology (IOV), IRCCS
Padua - Italy

Lisbon - Sep 20, 2013
Outline

1. Digital breast tomosynthesis (DBT)
2. (Contrast-enhanced) spectral mammography
3. Quantitative breast density
Outline

1. Digital breast tomosynthesis (DBT)
2. (Contrast-enhanced) spectral mammography
3. Quantitative breast density
Limitation of standard mammography

**Breast is 3D**

- **X-rays (invisible)**
- **Compression Plates**
- **Breast**
- **Anti-Scatter Grid**

**Transmitted X-ray image (invisible)**

**Signal proportional to X-ray photon intensity/number**

**Mammography image is 2D**

**MAMMOGRAM (visible)**
Limitation of standard mammography (2/3)

- Everything between the beam entrance and the breast exit is projected onto a plane
- A mammography image is an absorption map produced by superimposed structures
- Breasts are different in structure and produce very different absorption maps
On the Difficulty of Detecting Tumors in Mammograms

Arthur E. Burgess, Francine L. Jacobson, and Philip F. Judy

LESION DETECTION IS BASICALLY A PROBLEM OF LOCAL CONTRAST
What tomosynthesis is

- The digital application of old techniques called “laminography”

- A “small angle CT”, where multiple planes of an anatomical part are reconstructed ONLY IN ONE SPATIAL DIRECTION, starting from a limited number of low-dose, projection images, acquired within a limited angular aperture
The idea is not new...

A Bocage (1917): developed the «Biotome», a radiographic technique which allowed «cutting» the human body in longitudinal slices and, at the end, to select the level needed (Great War – to determine the depth of a metal foreign body in the body of a patient). Never produced.
Digital detectors made it possible.
How tomosynthesis works
CONCLUSION:
«Digital mammographic system make breast tomosynthesis possible. Tomosynthesis may improve the specificity of mammography with improved lesion margin visibility and may improve early breast cancer detection, especially in women with radiographically dense breasts.»

Senographe DMR modified
Digital detector developed by GE
ACR phantom
4 mastectomy specimens
NOWADAYS, TOMOSYNTHESIS HAS BEEN CONSIDERED BY MANUFACTURERS MORE INTERESTING THAN OTHER 3D TECHNIQUES (like breast CT) BECAUSE IT IS NOT A SEPARATE MODALITY, BUT IS JUST A «MODIFIED MAMMOGRAPHY SYSTEM». IT CAN BE SOLD AS AN OPTIONAL OF THE MAMMOGRAPHIC UNIT
Tomosynthesis and radiation dose

✓ Most of the studies with prototype devices kept «wide margins» with radiation dose, by applying the «non-inferiority principle» versus other well accepted technologies, like screen-film mammography. Dose reduced moving to commercial systems.

✓ It is difficult to go in depth in tomosynthesis dosimetry, the clinical protocol with DBT being still under discussion: DBT alone or added to mammography? One or two views? ...). USUALLY, TOTAL DOSE WITH DBT SHOULD NOT EXCEED THE TOTAL DOSE DELIVERED FOR MAMMOGRAPHY.

✓ The dose parameter used is still the average/mean glandular dose (AGD o MGD)

Sechopoulos et al. (2007), Med.Phys 34:221

\[ D_g = X_{CR} \times D_s N_0 \times \sum_{\alpha=\alpha_{MIN}}^{\alpha_{MAX}} RGD(\alpha) \]

Relative Glandular Dose

GIVEN THE SAME ENTRANCE DOSE (PER PROJECTION), DOSE ACTUALLY CONTRIBUTING TO PRODUCE THE IMAGE CHANGES WITH THE ANGLE
## Image detector / X-ray source

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>GEH</th>
<th>Hologic</th>
<th>IMS</th>
<th>Philips</th>
<th>Planmed</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Senographe Essential</td>
<td>Selenia Dimensions</td>
<td>Giotto TOMO</td>
<td>MicroDose</td>
<td>Nuance Excel DBT</td>
<td>Mammmomat Inspiration</td>
</tr>
<tr>
<td>Detector</td>
<td>FPD CsI</td>
<td>FPD a-Se</td>
<td>FPD a-Se</td>
<td>Photon counting</td>
<td>FPD a-Se</td>
<td>FPD a-Se</td>
</tr>
<tr>
<td>Pixel size (μm)</td>
<td>100</td>
<td>70 MG 140 DBT</td>
<td>85</td>
<td>50</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Anode</td>
<td>Mo e Rh</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>Mo e W</td>
</tr>
<tr>
<td>Filtration</td>
<td>0.03 mm Mo 0.025 mm Rh</td>
<td>0.05 mm Rh MG 0.7 mm Al DBT</td>
<td>0.05 mm Rh 0.05 mm Ag</td>
<td>0.5 mm Al</td>
<td>0.06 mm Rh 0.075 mm Ag</td>
<td>0.03 mm Mo 0.05 mm Rh</td>
</tr>
</tbody>
</table>
### Tomosynthesis

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>GEH</th>
<th>Hologic</th>
<th>IMS</th>
<th>Philips</th>
<th>Planmed</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Senographe Essential</td>
<td>Selenia Dimensions</td>
<td>Giotto TOMO</td>
<td>MicroDose</td>
<td>Nuance Excel DBT</td>
<td>Mammmomat Inspiration</td>
</tr>
<tr>
<td>Detector motion</td>
<td>static</td>
<td>rotating</td>
<td>static</td>
<td>continuous slit scan</td>
<td>rotating</td>
<td>static</td>
</tr>
<tr>
<td>Tube motion</td>
<td>step-and-shoot</td>
<td>continuous</td>
<td>step-and-shoot</td>
<td>continuous</td>
<td>continuous</td>
<td>continuous</td>
</tr>
<tr>
<td>Angular range (°)</td>
<td>25</td>
<td>15</td>
<td>40</td>
<td>11</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>N° of projections</td>
<td>9</td>
<td>14</td>
<td>13</td>
<td>21</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Scan time(s)</td>
<td>7</td>
<td>4</td>
<td>12</td>
<td>3-10</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>mAs/projection</td>
<td>variable*</td>
<td>uniform</td>
<td>variable*</td>
<td>uniform</td>
<td>uniform</td>
<td>uniform</td>
</tr>
<tr>
<td>Reconstruction algorithm</td>
<td>iterative</td>
<td>FBP</td>
<td>iterative</td>
<td>iterative</td>
<td>iterative</td>
<td>FBP</td>
</tr>
<tr>
<td>Development stage**</td>
<td>CE mark</td>
<td>FDA approval</td>
<td>CE mark</td>
<td>prototype</td>
<td>prototype</td>
<td>CE mark</td>
</tr>
</tbody>
</table>

*different dose distribution between central projection and angled projections*

** possible evolution
### DBT: angle and number of projections

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>GEH</th>
<th>Hologic</th>
<th>IMS</th>
<th>Philips</th>
<th>Planmed</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Senographe Essential</td>
<td>Selenia Dimensions</td>
<td>Giotto TOMO</td>
<td>MicroDose</td>
<td>Nuance Excel DBT</td>
<td>Mammomat Inspiration</td>
</tr>
<tr>
<td>Angular aperture (°)</td>
<td>25</td>
<td>15</td>
<td>40</td>
<td>11</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>N° of projections</td>
<td>9</td>
<td>14</td>
<td>13</td>
<td>21</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

- Wide differences in angular aperture across manufacturers
- The number of projections is limited by the overall radiation dose (and by the angle itself)
- Small angles show advantages to depict small objects (ex. microcalcs)
- Wide angles show advantages to depict «large» objects (ex. masses)

<Diagram by Siemens>

G. Gennaro – Lisbon - Sep 20, 2013
DBT: projections vs. tomographic planes

- DBT «slices» have no thickness, they are planes
- The value reported as «slice thickness» (typ. 0.5-1.0 mm) is the sampling interval
- Breast volume reconstruction possible only in the direction of breast compression

© Veneto Institute of Oncology, Padua, Italy

G. Gennaro – Lisbon - Sep 20, 2013
Reconstruction algorithms


TOMOSYNTHESIS ACQUISITION GEOMETRY IS LIMITED FOR THE FOLLOWING RECONSTRUCTION:
• LIMITED NUMBER OF PROJECTIONS
• LOW DOE PROJECTIONS
• LIMITED ANGULAR RANGE

“DIRECT” ALGORITHM
• back-projection (BP)
• filtered back-projection (FBP)

ITERATIVE ALGORITHMS
• Algebraic methods:
  - Algebraic Reconstruction Technique (ART)
  - Simultaneous Algebraic Reconstruction Technique (SART)
  - Simultaneous Iterative Reconstruction Technique (SIRT)

• Statistical methods:
  - Maximum Likelihood (ML)
DBT: strengths

- TOMOSYNTHESIS IS VERY EFFECTIVE IN DEPICTION OF ARCHITECTURAL DISTORSIONS AND SPICULATED MASSES
- FALSE POSITIVES FROM SCARS / PREVIOUS BIOPSIES ...

- VERY GOOD FOR MASSES
- ALLOWS SEPARATION OF MASSES IN-FOCUS IN DIFFERENT PLANES
DBT: potential weaknesses

✓ MICROCALCIFICATIONS ARE DISTRIBUTED IN DIFFERENT PLANES AND CAN LOOSE CLUSTER APPAREANCE
✓ THEY LOOK LIKE «BRIGHTER» THAN IN STANDARD MAMMOGRAPHY, AND THIS MIGHT INDUCE THE READERS TO UNDERESTIMATE THE PROBABILITY OF MALIGNANCY, CALCIFICATION DENSITY BEING USUALLY ASSOCIATED TO BENIGN LESIONS

Gennaro et al (2013), Eur Radiol
DOI 10.1007/s00330-013-2831-0


CONCLUSION. In this small data set, FFDM appears to be slightly more sensitive than digital breast tomosynthesis for the detection of calcification. However, diagnostic performance as measured by area under the curve using BI-RADS was not significantly different. With improvements in processing algorithms and display, digital breast tomosynthesis could potentially be improved for this purpose.
Slab computation

- Slabs:
  - combine information spread on several consecutive slices (microcalcs)
  - overlap (half thickness): reduce risk of lesions spread on two consecutive slabs
  - reduced dataset (12 images as an average to scroll the entire volume)

Courtesy of Sylvain Bernard, GEH

© Veneto Institute of Oncology, Padua, Italy
Many published results have been obtained by prototype devices
(SOME «PREFERENCE» STUDIES)
MOSTLY RETROSPECTIVE STUDIES
FIRST RESULTS FROM PROSPECTIVE STUDIES

CARE NECESSARY TO COMPARE CLINICAL STUDIES WITH DIFFERENT DESIGNS (IS WRONG TO CONSIDER ONLY CONCLUSIONS)
Clinical performance studies

✓ Images obtained with the two compared modalities, separately evaluated, taking all the actions to limit possible biases reduction; usually, readers are asked to localize features and rate them according to given scales.

✓ Typical scales: probability of malignancy or BI-RADS score (5-7 steps)

✓ Truth is established from histology (in case of surgery or biopsy) and/or long-term follow-up (at least 1 y)

✓ Radiologists ratings are compared with the truth, and differences between clinical performance variables (Se, Sp, PPV, PNV, ROC, AUC, FROC, etc) for each modality analyzed
<table>
<thead>
<tr>
<th>1° author/journal</th>
<th>Population</th>
<th>Readers</th>
<th>Comparison</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersson et al / Eur Radiol 2008</td>
<td>36 cases (40 K)</td>
<td>2</td>
<td>DBT&lt;sub&gt;MLO&lt;/sub&gt; vs. MX</td>
<td>Cancer visibility superior with DBT</td>
</tr>
<tr>
<td>Gur et al / AJR 2009</td>
<td>125 cases (35 K)</td>
<td>8</td>
<td>DBT + MX vs. MX</td>
<td>30% reduction recall rate</td>
</tr>
<tr>
<td>Spangler et al / AJR 2012</td>
<td>100 cases (20 K)</td>
<td>5</td>
<td>DBT vs. MX</td>
<td>Calcs: slightly better detection with DBT</td>
</tr>
</tbody>
</table>
| Teerstra et al / Eur Radiol 2010 | 513 cases (112 K) | 1       | DBT vs. MX          | ✓ Same Se: 92.9%  
✓ Sp: MX = 86.1%; DBT = 84.4%                                             |
| Gennaro et al / Eur Radiol 2010 | 376 cases (63 K) | 6       | DBT<sub>MLO</sub> vs. MX | AUC: DBT non-inferiority                                                |
| Gur et al / AJR 2011 | 125 cases (35 K) | 8       | DBT + MX vs. MX     | DBT + MX superior in lesion detection                                   |
| Wallis et al / Radiology 2012 | 130 cases (40 K) | 10      | DBT<sub>MLO</sub> vs. MX  
DBT vs. MX              | ✓ DBT non-inferiority  
✓ DBT superiority         |
| Svahn et al / BJR 2012 | 185 cases (95 K) | 5       | DBT<sub>MLO</sub> vs. MX | DBT better performance (JAFROC)                                         |
| Rafferty et al / Radiology 2012 | 312 cases (48 K) 312 cases (51 K) | 12  15  | DBT + MX vs. MX     | DBT+MX > accuracy (AUC)  
DBT+MX < recall rate                                                        |
| Zuley et al / Radiology 2012 | 217 cases (72 K) | 8       | DBT+MX vs. MX + extra views | Superiority DBT+MX                                                      |
| Gennaro et al / Eur Radiol 2013 | 469 cases (68 K) | 6       | DBT<sub>MLO</sub> + MX<sub>CC</sub> vs. MX per-breast | DBT<sub>MLO</sub> + MX<sub>CC</sub> non-inferiority  
Superiority for Sp benign                                                  |
| Gennaro et al / Eur Radiol 2013 | 463 cases (77 K) | 6       | DBT<sub>MLO</sub> + MX<sub>CC</sub> vs. MX per-lesion | Superiority lesion detection and characterization                      |
Prospective trials

**Oslo trial**
- 17,960 women
- 2-view DBT + 2-view MX vs. 2-view MX
  - higher detection rate (27% increase)
  - lower recall rate (15%)
  - Higher detection invasive cancers (40%)

**Malmo trial**
- 15,000 women
- 1-view DBT + 2-view MX vs. 2-view MX

**STORM trial (Italy)**
- 7292 women
- 2-view DBT + 2-view MX vs. 2-view MX
  - higher detection rate
  - lower recall rate

**TOMMY trial (UK)**
- 7000 women
- 2-view DBT vs. 2-view MX in screening recalled cases
Clinical trial are time consuming and complex, and it is forbidden to change the study design while it is going on.

This is the major reason why trial designs are «conservative» (in particular, prospective studies).

Radiologists are not «traumatized» from DBT evaluation, images being very similar to mammography images; however, it might be necessary some time to learn (for example to properly interpret some DBT features)

While DBT is allowed to be used together with mammography, some risks of «misuse» exist.
Open questions

✔ Which protocol? DBT alone? How many projections (CC/MLO/both)? DBT combined with mammography? Which combination?


✔ Review time: is it «compatible» with the screening workflow in real life?

✔ Is DBT sufficient for dense breasts or do we still need ultrasound?

✔ Cost-effectiveness MX+DBT vs. MX+US

✔ Layout to compare possible combined protocols with prior examinations.

✔ Image storage (1-3 GB vs. 200 MB per patient) and retrieving from PACS.
Take home messages

1. DBT is a quasi-3D technique which reconstructs breast volume starting from a limited number of low-dose projection within a small angle. Differences across systems.

2. Strong with masses and architectural distortions, still questions on detection of microcalcifications (CAD?)

3. Several retrospective studies, different in designs and populations: combination of DBT with MX improves clinical performance (different combined protocols).

4. Screening perspective studies: significant increase in cancer detection rate and decrease in recall rate.

5. Some questions still open
Outline

1. Digital breast tomosynthesis (DBT)

2. (Contrast-enhanced) spectral mammography

3. Quantitative breast density
Limitation of standard mammography

Breast is 3D

Mammography image is 2D

X-rays (invisible)

Transmitted X-ray image (invisible)

Signal proportional to X-ray photon intensity/number

MAMMOGRAM (visible)

G. Gennaro – Lisbon - Sep 20, 2013
Subtraction techniques in mammography

- TO ENHANCE CONTRAST OF FINDINGS
- TO INCREASE LESION CONSPICUITY

**3D techniques**
- (CT, tomosynthesis)

**Temporal subtraction**
- (angiography, breast)

**Combination of two images/sets of images obtained with different spectra**

**Digital Radiography**

- Depth
- Energy
- Time
- Space

**Phase contrast**
Temporal subtraction

Figure 2. Temporal contrast-enhanced mammography images. (a) shows a craniocaudal digitized screen-film mammogram obtained in a patient with infiltrating ductal carcinoma. (b) shows a craniocaudal contrast-enhanced digital subtraction image obtained 1 minute after the start of contrast medium injection and shows a small nodule with rim enhancement of the entire mass (arrow). (c) shows subtraction image obtained 10 minutes after start of contrast medium injection and shows washout of contrast medium. Note that only a single breast can be obtained in one view and that in this specific case, the breast needed to be compressed for 10 minutes. Images used with permission (Jong et al., Radiology 2003; 228: pages 842-850).
Dual-energy techniques

✓ TWO IMAGES ARE OBTAINED USING TWO DIFFERENT SPECTRA, WELL SEPARATED IN ENERGY, USUALLY INDICATED WITH «LOW ENERGY» AND «HIGH ENERGY». FOR THIS REASON, DUAL ENERGY IMAGING IS OFTEN REPORTED AS «SPECTRAL IMAGING».

✓ HYBRID IMAGES (ARE PRODUCED BY NON-LINEAR COMBINATION OF THE LOW- AND THE HIGH-ENERGY IMAGES

CONTRAST MEDIA ARE USED IN DUAL ENERGY MAMMOGRAPHY

DUAL ENERGY TECHNIQUES ARE USED:
• IN COMPUTED TOMOGRAPHY (DECT)
• IN DIGITAL RADIOGRAPHY (chest, musculoskeletal, etc)
• TO DIFFERENTIATE MATERIALS LIKE IN DENSITOMETRY (DEXA, dual-energy x-ray absorption)
• IN DIGITAL MAMMOGRAPHY
Contrast-enhanced spectral mammography

LOW-ENERGY (below iodine k-edge)
- Mo or Rh target
- Mo or Rh filter
- 26-31 kV_p

HIGH-ENERGY (above iodine k-edge)
- Mo target
- 0.3 mm Cu + 0.3 mm Al
- 45-49 kV_p

Iodine injection

RADIATION DOSE:
Low+High energy images: ~20% extra dose than a standard mammogram

Iodinated CM: same dose as used in CT (1.5 ml/kg)

Dromain et al., Eur J Radiol 69:34 (2009)
Contrast-enhanced spectral mammography

TWO SPECTRA, SEPARATED IN ENERGY

Iodine k-edge

Arvanitis et al., PMB 54:6041 (2009)

Lobbes et al., Clin Radiol 68:935 (2013)
Low-energy image: equivalent to standard mammogram

Subtracted image

Dual-energy contrast-enhanced digital mammography: initial clinical results of a multireader, multicase study

Dromain et al.
Spectral mammography

SPECTRAL IMAGING USING PHOTON-COUNTING TECHNOLOGY

Figure 3: Spectral imaging tomosynthesis slice with iodine enhancement visualized in color. Image courtesy Felix Diekmann MD, Charité, Berlin, Germany.
Clinical results

<table>
<thead>
<tr>
<th>Reader</th>
<th>MX ± US</th>
<th>MX ± US ± CEDM</th>
<th>Increase in Az</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.835 ± 0.047</td>
<td>0.872 ± 0.041</td>
<td>0.037 ± 0.026</td>
</tr>
<tr>
<td>2</td>
<td>0.907 ± 0.042</td>
<td>0.916 ± 0.030</td>
<td>0.009 ± 0.036</td>
</tr>
<tr>
<td>3</td>
<td>0.843 ± 0.042</td>
<td>0.851 ± 0.044</td>
<td>0.009 ± 0.031</td>
</tr>
<tr>
<td>4</td>
<td>0.809 ± 0.047</td>
<td>0.849 ± 0.040</td>
<td>0.041 ± 0.026</td>
</tr>
<tr>
<td>5</td>
<td>0.791 ± 0.050</td>
<td>0.844 ± 0.040</td>
<td>0.053 ± 0.041</td>
</tr>
<tr>
<td>6</td>
<td>0.780 ± 0.049</td>
<td>0.891 ± 0.032</td>
<td>0.111 ± 0.033 (P = 0.001)</td>
</tr>
<tr>
<td>Overall</td>
<td>0.827 ± 0.036</td>
<td>0.871 ± 0.027</td>
<td>0.043 ± 0.019</td>
</tr>
</tbody>
</table>

95% CI: 0.756 to 0.899, 0.817 to 0.92, 0.001 to 0.085 (P = 0.045)

110 cases (148 lesions)
6 readers
CESM+MX+US vs. MX+US

Advances in Knowledge

- Bilateral dual-energy (DE) contrast agent–enhanced (CE) digital mammography is feasible.
- DE CE digital mammography can be used to detect breast cancer by demonstrating enhancement of neovascularity associated with breast cancer.
- DE CE digital mammography depicted additional cancers in the breast with better specificity than did MR imaging.
1. Subtraction techniques can be applied to mammography, either temporal or dual-energy subtraction. DE currently preferred.

2. With contrast media (typ. Iodine)

3. Promising as «problem solver» for cases referred to breast MRI. Faster and easier than MRI.
Outline

1. Digital breast tomosynthesis (DBT)

2. (Contrast-enhanced) spectral mammography

3. Quantitative breast density
What breast density is


Fat has lower attenuation coefficient than fibro glandular tissue, which means it is more transparent to X-rays.
Usually, in mammography images, fat is dark, while fibro glandular tissue is brighter. The denser the breast, the larger the bright parts in the image.
Why «measuring breast density»?

1. To «officially state» potential difficulties in diagnosis
   (radiologists are well aware about differences in lesion detectability depending on breast pattern/density)

2. To «quantify» a risk factor
   «...substantial literature shows that more extensive density is associated with an increased risk of breast cancer. Women with dense tissue in 75% or more of the breast have a risk of breast cancer 4-6 times as great as the risk among women with little or no dense tissue.»

All published papers on breast density, quote the sentence «Women with dense breasts have a cancer risk increased by 4-6 times compared to women with fatty breasts». 
Breast density and risk factors


Mammographic Density and the Risk and Detection of Breast Cancer


Nature 2012, vol 490

NEWS & VIEWS

CANCER

Destiny from density

The identification of a signalling protein that regulates the accumulation of fat and connective tissue in breasts may help to explain why high mammographic density is linked to breast-cancer risk. It may also provide a marker for predicting this risk.
Human-based evaluation of breast density

Wolfe’s Classification (1976)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>the breast consists mainly of fat, lower risk for breast cancer</td>
</tr>
<tr>
<td>P1</td>
<td>this pattern includes fat as well as linear densities (enlarged ducts) occupying no more than 25% of the breast</td>
</tr>
<tr>
<td>P2</td>
<td>linear densities (from enlarged ducts) occupying more than 25% of the breast. They are prominently in the upper outer quadrant but may be distributed throughout the breast</td>
</tr>
<tr>
<td>Dy</td>
<td>dense, radiopaque breast, highest risk for breast cancer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A: 0%</td>
<td>I : balanced proportion of all components of breast tissue with a slight predominance of fibrous tissue</td>
<td>Type 1: extremely fat</td>
</tr>
<tr>
<td>2</td>
<td>B: 1-10%</td>
<td>II : predominance of fat tissue</td>
<td>Type 2: minimal density</td>
</tr>
<tr>
<td>3</td>
<td>C: 11-25%</td>
<td>III : predominance of fat tissue with retroareolar residual fibrous tissue</td>
<td>Type 3: heterogeneous density</td>
</tr>
<tr>
<td>4</td>
<td>D: 26-50%</td>
<td>IV : predominantly nodular densities</td>
<td>Type 4: extremely dense</td>
</tr>
<tr>
<td>5</td>
<td>E: 51-75%</td>
<td>V : predominantly fibrous tissue</td>
<td>/</td>
</tr>
<tr>
<td>6</td>
<td>F: &gt;75%</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

* FILM MAMMOGRAMS IN THE 70s-80s LOOKED MUCH DIFFERENT THAN THE CURRENT IMAGES IN TERMS OF CONTRAST

- 4-6 categories
- Defined by «descriptions»
- Attempt to quantify «at a glance» the «black and white» percentages in the image

* G. Gennaro – Lisbon - Sep 20, 2013
BIRADS classification of breast density

- ALMOST ENTIRELY FATTY: < 25%
- SCATTERED FIBROGLANDULAR: 25-50%
- HETEROGENEously DENSE: 50-75%
- EXTREMELY DENSE: > 75%

✓ Categorical scales (descriptive) can be subjectively interpreted
✓ Some breast patterns are border line between two adjacent categories (1/2, 2/3, 3/4)
✓ Attempt (unsuccessful) to «quantify» the percentage of glandular component

G. Gennaro – Lisbon - Sep 20, 2013
Padua, IOV

- 2103 cases, 6 radiologists
- Moderate agreement (k=0.56)

<table>
<thead>
<tr>
<th>Kappa value</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.2</td>
<td>Poor</td>
</tr>
<tr>
<td>0.21 – 0.40</td>
<td>Fair</td>
</tr>
<tr>
<td>0.41 – 0.60</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.61 – 0.80</td>
<td>Strong</td>
</tr>
<tr>
<td>&gt; 0.80</td>
<td>Near complete</td>
</tr>
</tbody>
</table>
Breast density can be quantified

Quantitative evaluation of breast density

Mammography

Other modalities (MRI / US)

Tomosynthesis/ Breast CT
Methods based on area

JW Bing et al. (1998), Analysis of mammographic density and breast cancer risk from digitized mammograms, Radiographics 18:1587

L-JW Lu et al. (2007), Computing mammographic density from a multiple regression model constructed with image acquisition parameters from a full-field digital mammographic unit, Phys Med Biol 52:4905

- Algorithms: segmentation/texture/fractals, automatic or semi-automatic
- PD = «dense» area/breast area
The myth of the 50/50 breast

**Med Phys 2009, vol 36**

**The myth of the 50-50 breast**

M. J. Yaffe
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada

J. M. Boone and N. Packard
UC Davis Medical Center, University of California-Davis, Sacramento, California 95817

O. Alonzo-Proulx
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada

S.-Y. Huang
UC Davis Medical Center, University of California-Davis, Sacramento, California 95817

C. L. Peressotti
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada

A. Al-Mayah and K. Brock
University Health Network, University of Toronto, Toronto, Ontario M5G 2M9, Canada

**MEAN BREAST DENSITY:** 13.7% - 25.6%

80% WOMEN: < 27% GLANDULAR

95% WOMEN: < 45% GLANDULAR

«(based on the results obtained in our study), THE “50-50” BREAST IS NOT A REPRESENTATIVE MODEL OF THE BREAST COMPOSITION»
Volumetric methods

- VBD is the ratio between the fibroglandular volume and the breast volume
- From a physical model of the mammography system (X-ray source, detector, scattering, beam hardening), attenuation is calculated pixel-by-pixel
- For each pixel, thicknesses of glandular tissue and fat are computed
- For processing images required
- Volpara (Matakina), Quantra (Hologic), Cumulus V (University of Toronto)
The scale is clearly not [0-100%]
Breast density is below 50% (min 1.47% - max 47.2%)
Breast density is below 30% in 97.9% of cases
Mean: 12.4%
Median: 10.5%
VBD: results

PADUA, IOV
- Volpara 1.4.3
- Images from GE DS, GE Essential, IMS Giotto Image 3DL

Thicker breasts can be less dense
Breast density tends to decrease with patient age
The Latest Mammogram Controversy: Density Many Women Aren't Told Their Breast Type May Cloud Cancer Screening; More States Consider Notification

http://areyoudenseadvocacy.org/dense/
1. Breast density is associated to mammography sensitivity (lesion detection) and to additional cancer risk.
2. Can be evaluated by human readers (subjectivity)
3. Can be quantified by digital mammography (percentage of glandular components, either area or volume based).
4. In the U.S. quantification of breast density is becoming mandatory by law.
5. Attempt to define a threshold to have additional imaging (for example US) in screening.
Thank you!

gisella.gennaro@ioveneto.it