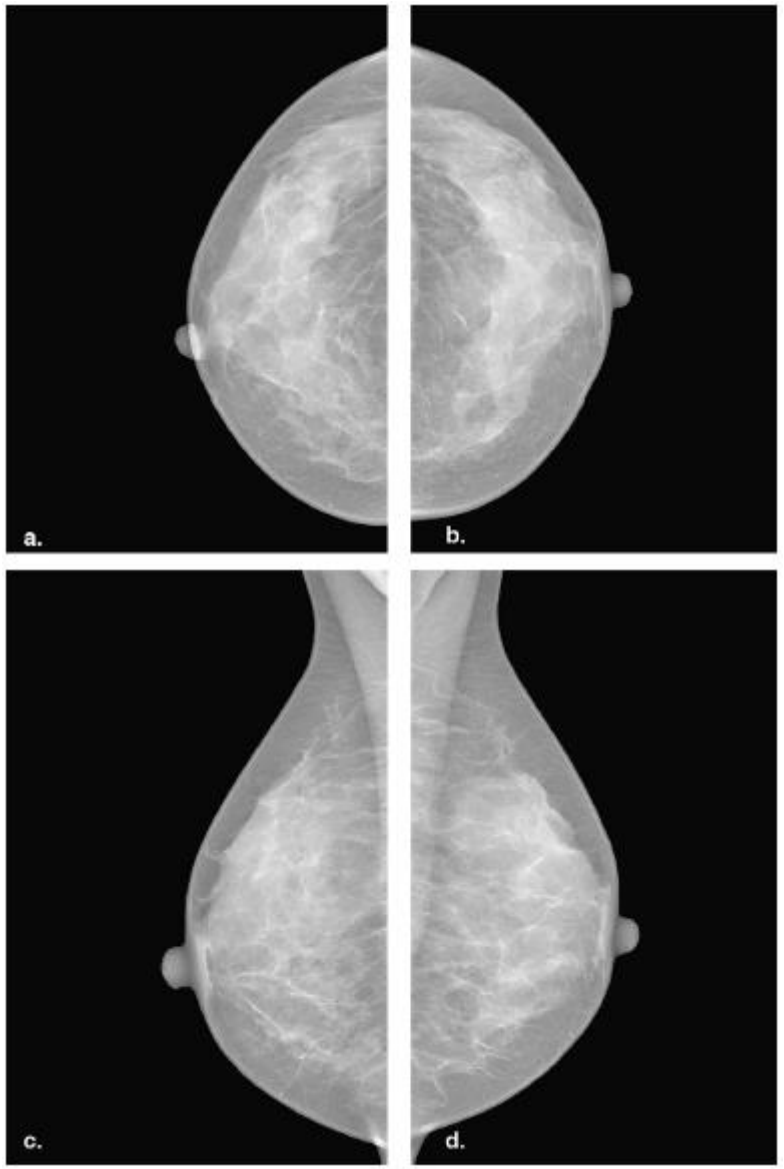
An automatic mammogram system: from screening to diagnosis

Inês Domingues

Outline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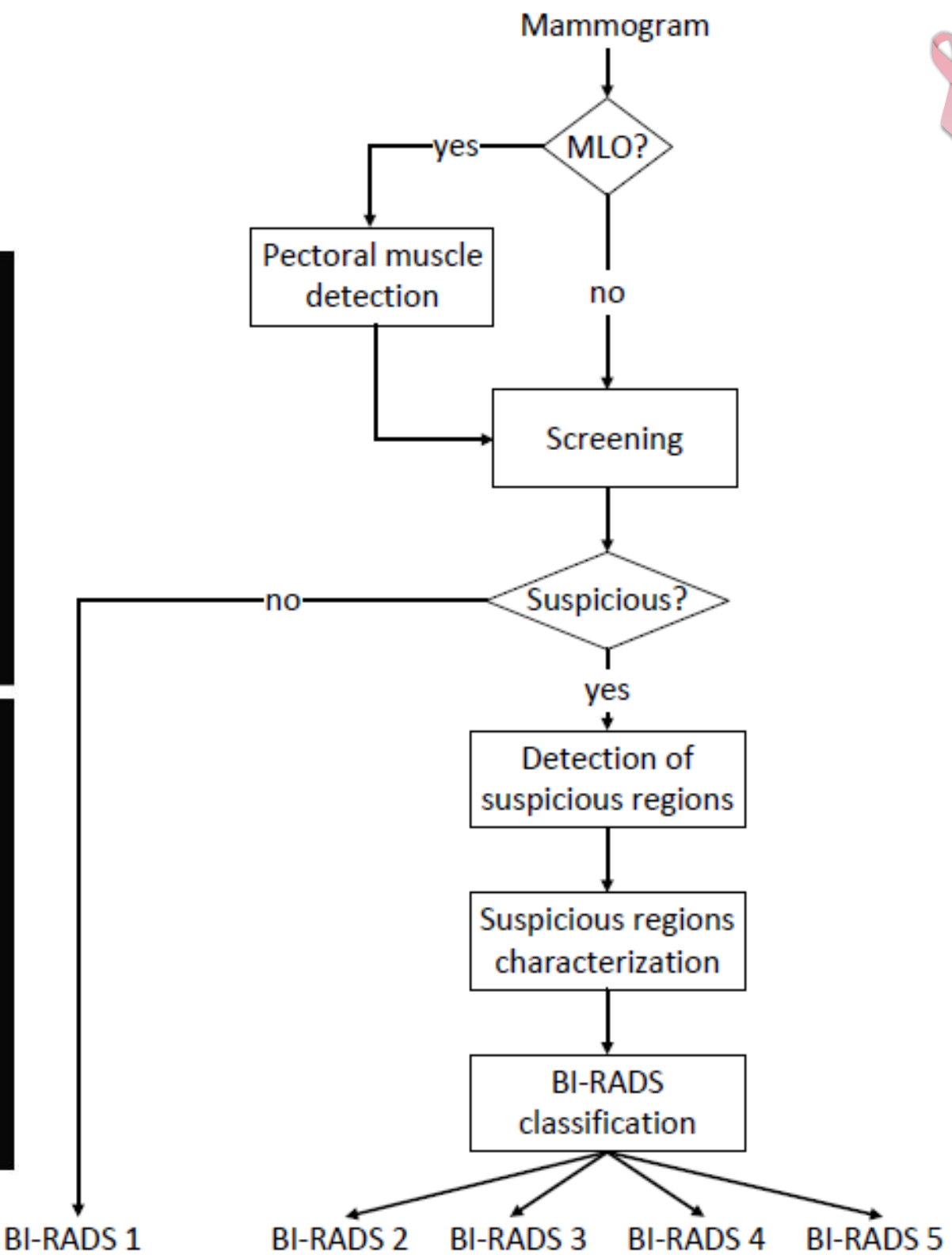
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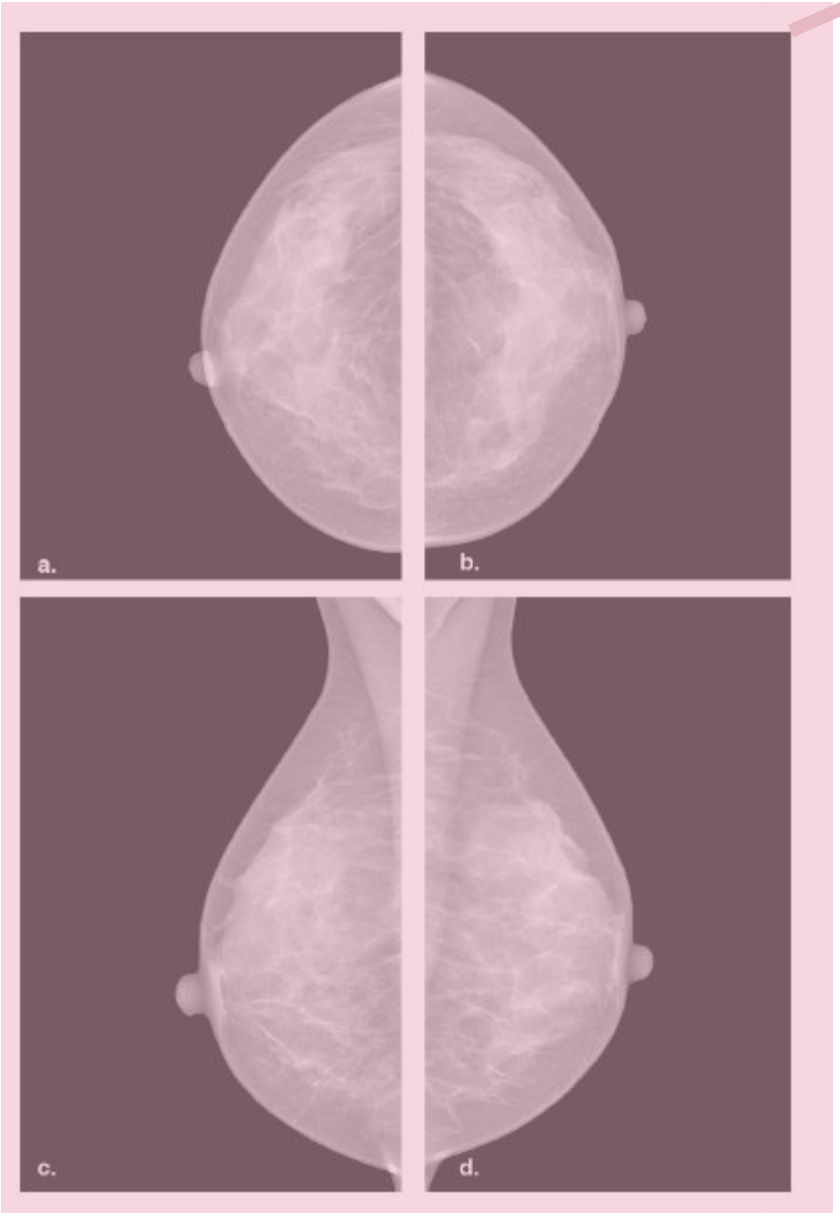
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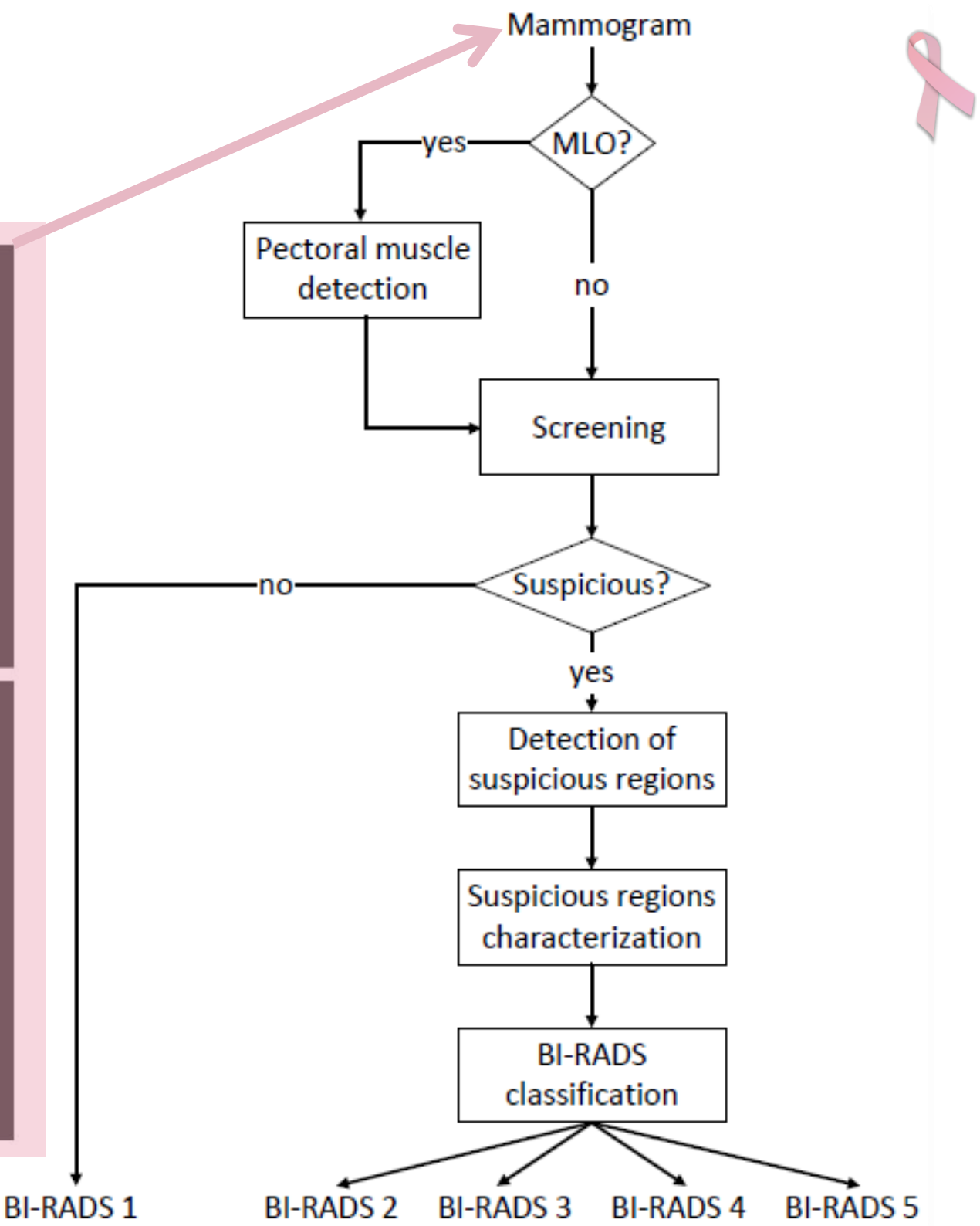
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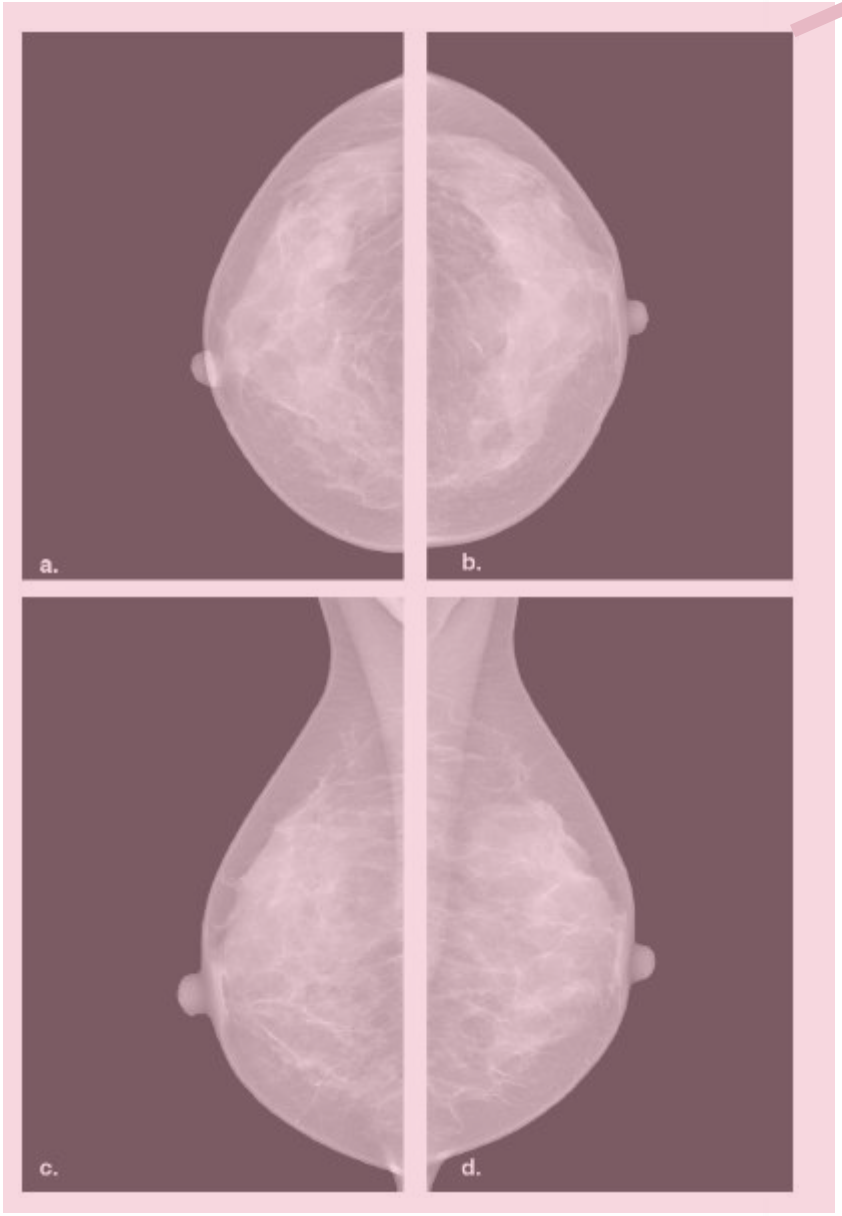
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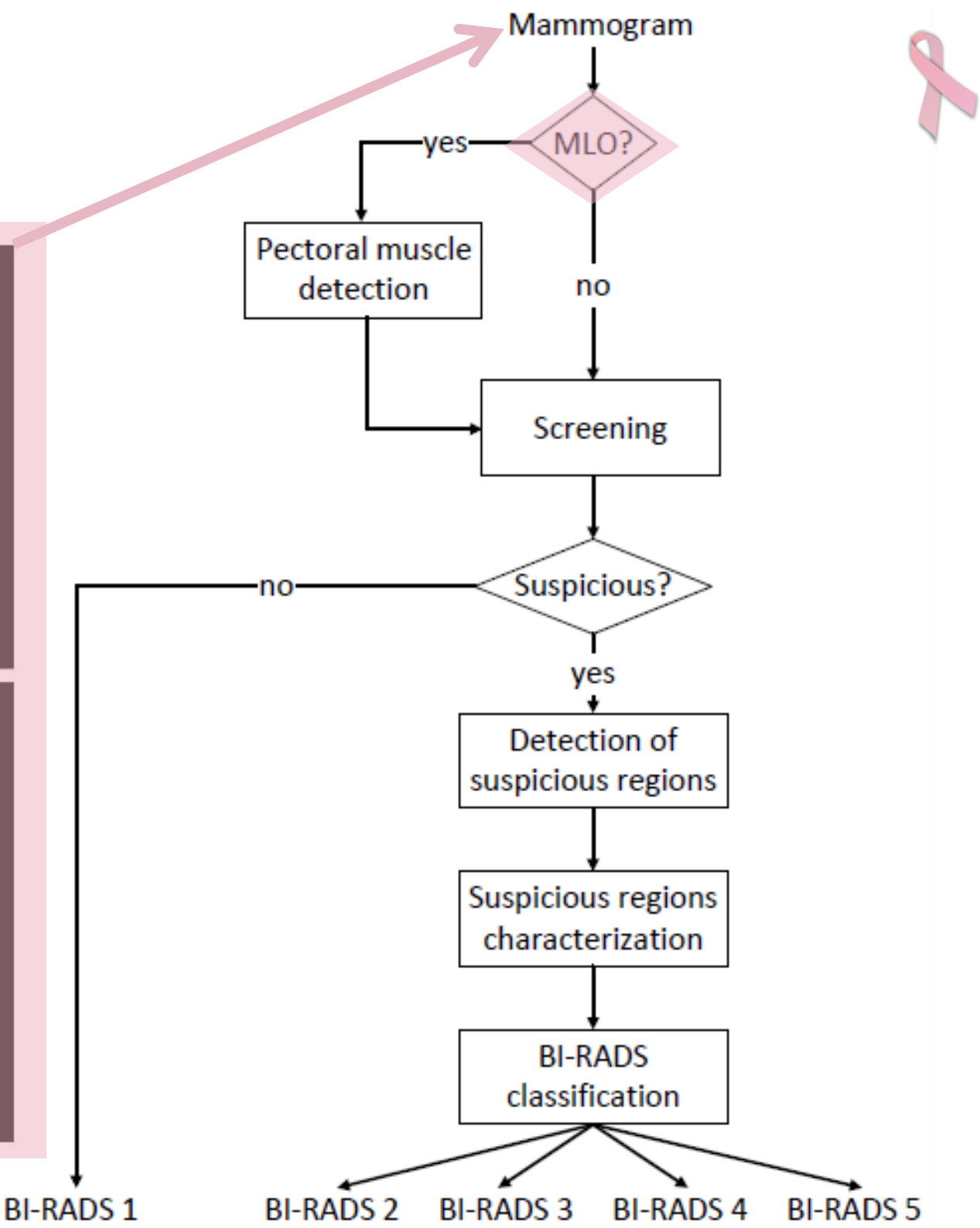
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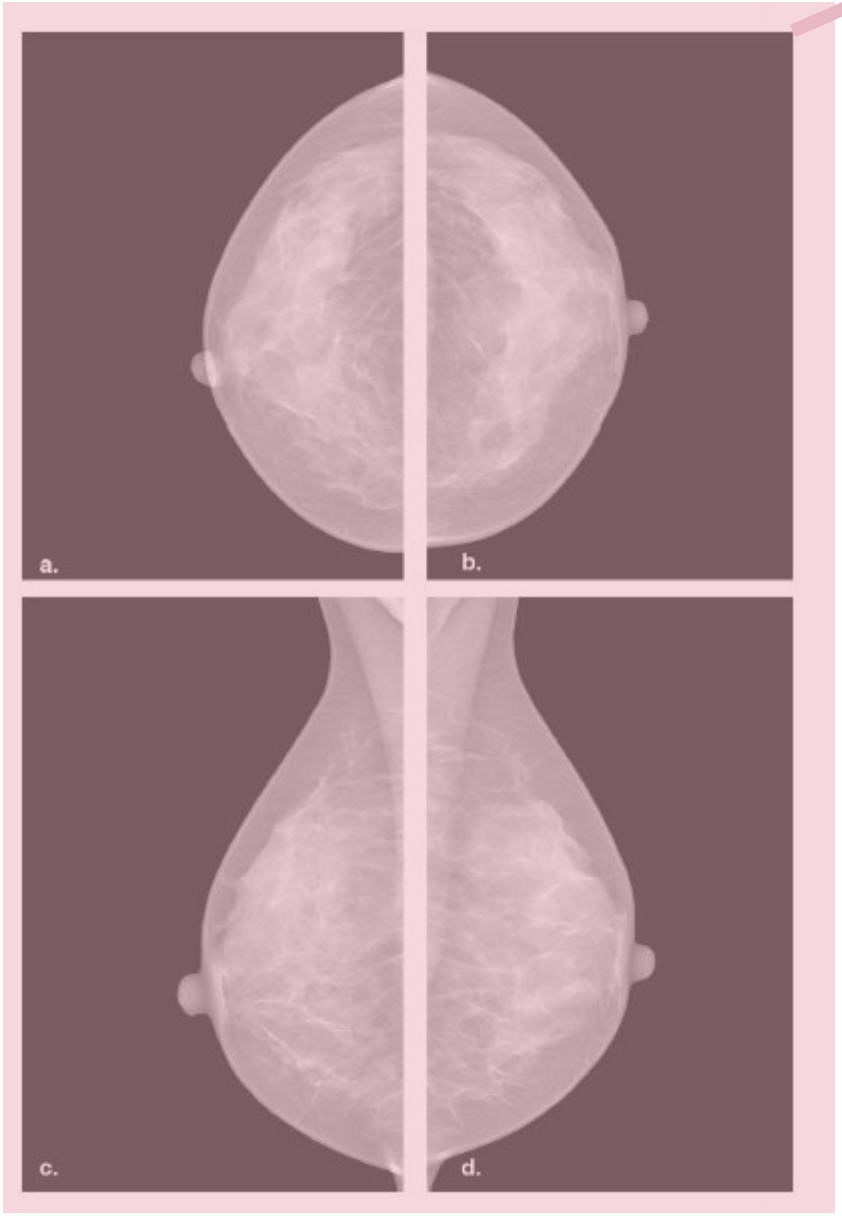
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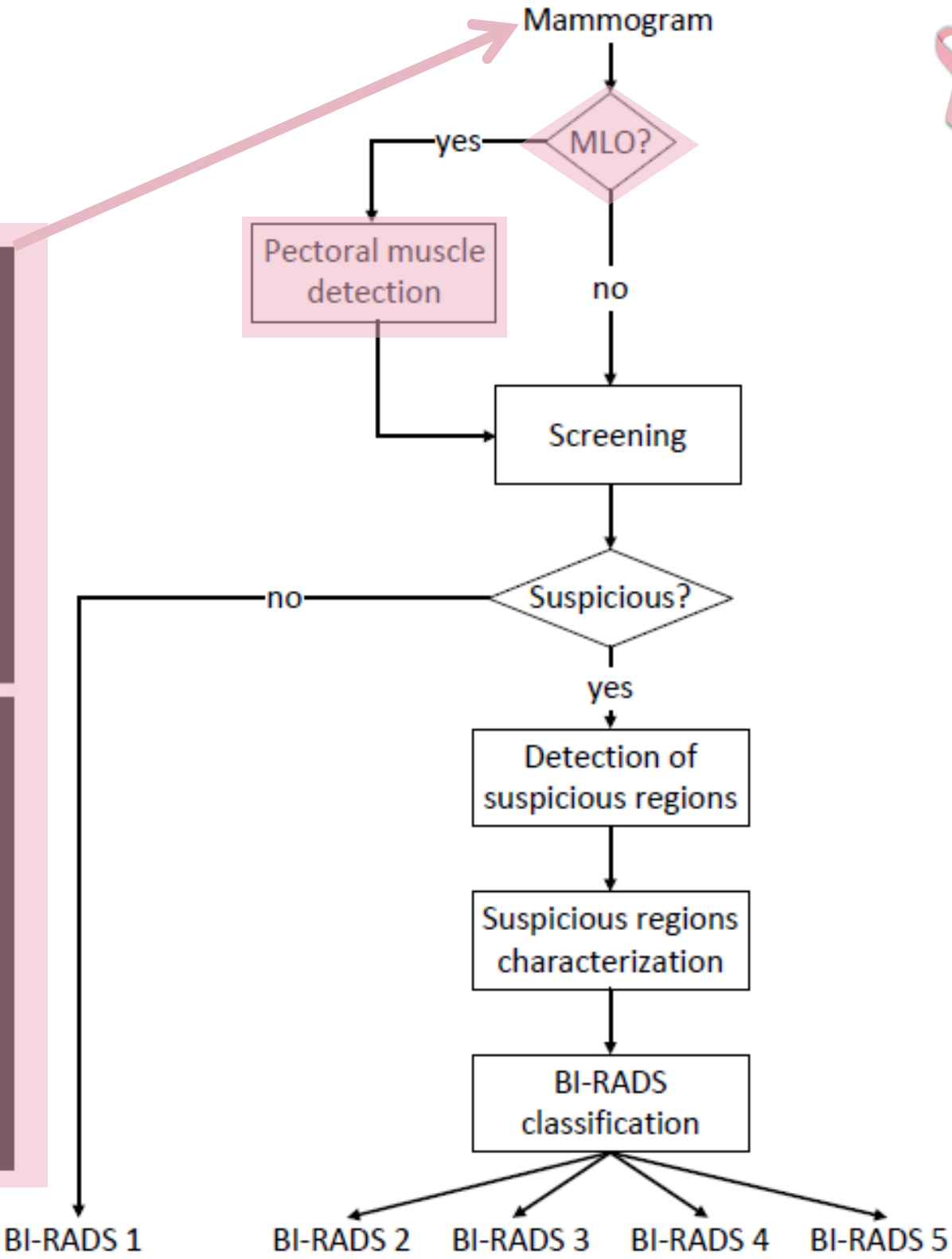
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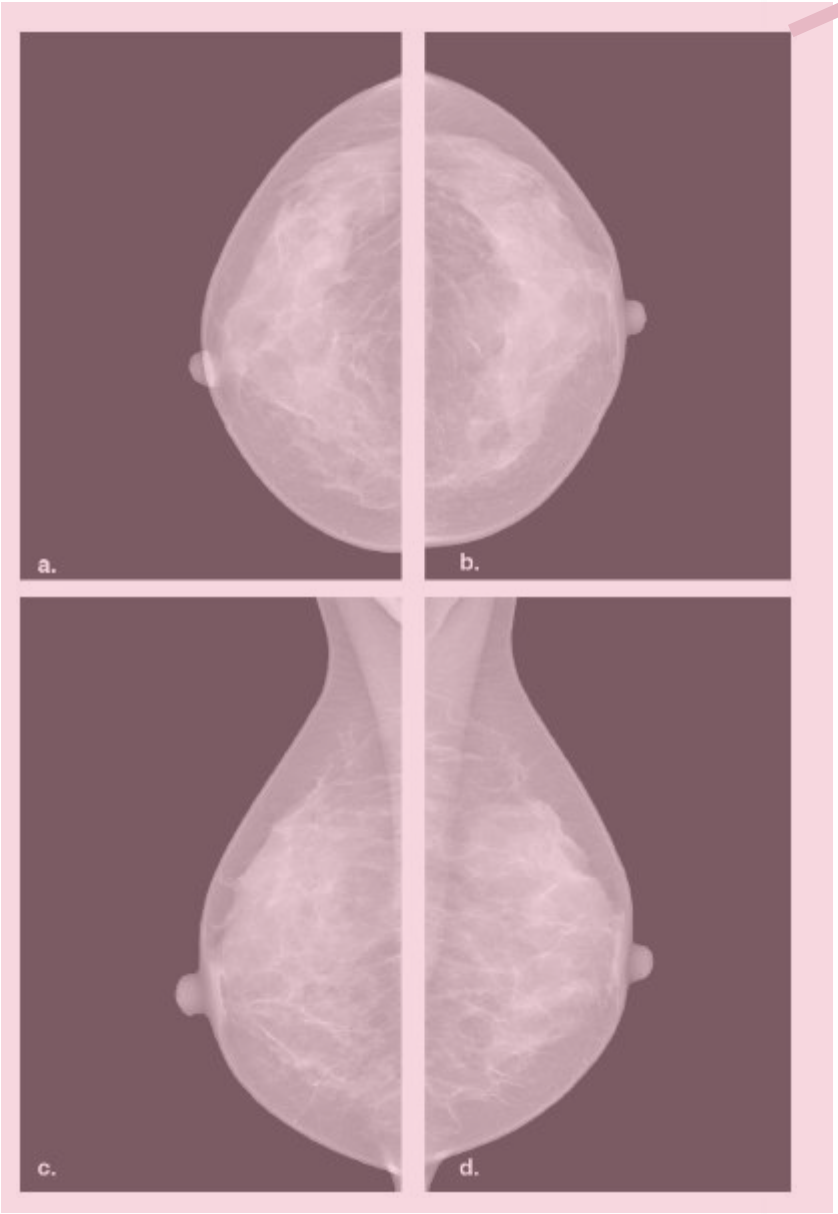
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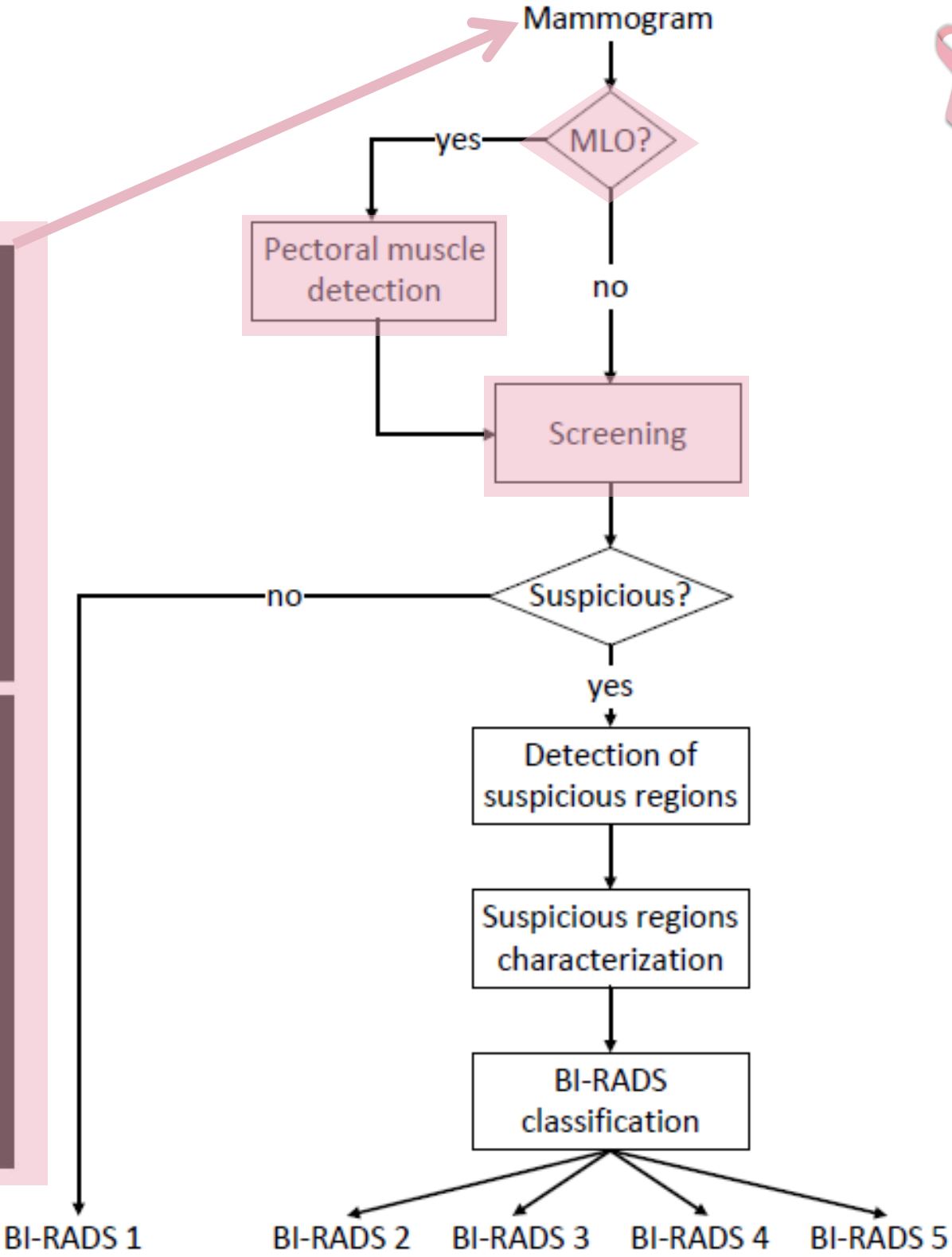
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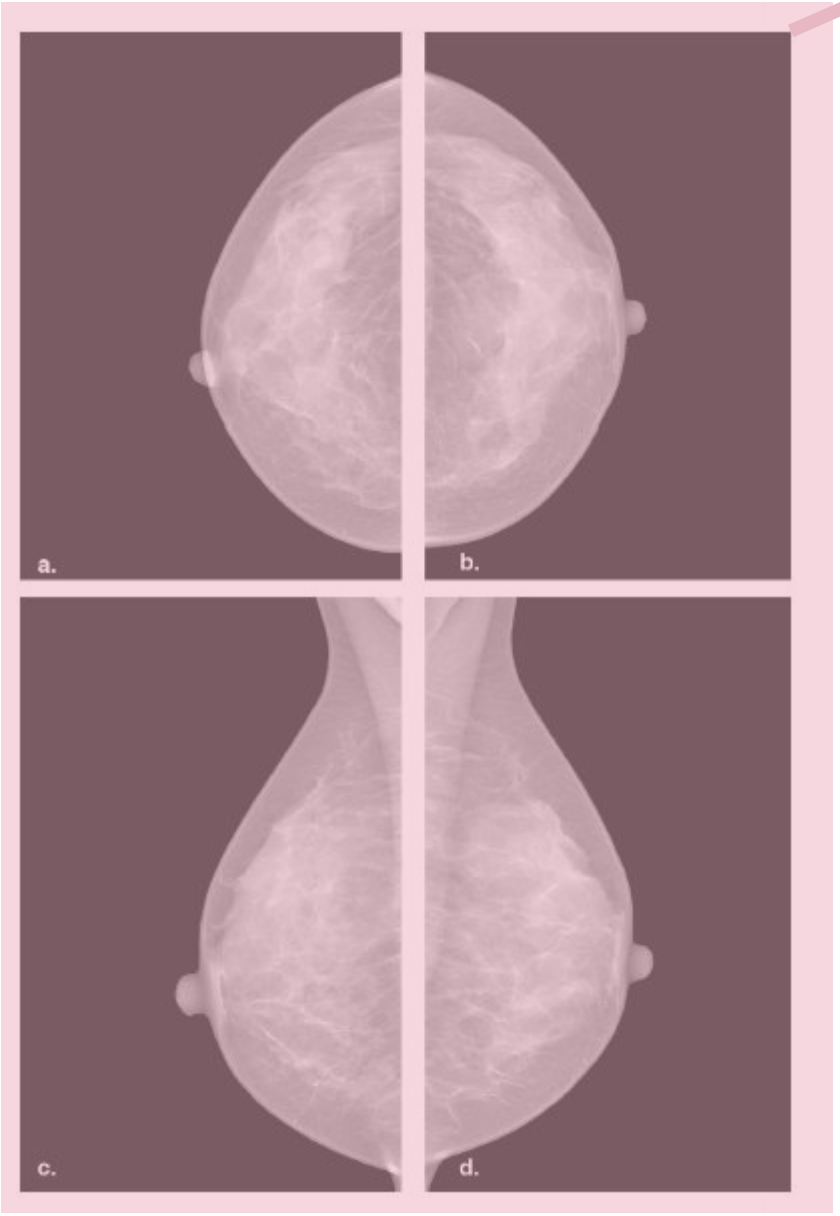
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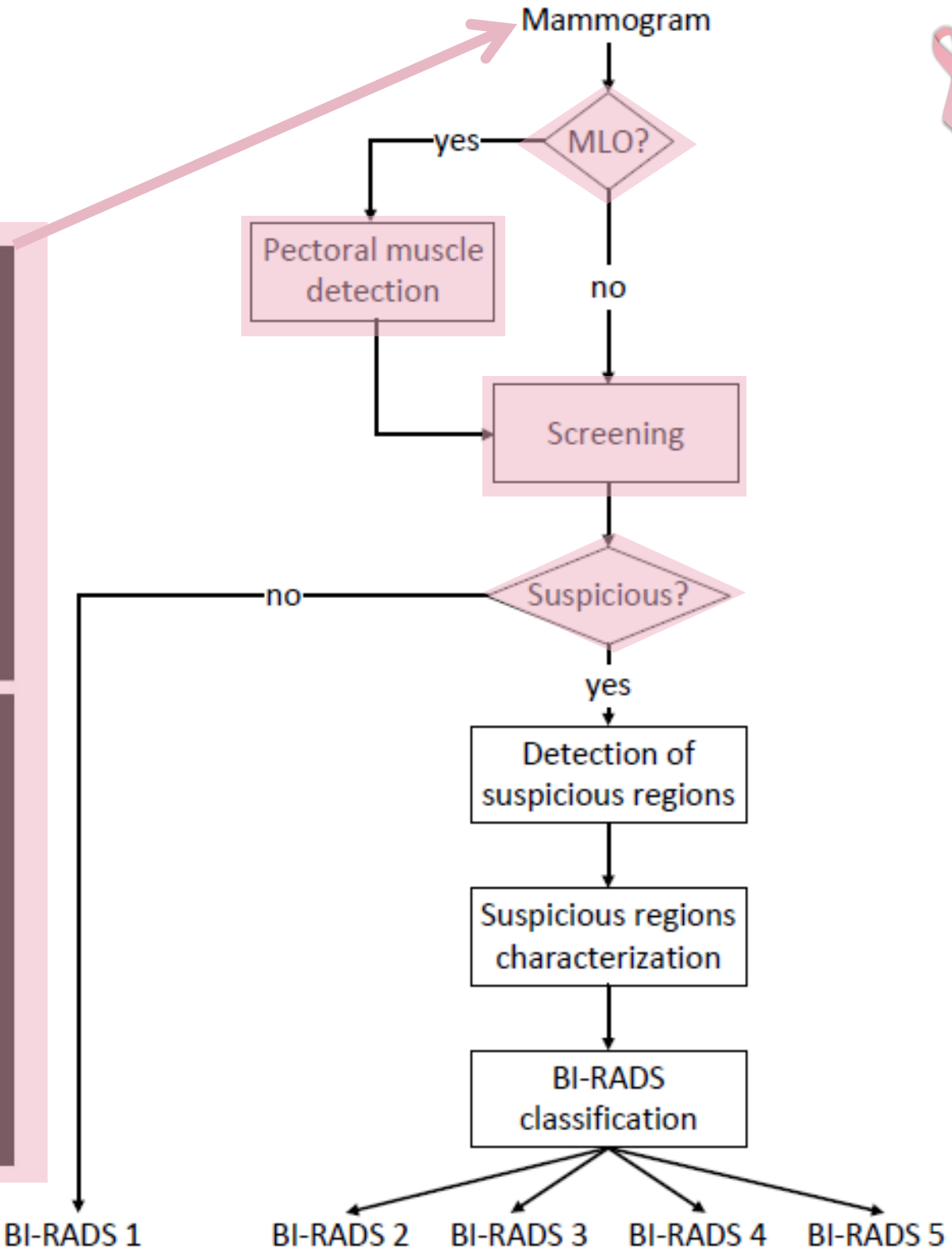
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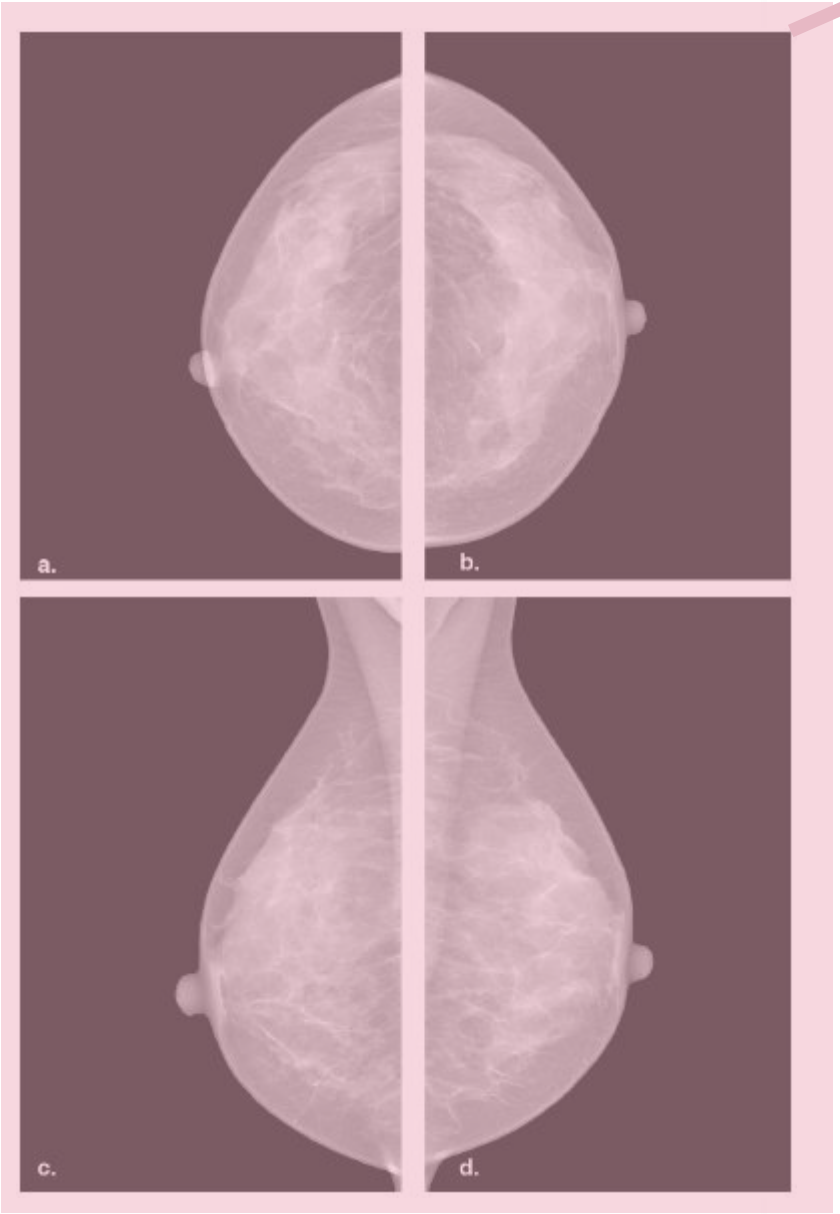
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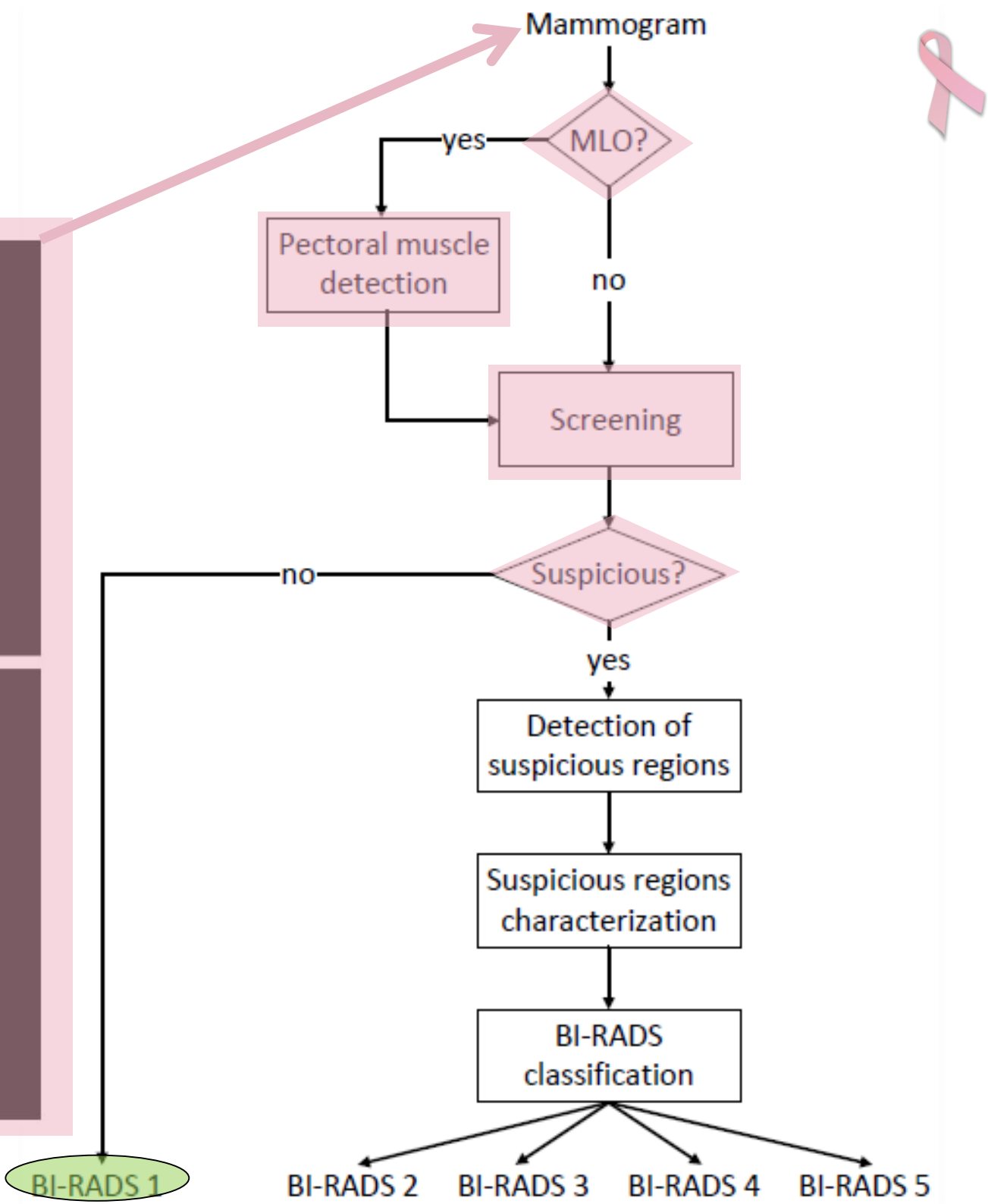
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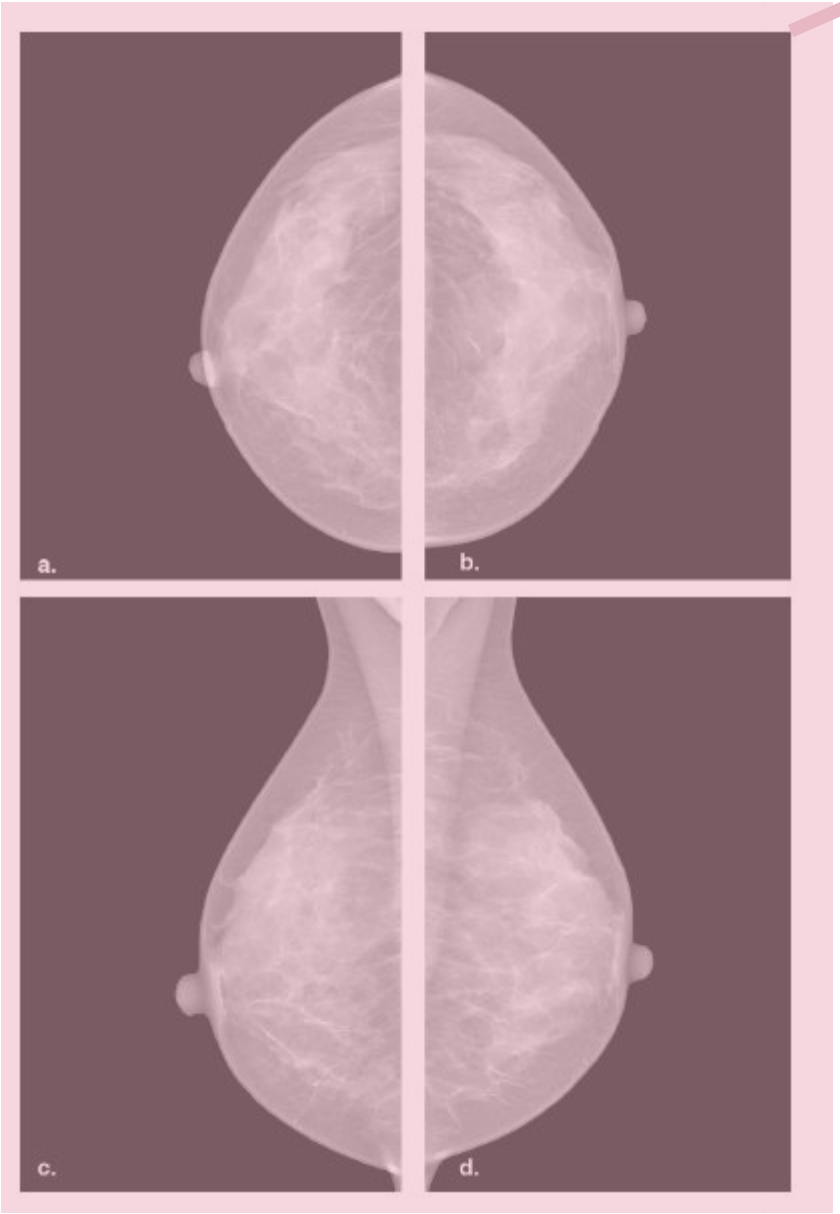
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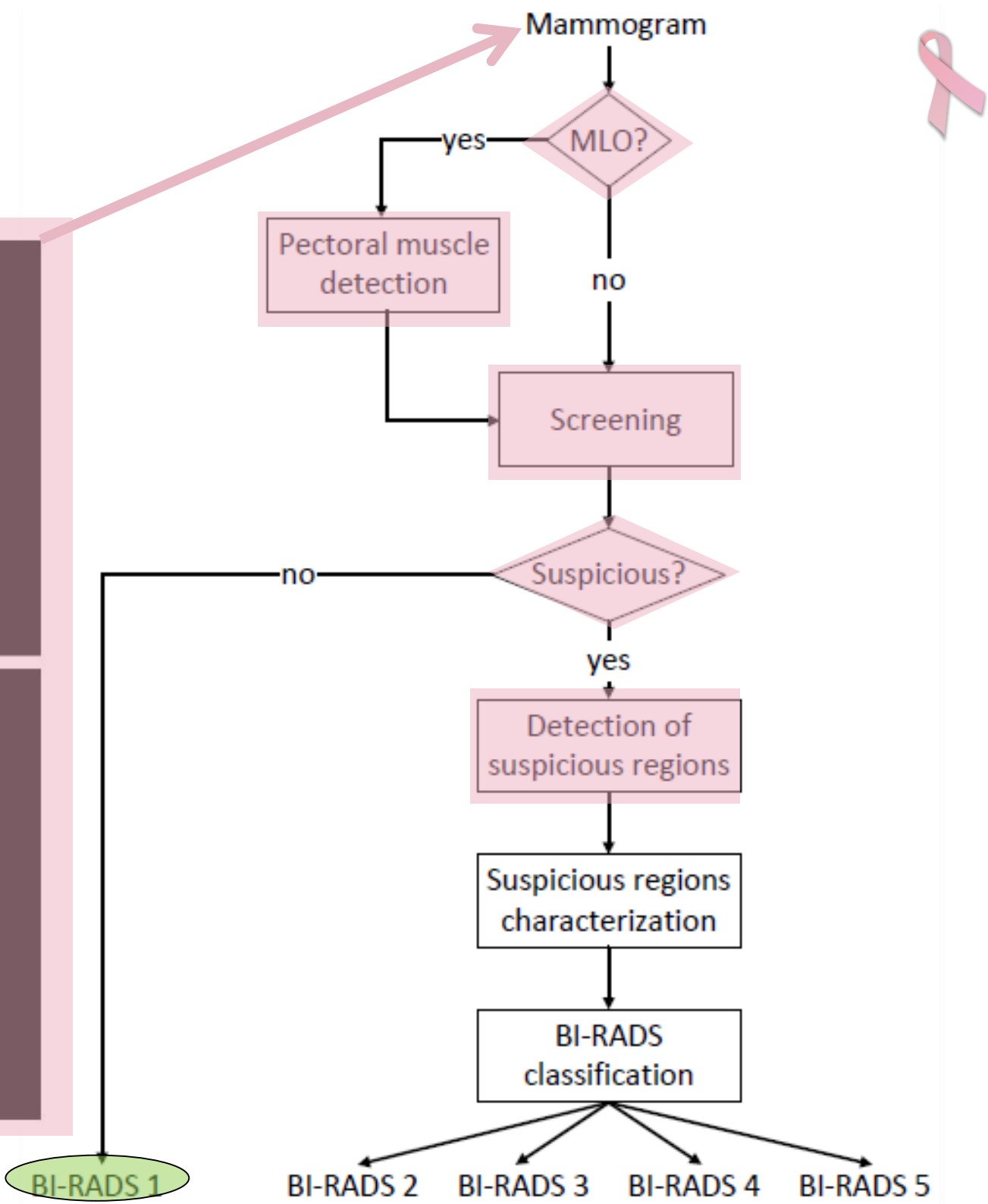
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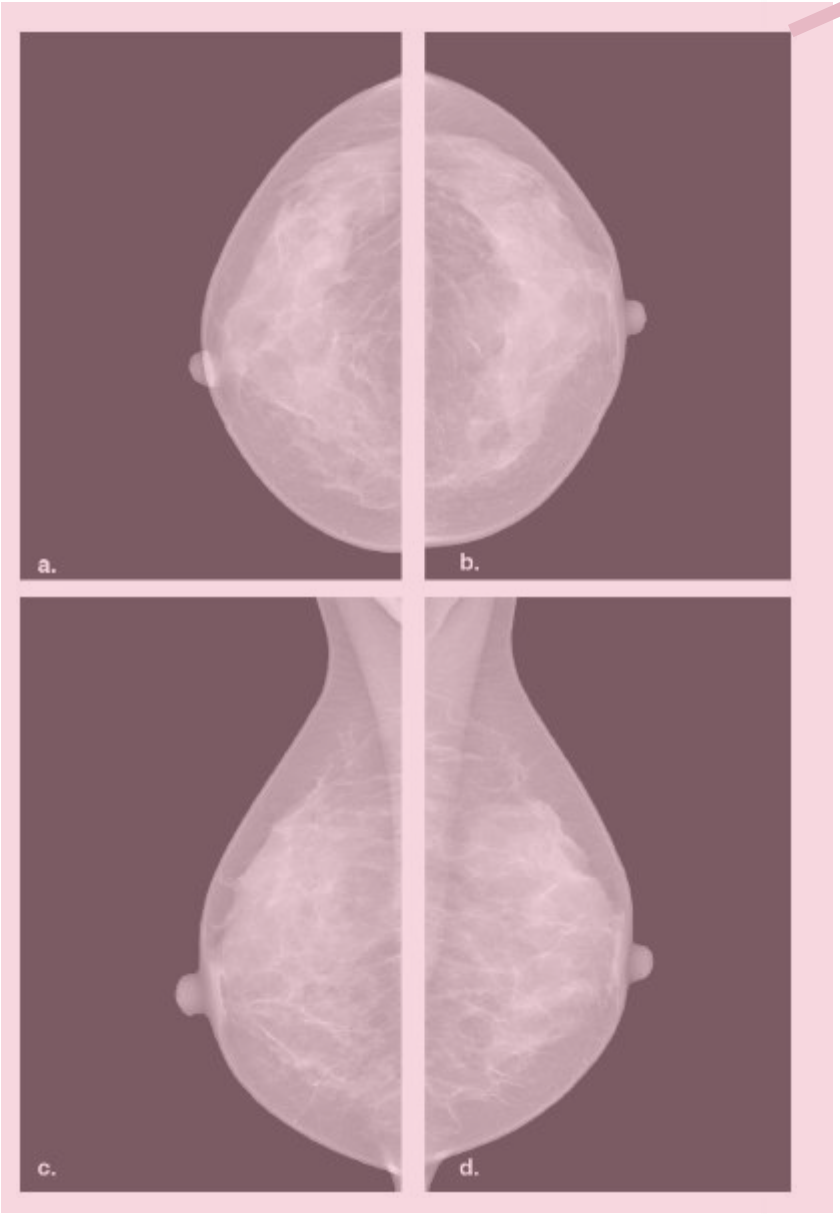
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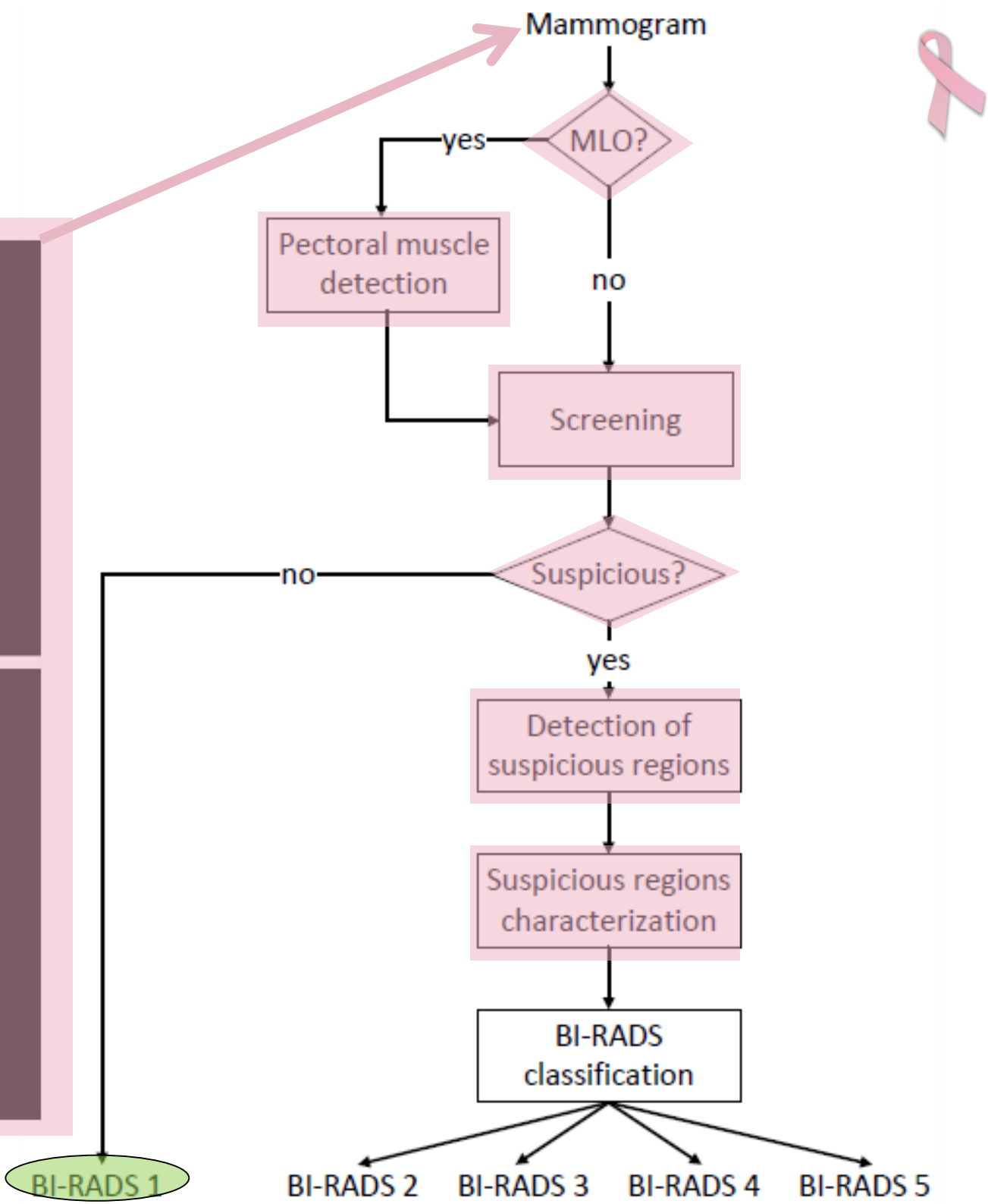
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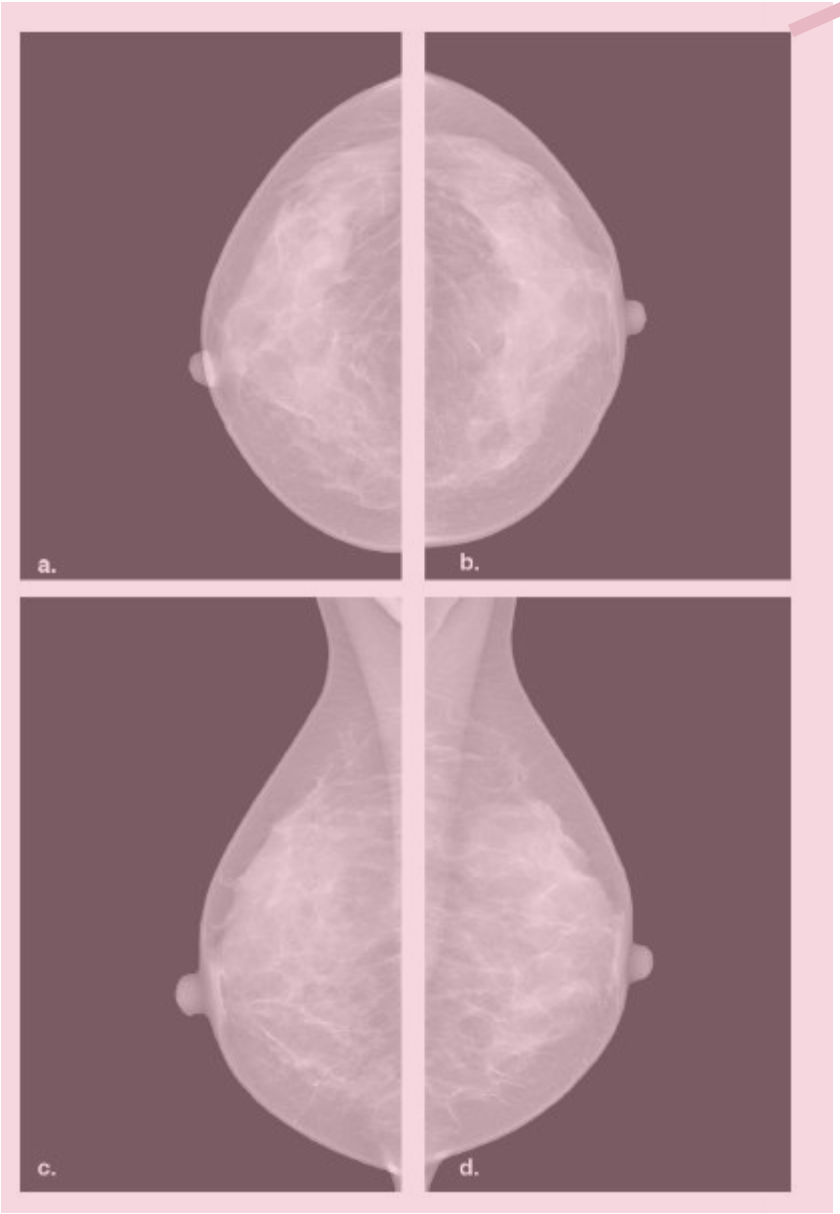
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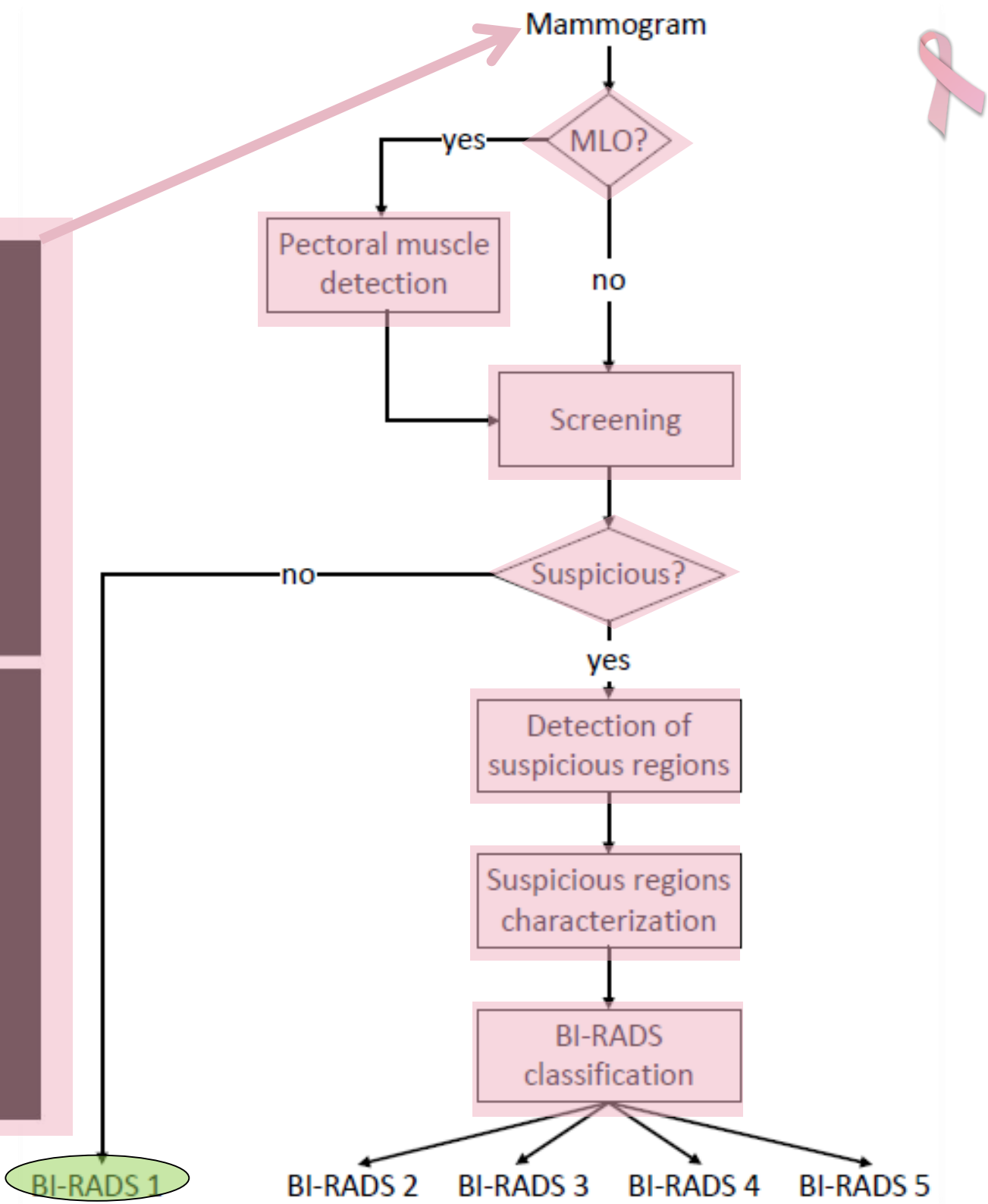
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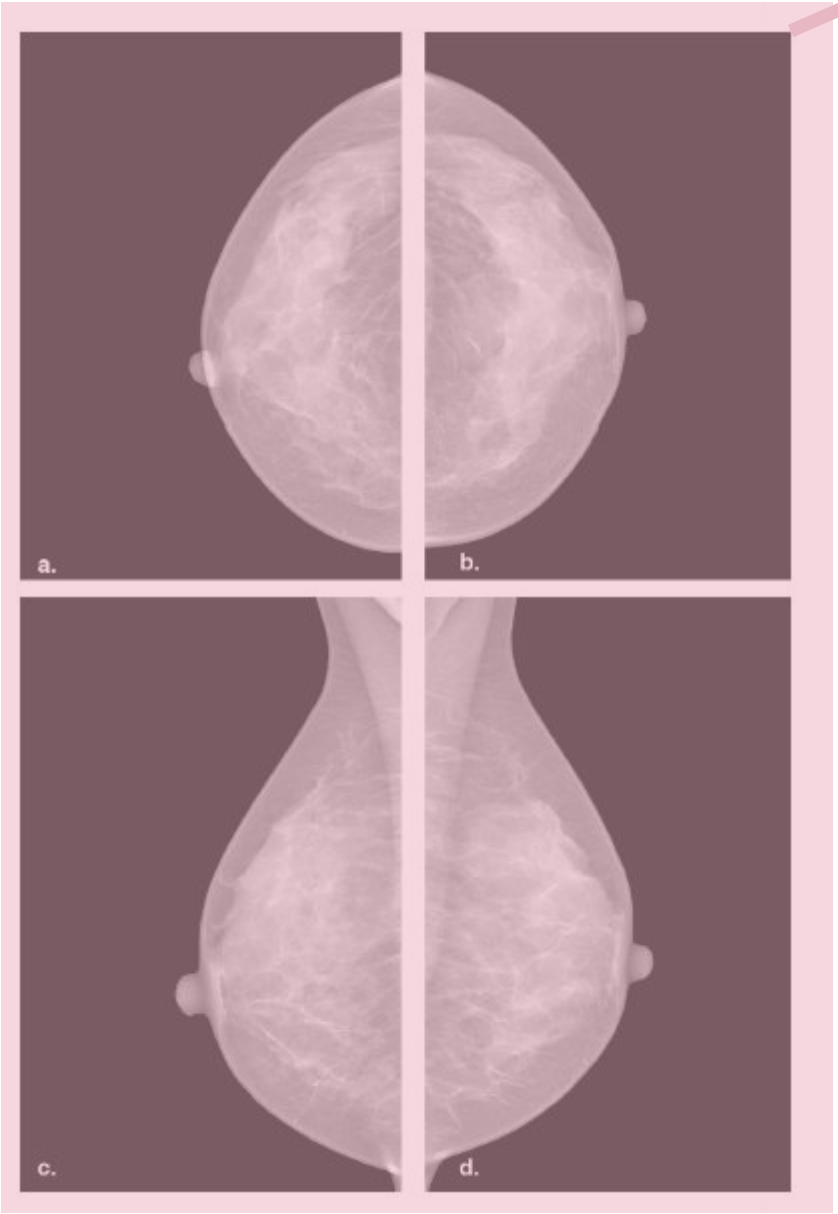
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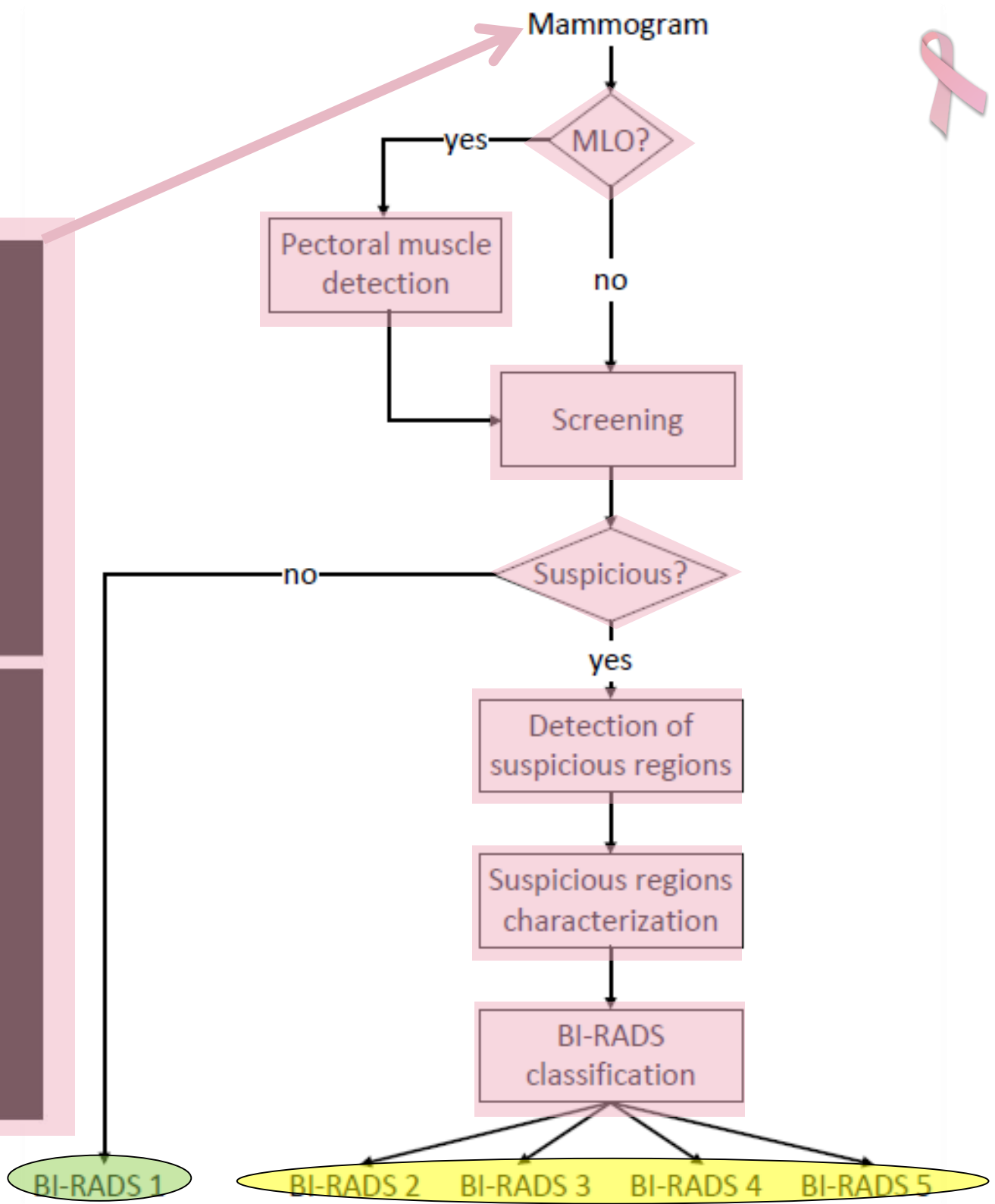
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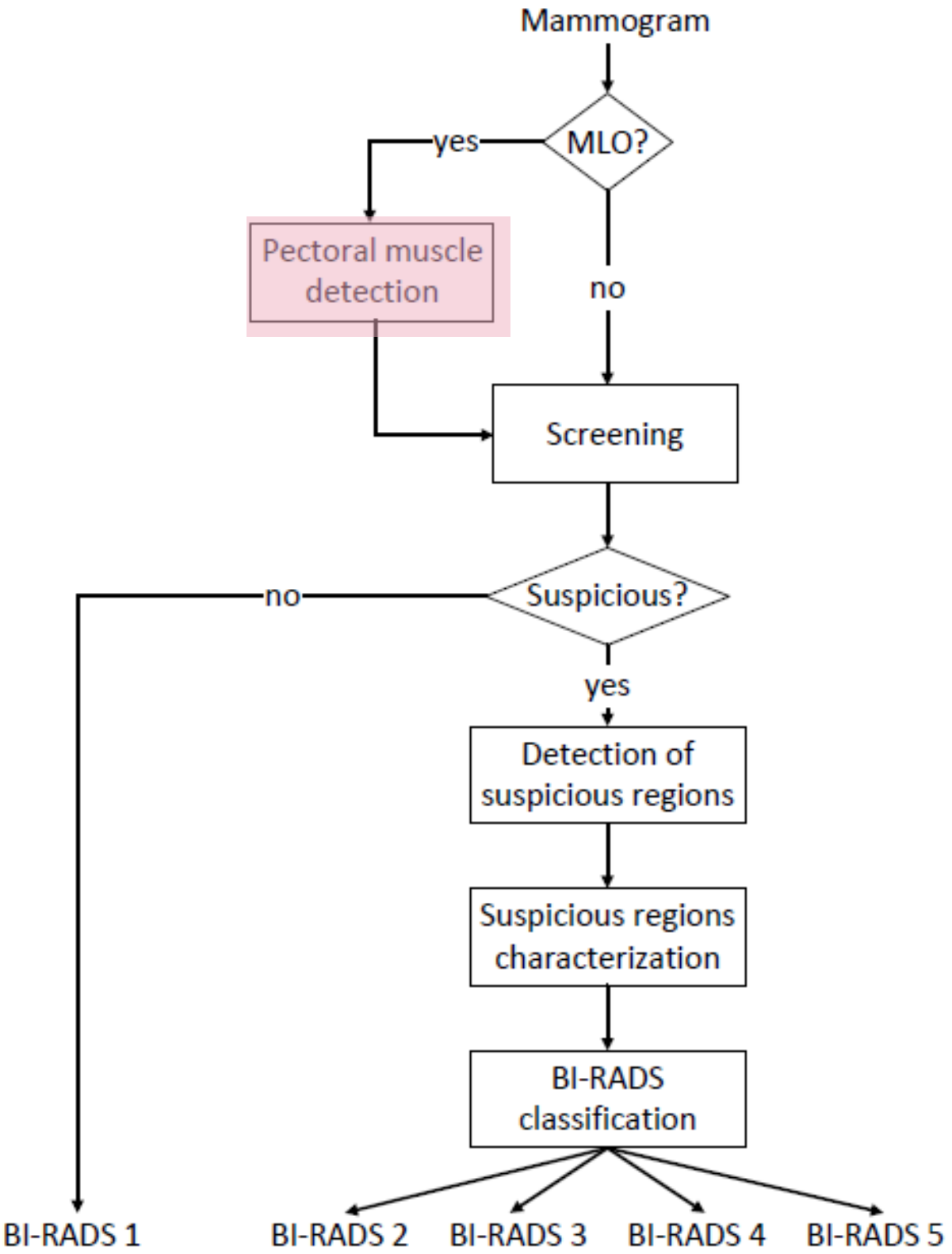
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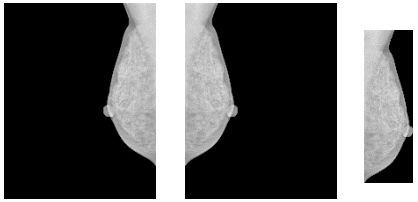
Pectoral muscle detection

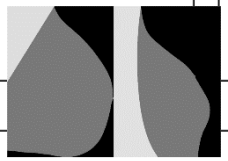
Polar coordinates and the shortest path (SPPC)



Pre-processed MLO mammogram

Main processing

Transform to Polar coordinates

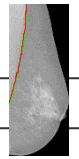


Compute the weighted graph

Compute muscle contour as the shortest path between top and bottom rows

Post processing

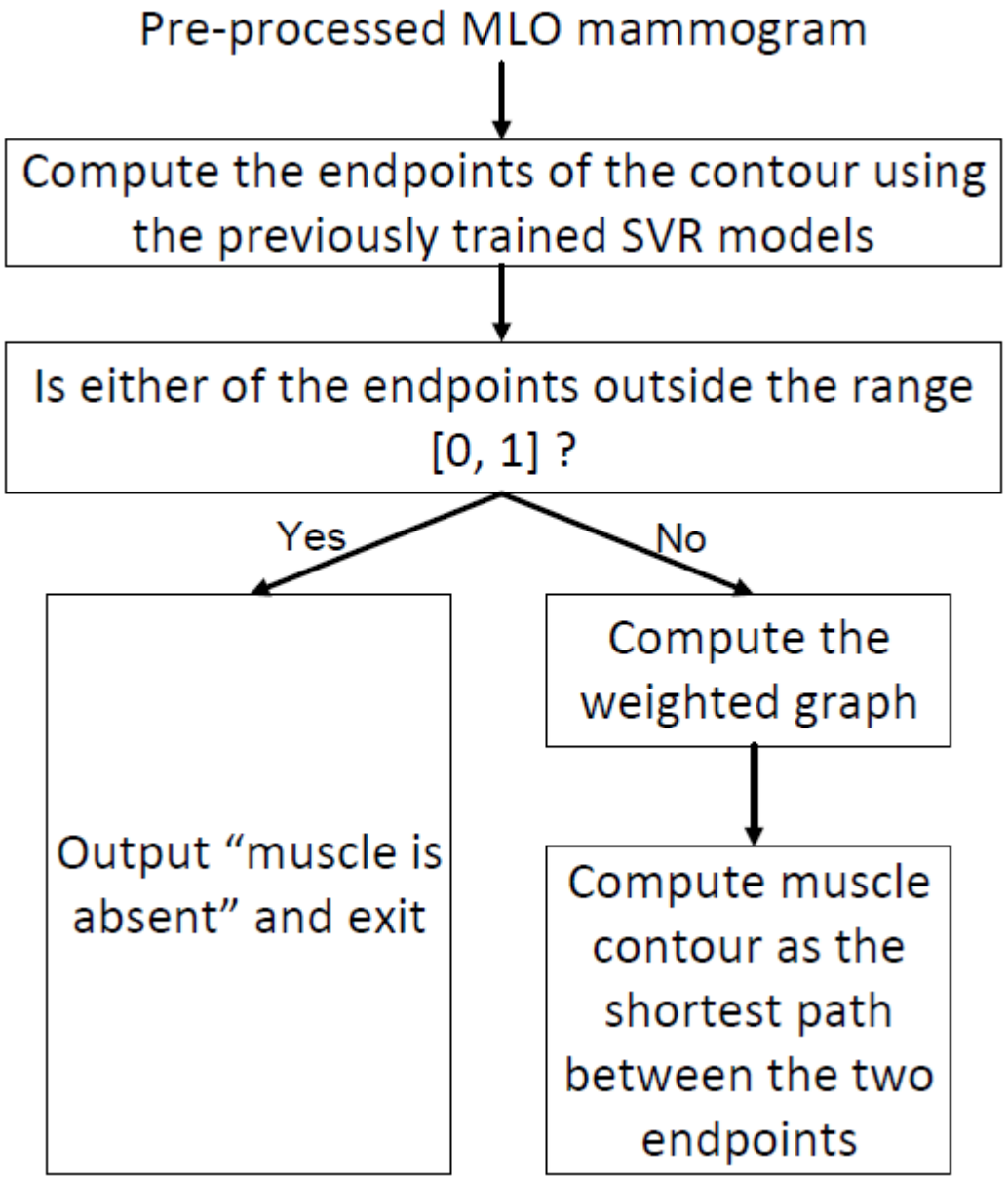
Transform contour to Cartesian coordiantes

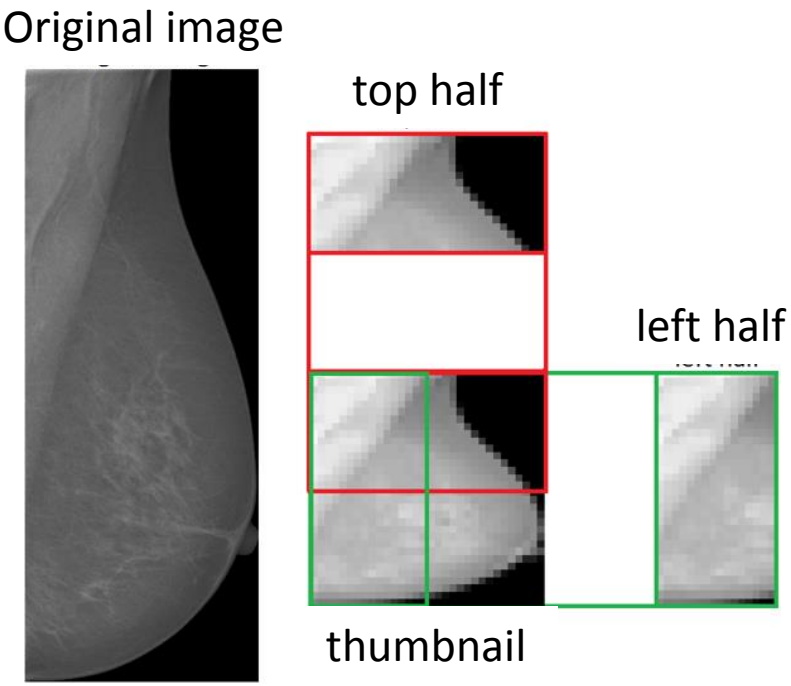


Reject contour if it is not valid

Pectoral muscle detection

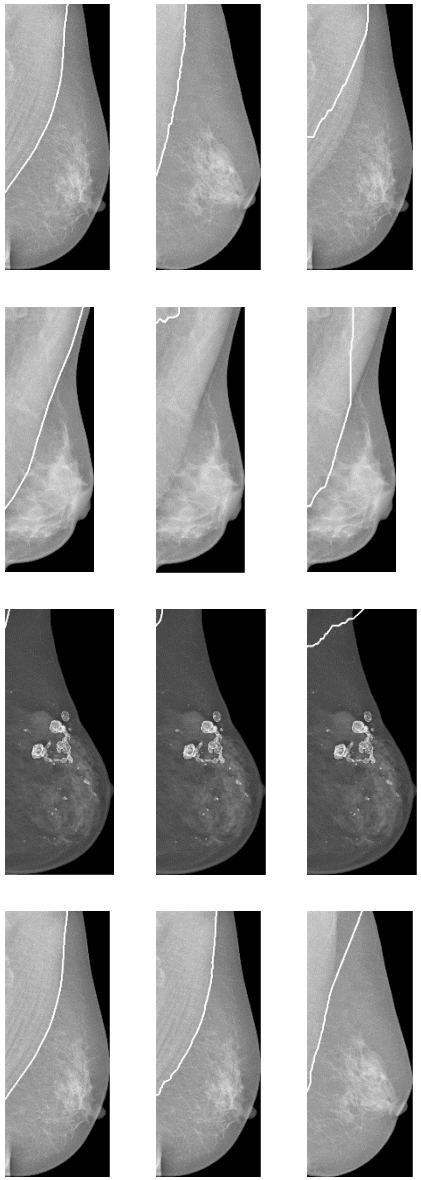
Shortest path with endpoints learnt by SVMs (SPLE)





Pectoral muscle detection

Results



- Differences between SPPC and SPLE are not significant
- SPLE
  - if a robust estimation of the endpoints can be achieved
  - the pectoral muscle boundary can be effectively predicted
  - the prediction of the endpoints seems to be the main source of errors

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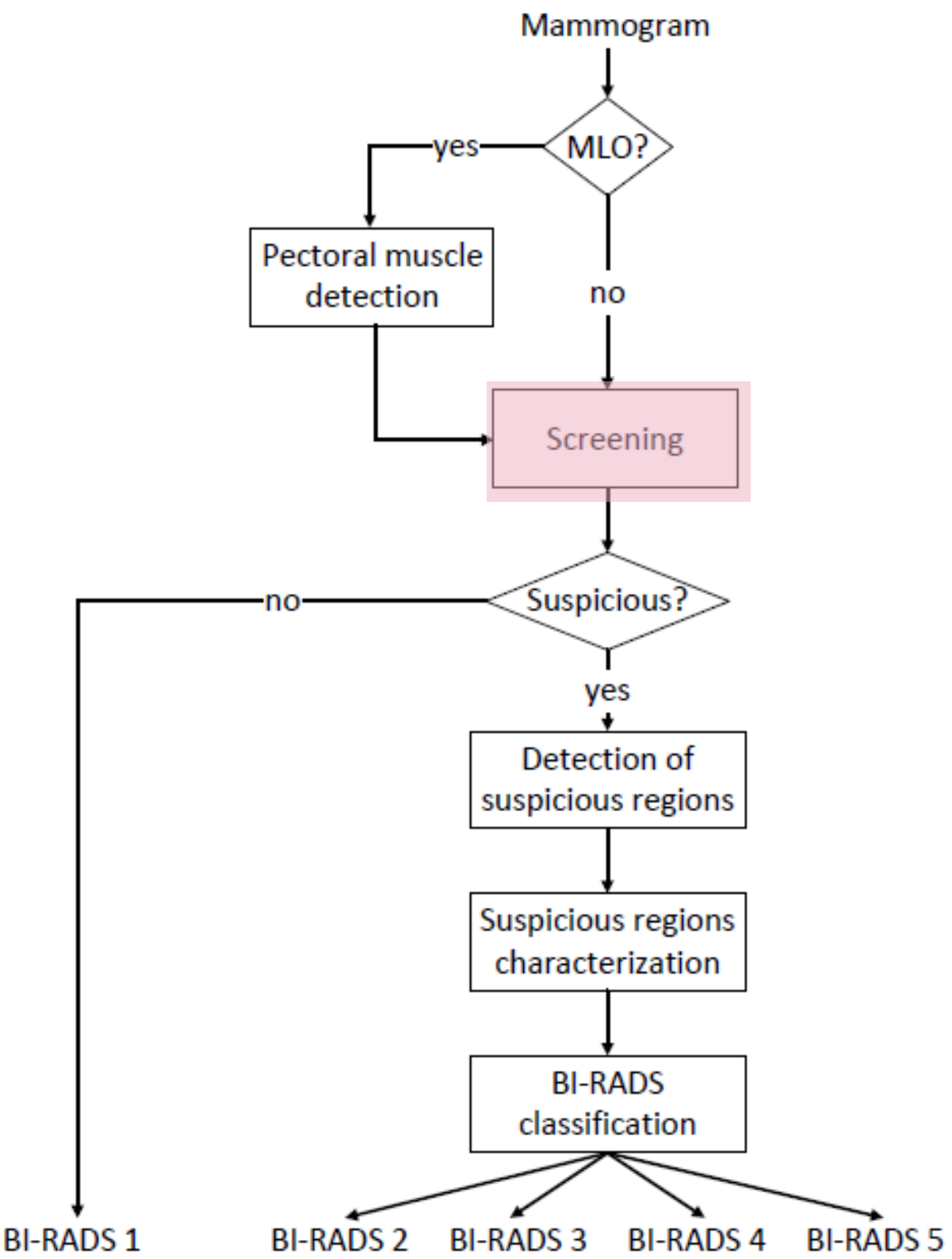
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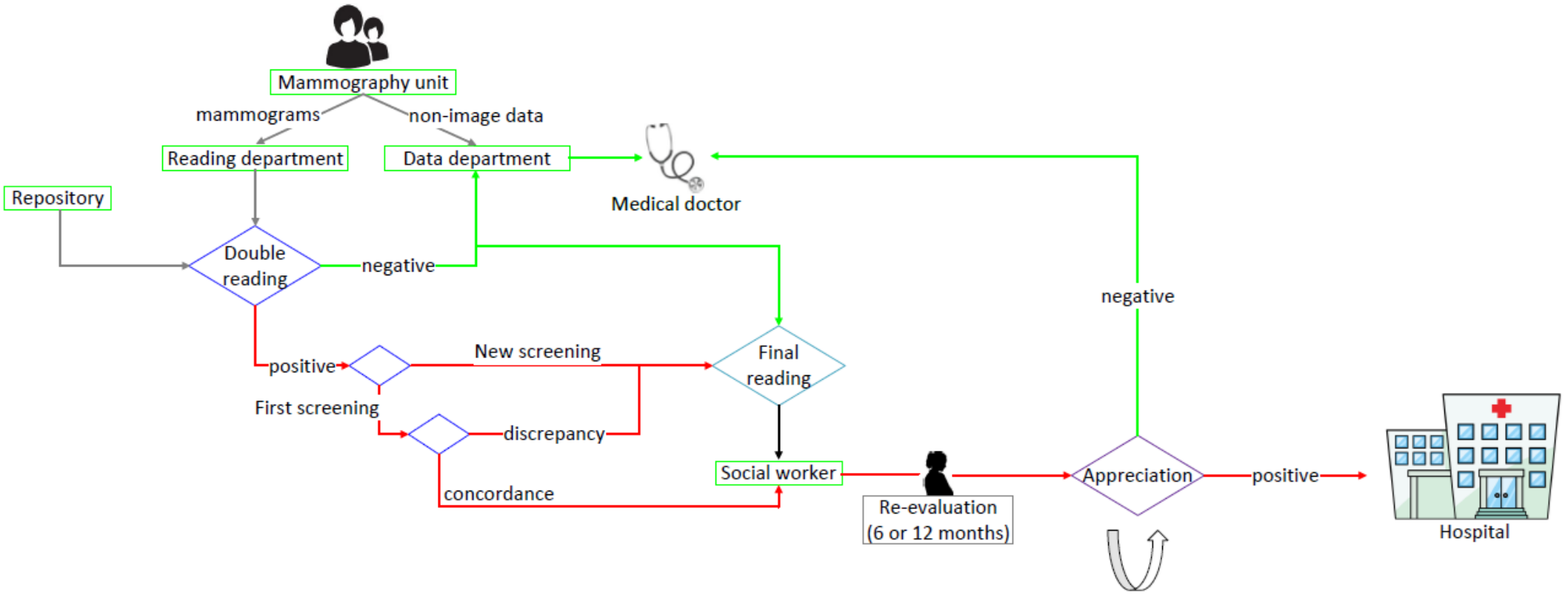
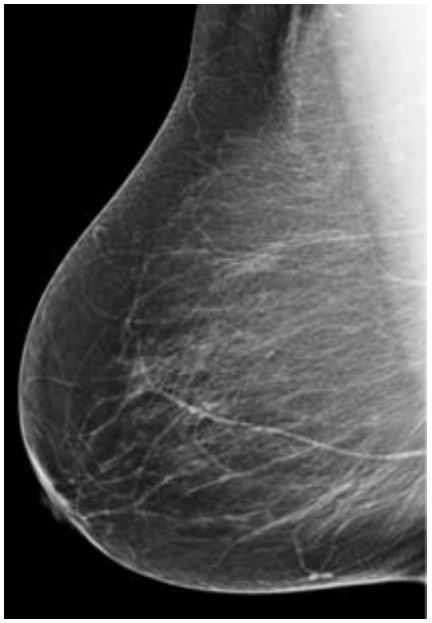
Screening

Portuguese Breast Cancer Screening Program

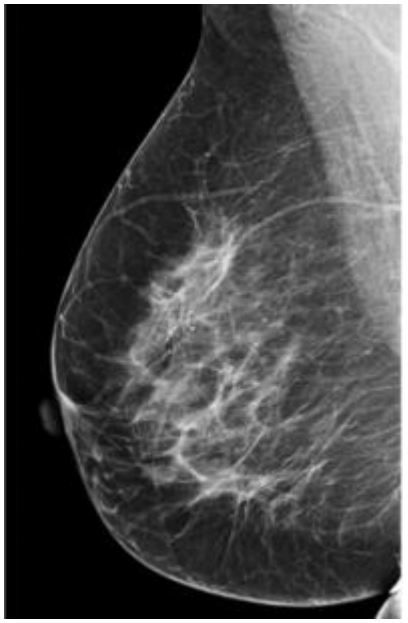


Screening

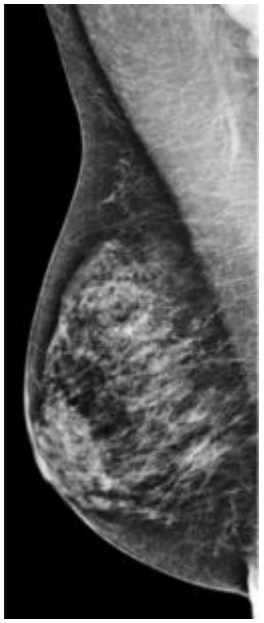
Breast density



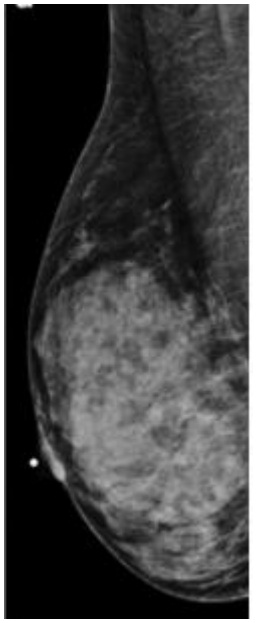
almost entirely fatty



scattered areas of fibroglandular density



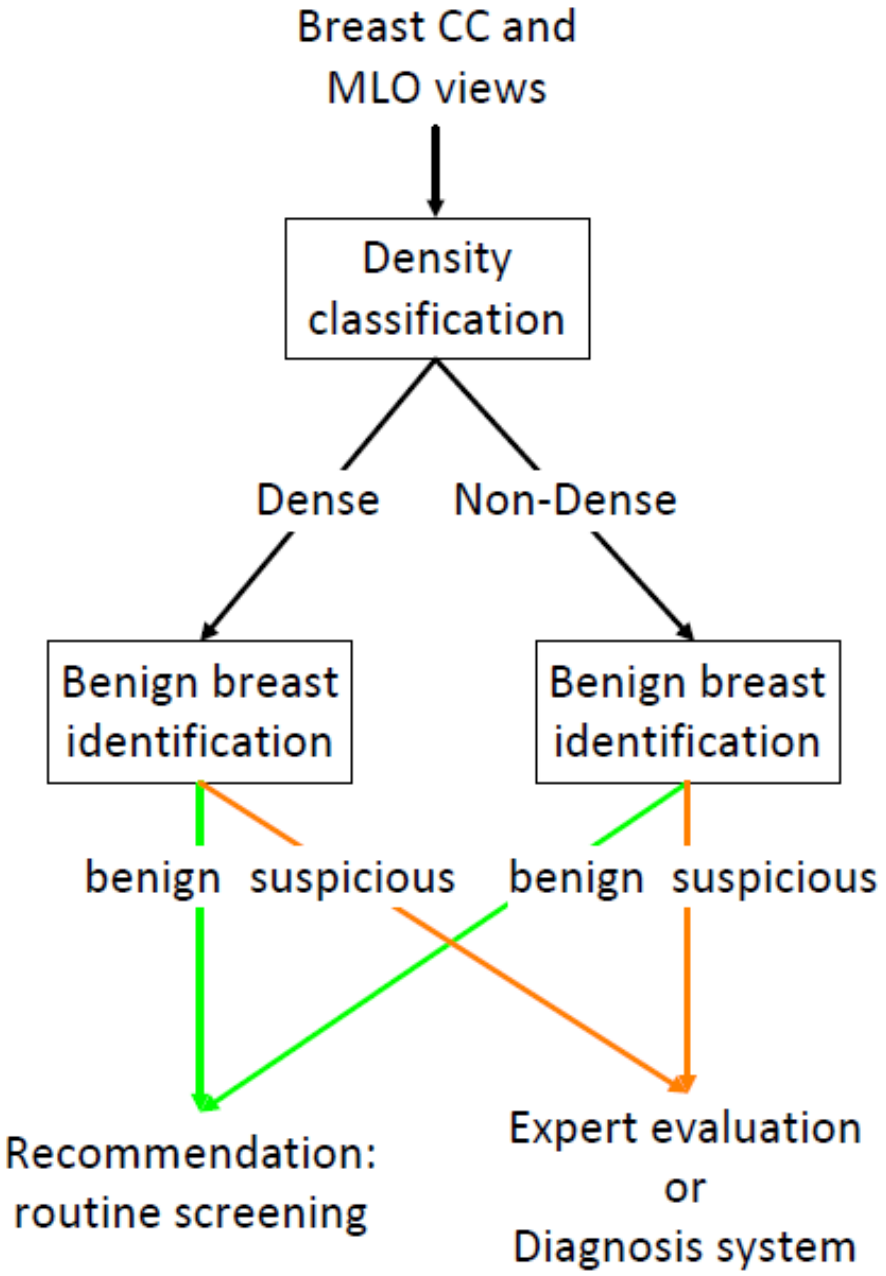
heterogeneously dense



dense

- density has been associated with a higher risk of cancer
- masses and calcifications are harder to detect in dense breasts
- density decreases the sensitivity of automatic systems

Screening



- sensitivity and FNr better than reported for human specialists
  - real clinical setting example
  - replace one of the radiologists during the double-reading
  - if a disagreement exists, the exam is sent for further investigation

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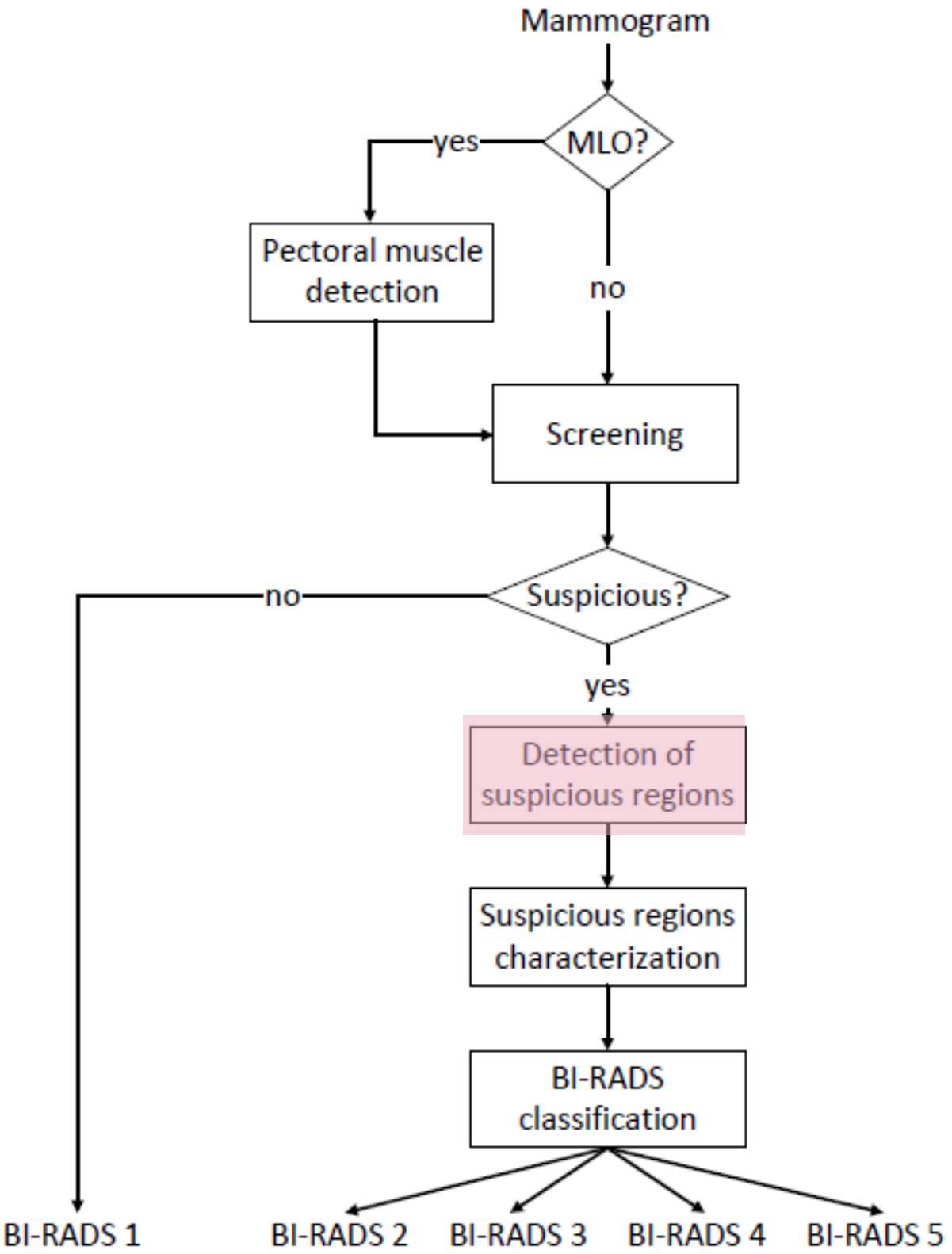
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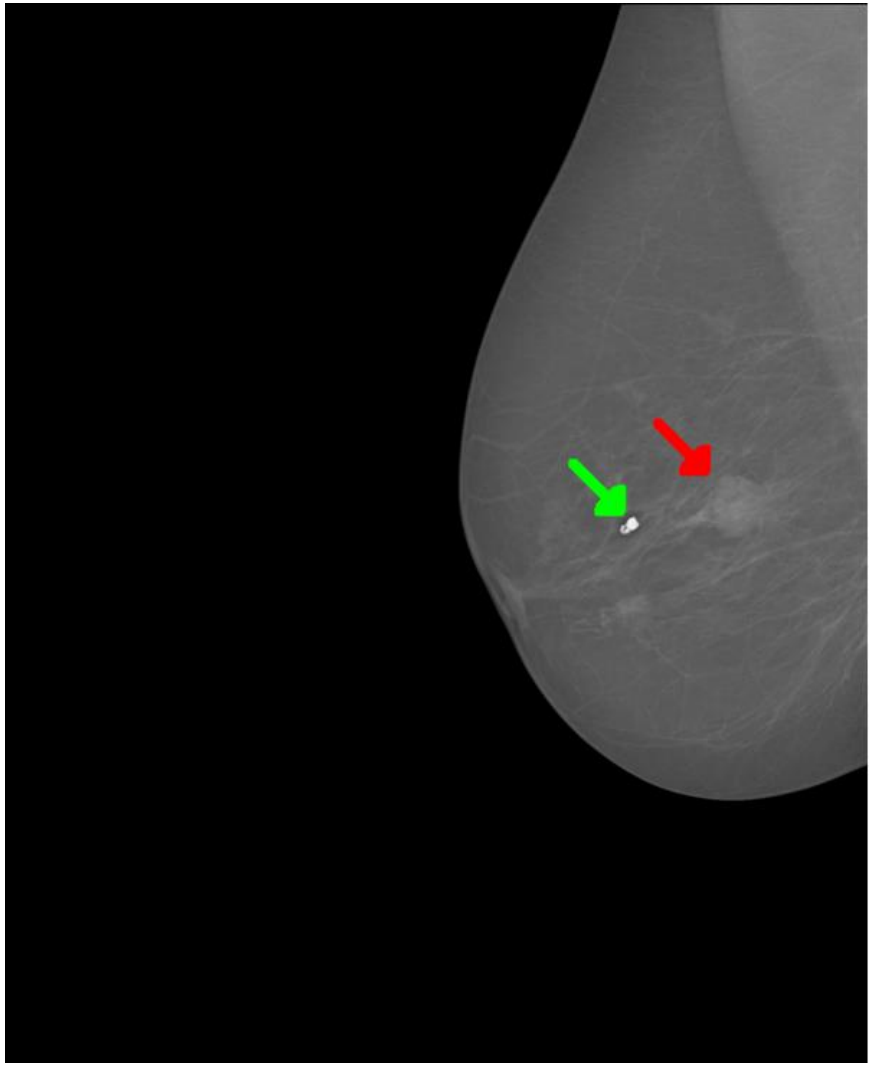
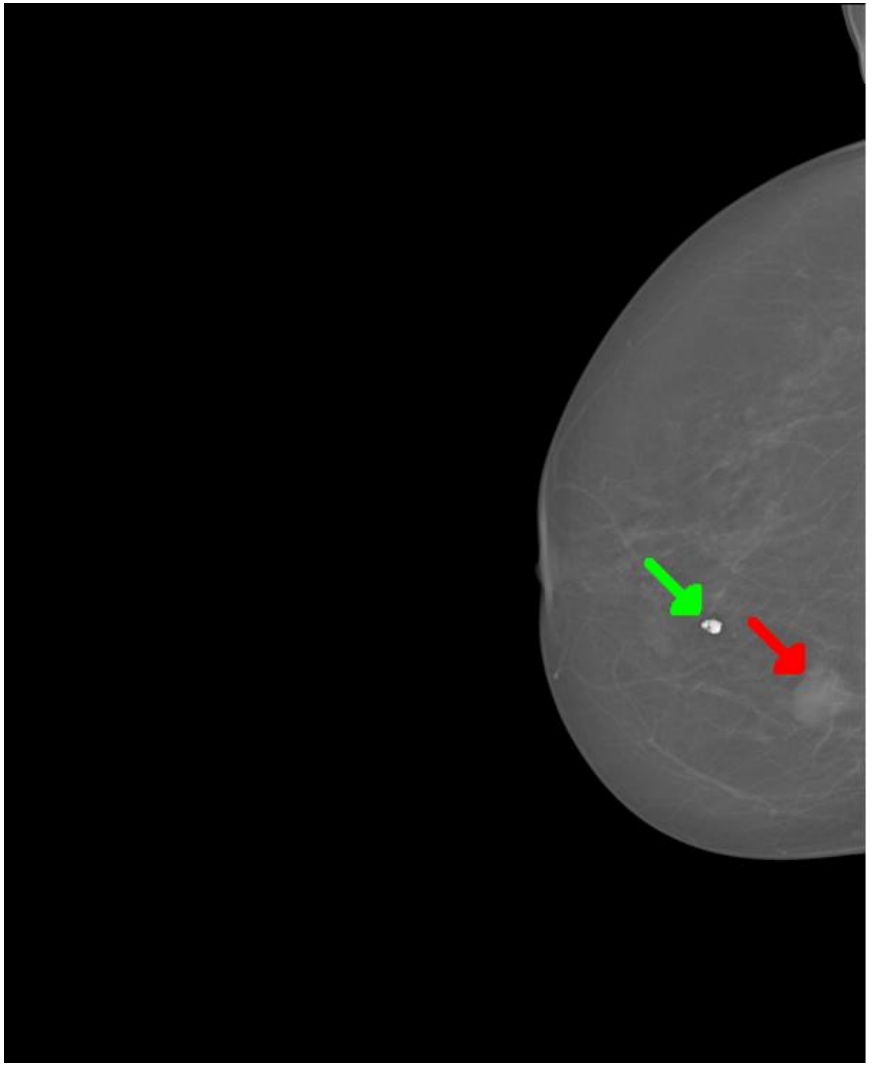
Detection of suspicious regions

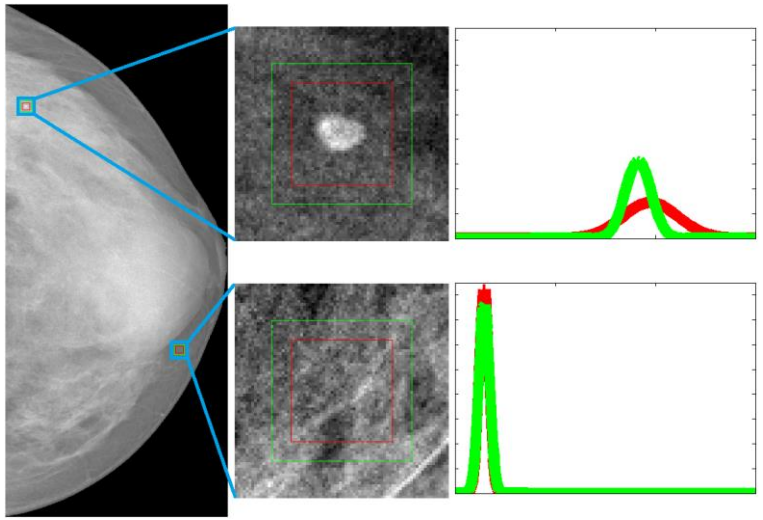
Some types of suspicious regions





Detection of suspicious regions

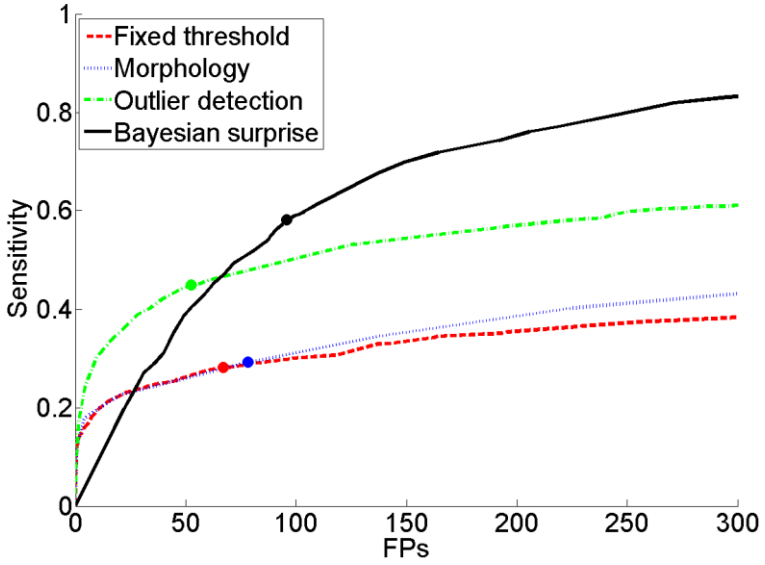
Calcifications

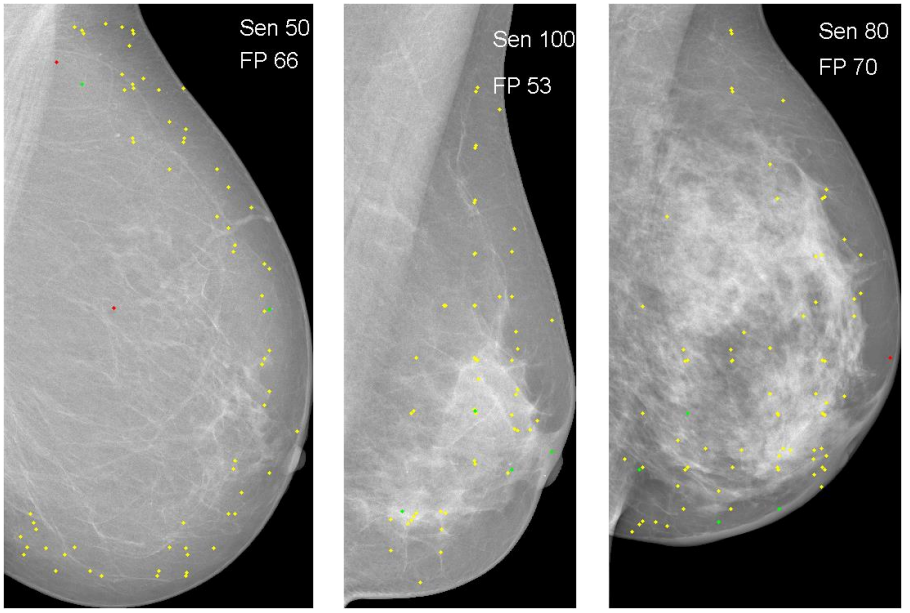


- for each patch of the image
  - compute surprise

$$S(D,\mathscr{M}) = K(P(M)||P(M|D)) = \sum_{M\in\mathscr{M}} P(M) log \frac{P(M)}{P(M|D)}$$

    - if surprise > threshold
      - ❑ calcification

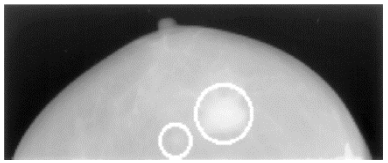


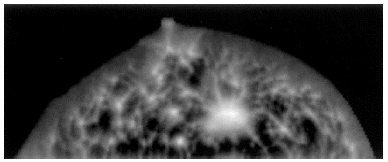


Detection of suspicious regions

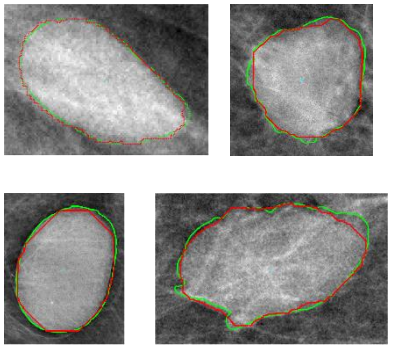
Masses

Mammogram → Iris Filter → Local maximum selection → Layer 1 of FPs reduction → Seeded segmentation → Layer 2 of FPs reduction





- SVMs with RBF kernel
- features
  - original images
  - intensity value
  - Patch standard deviation
  - Patch 25th percentile
  - Patch median value
  - Patch mean value
  - Patch 75th percentile
  - Patch maximum intensity
  - Iris filtered images
  - Patch 25th percentile
  - Patch median value
  - Patch maximum value

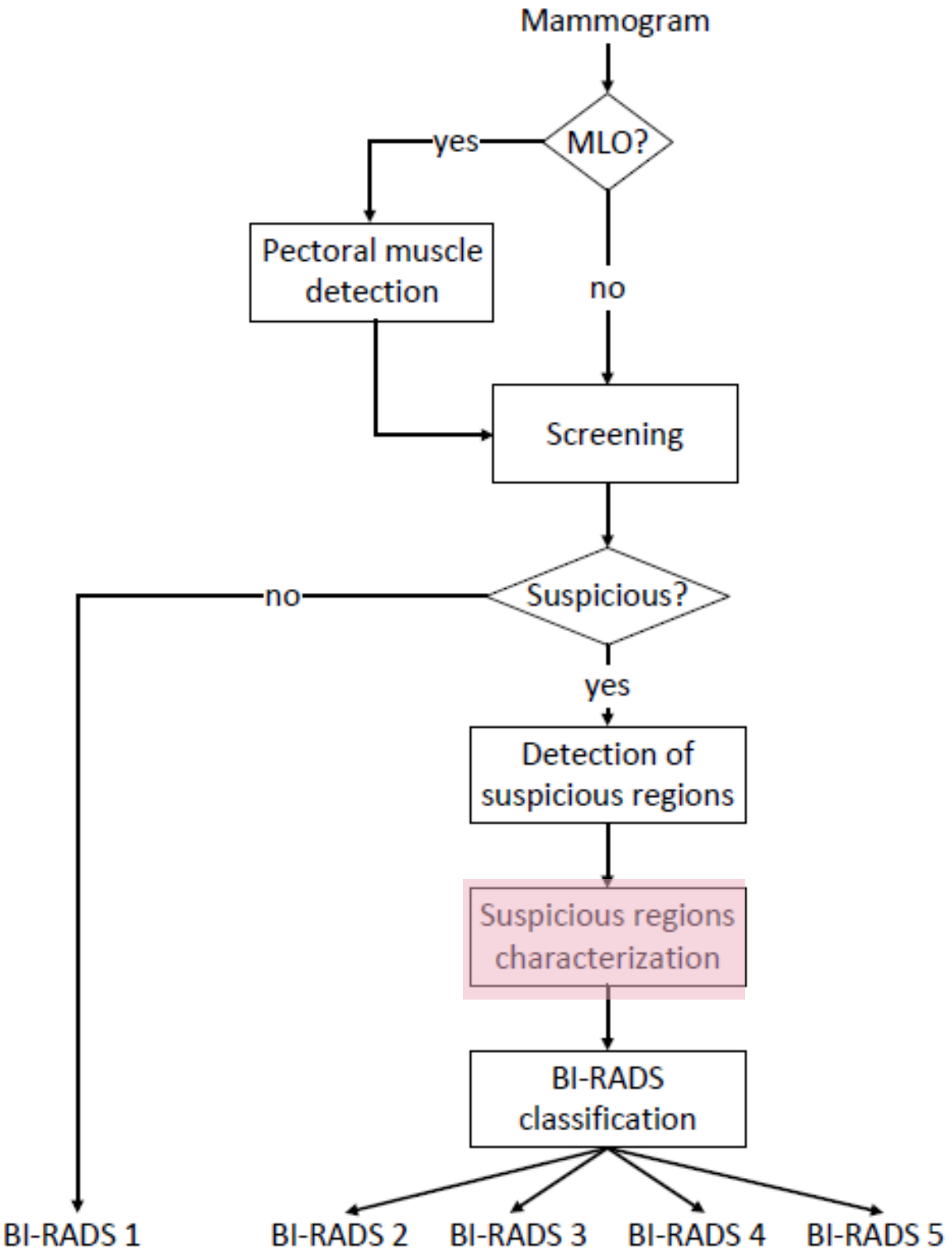


ACR density	Sensitivity (%)	False Positives
I	**52**	**3**
II	30	**3**
III	26	6
IV	7	9

overall performance: Sensitivity = 38% with 5 false positives

- SVMs with RBF kernel
- 9 shape features
  - area of the segmented region
  - area of the bounding box of the region
  - area of the region's convex hull
  - eccentricity
  - length of the major axis of the ellipse that has the same normalized 2nd-moments as the region
  - length of the minor axis of the ellipse that has the same normalized 2nd-moments as the region
  - diameter of a circle with the same area as the region, orientation
  - Perimeter
- 1 feature that uses both shape and intensity information
  - distance between the centroid and the weighted centroid

Outline


Mammogram
MLO?
yes
no
Pectoral muscle detection
Screening
Suspicious?
no
yes
Detection of suspicious regions
Suspicious regions characterization
BI-RADS classification
BI-RADS 1
BI-RADS 2
BI-RADS 3
BI-RADS 4
BI-RADS 5

Characterization of suspicious regions

Breast Imaging Lexicon

Masses

Shape
- Round
- Oval
- Lobular
- Irregular

Margins
- Circumscribed
- Microlobulated
- Obscured
- Indistinct
- Spiculated

Density
- High
- Equal
- Low
- Fat containing

Calcifications

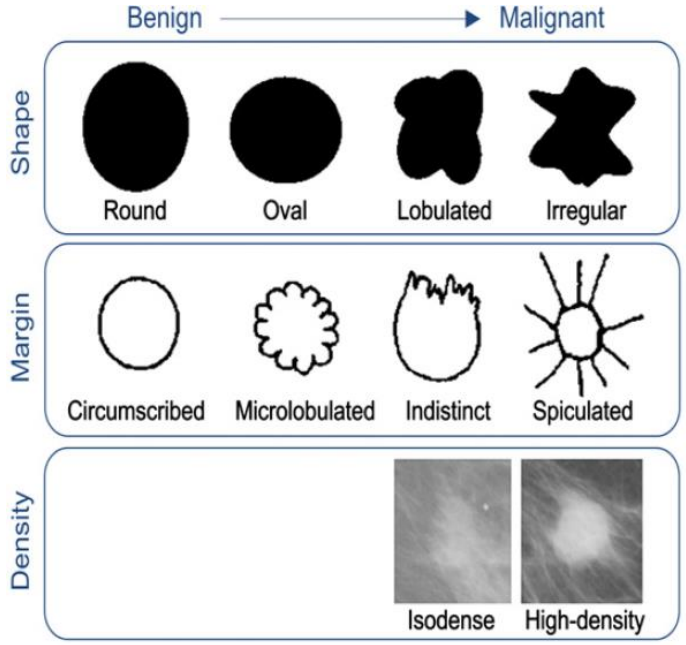
Distribution
- Grouped
- Linear
- Segmental
- Regional
- Diffuse

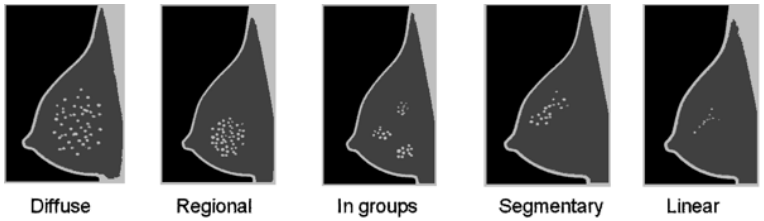
Morphology

Higher probability of malignancy:
- Pleomorphic
- Fine, linear

Intermediate:
- Amorphous

Typically benign:
- Skin
- Vascular
- Coarse
- Rod-like
- Round
- Lucent-centred
- Eggshell
- Milk of calcium
- Suture
- Dysttrophic
- Punctate





Characterization of suspicious regions

Pearson correlation, distance correlation and Maximal Information Coefficient

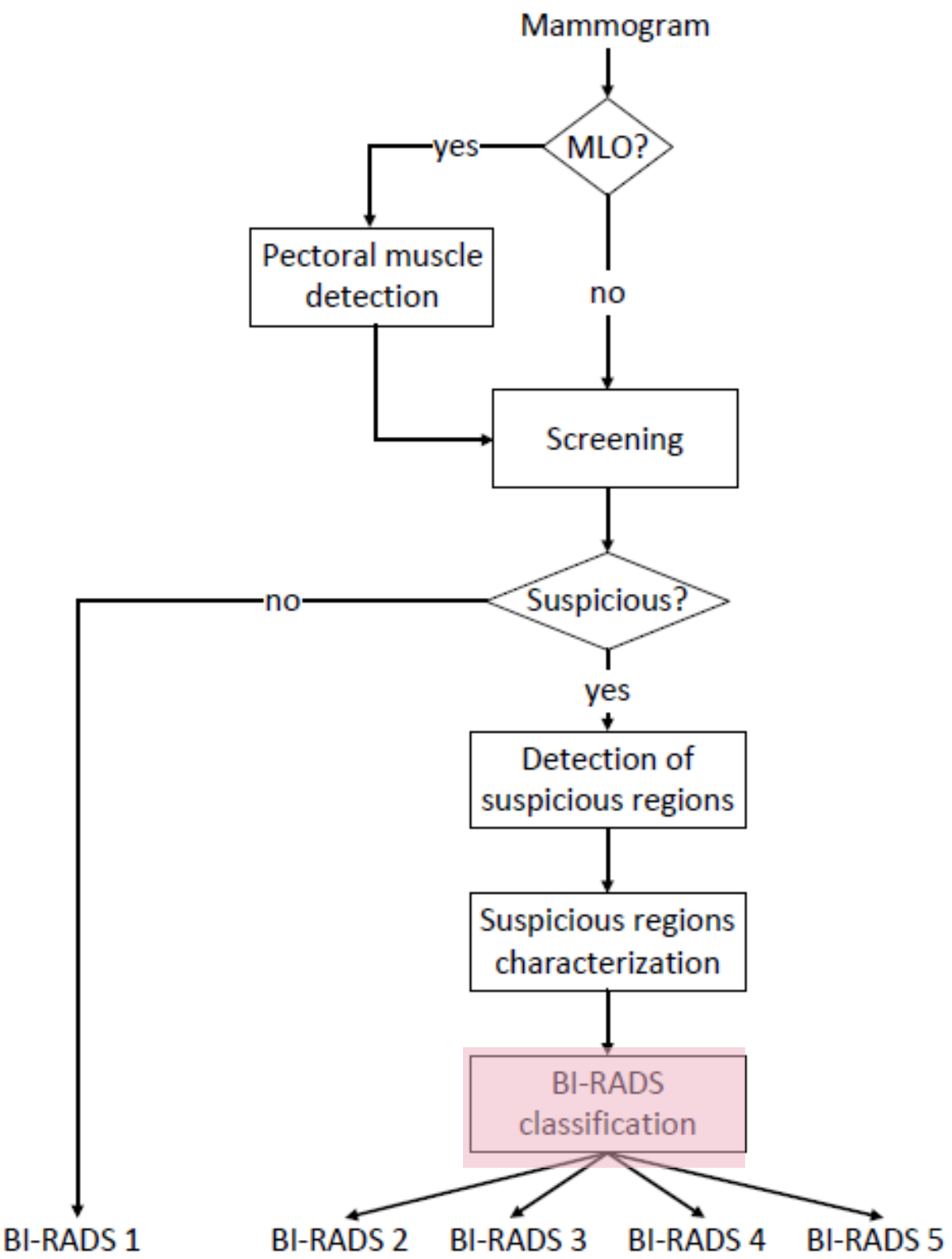
7 calcification features:

1. Zernike moment of order 3 and repetition +3
2. Zernike moment of order 4 and repetition 0
3. Zernike moment of order 4 and repetition -4
4. Eccentricity extracted from the Spatial Density Function
5. Minimum of the mean intensities of the calcifications
6. Intensity std
7. Std of the mean intensities of the calcifications

9 mass features

1. Solidity
2. Compactness
3. Thinness ratio
4. Skeleton end points
5. Shape Index
6. Convexification
7. Extent
8. Contained lines
9. $CC_2 = \sqrt{}(Rmin / Rmax)$

Outline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BI-RADS classification

The scale

BI-RADS	Description
0	the exam is not conclusive
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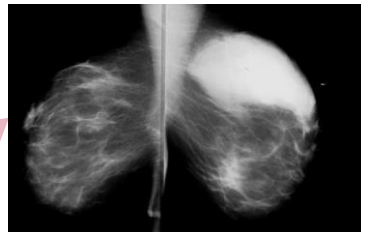
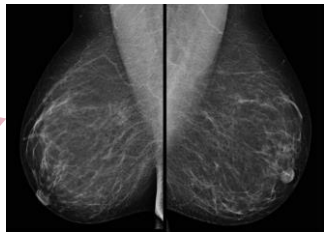
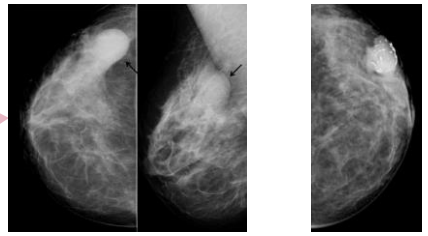
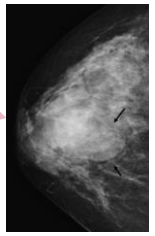
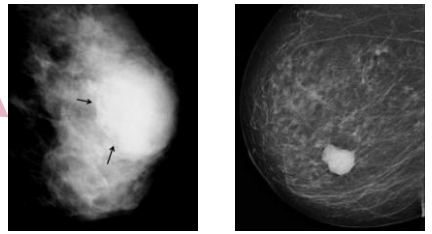
6	proved cancer

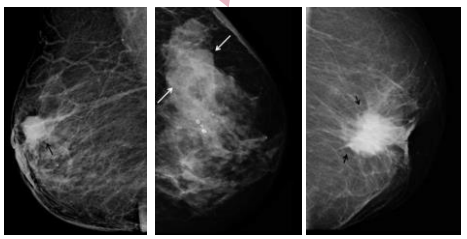












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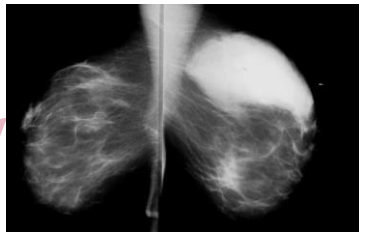

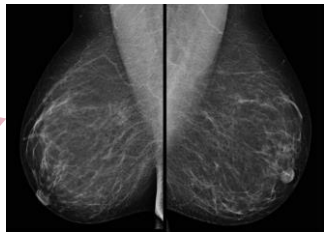

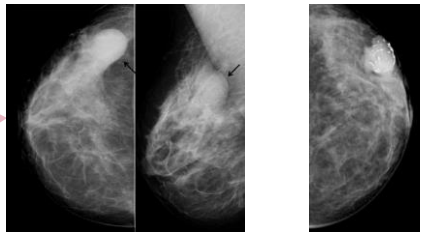

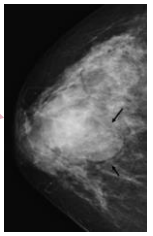

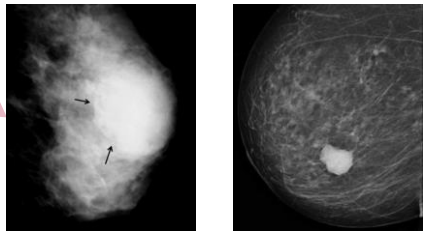

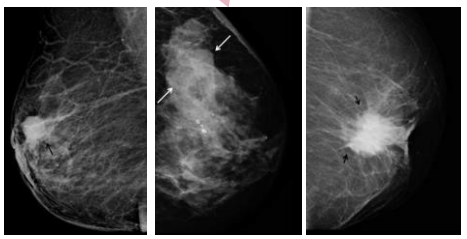

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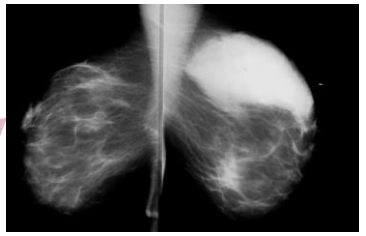

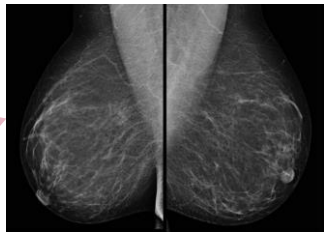

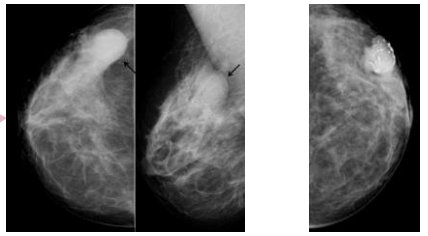

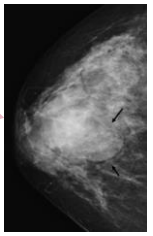

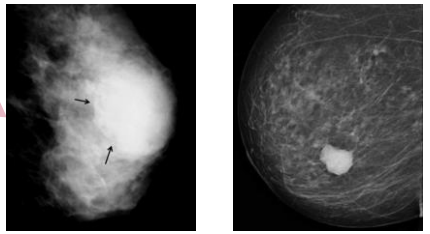

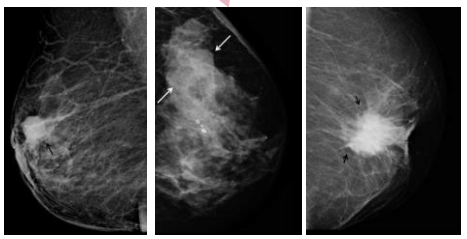

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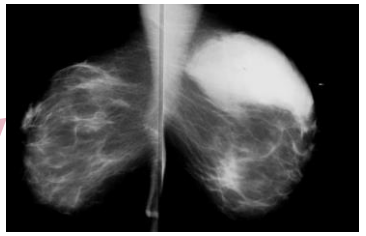
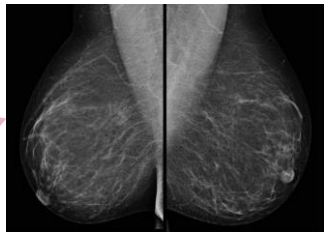
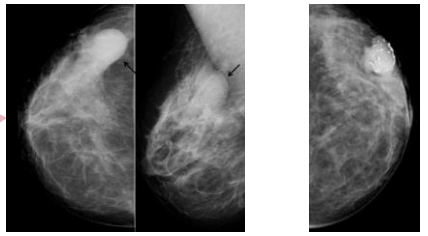
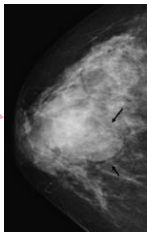
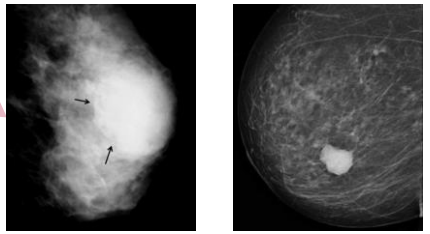
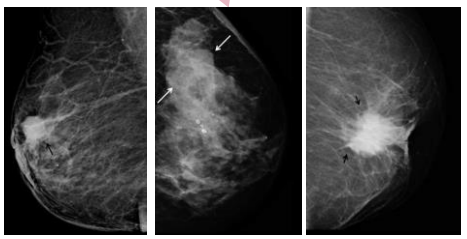






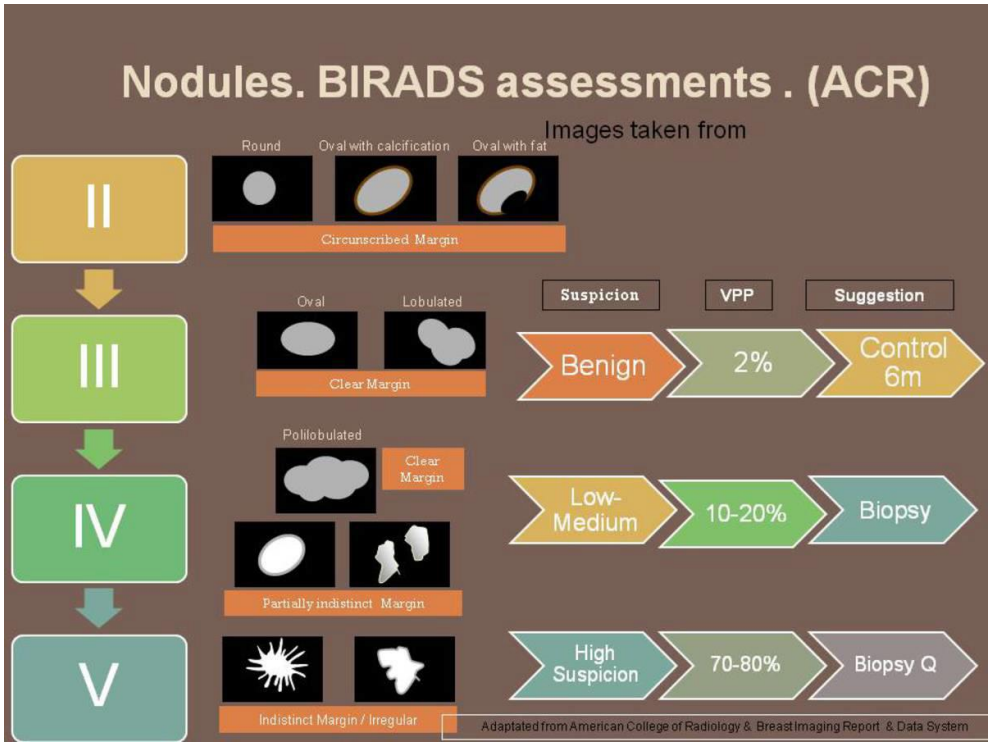


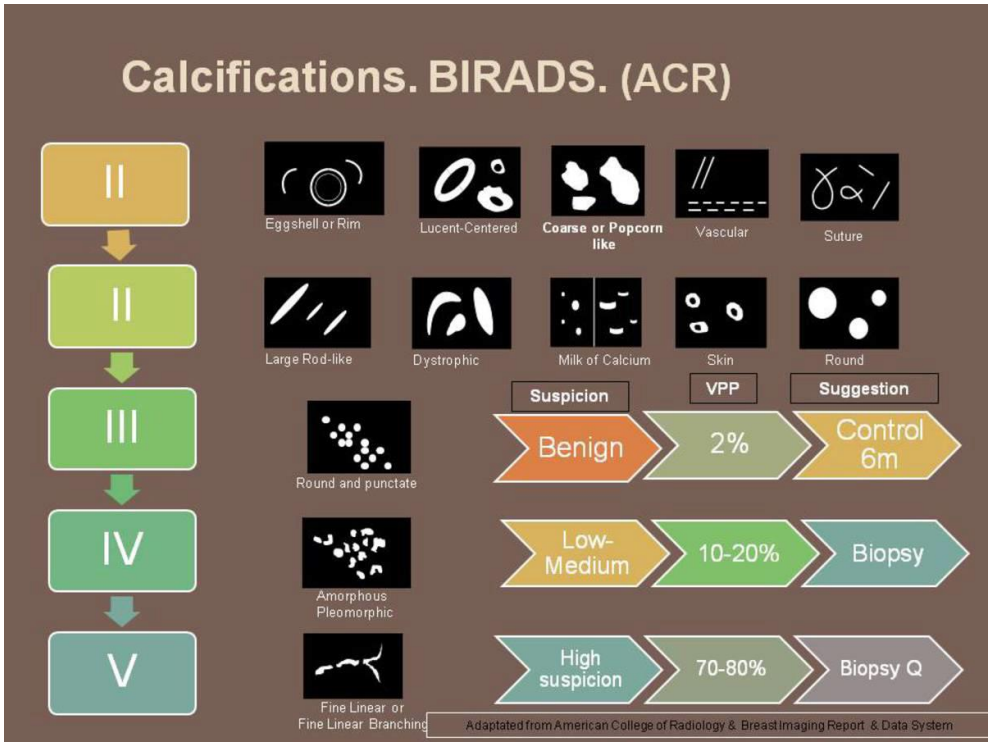




BI-RADS classification

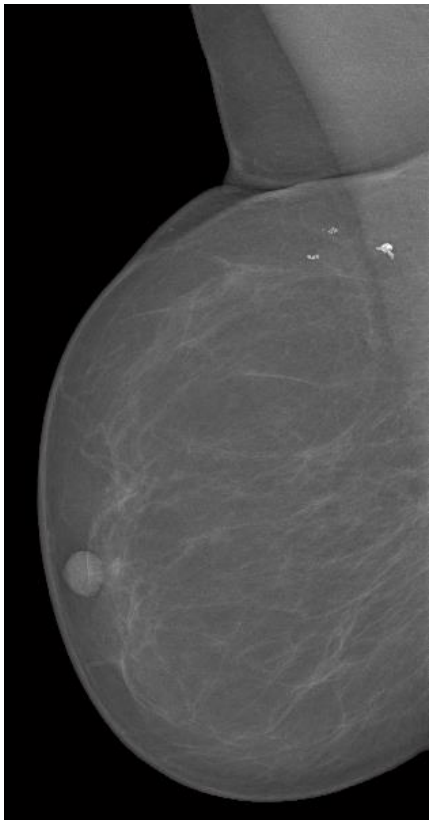
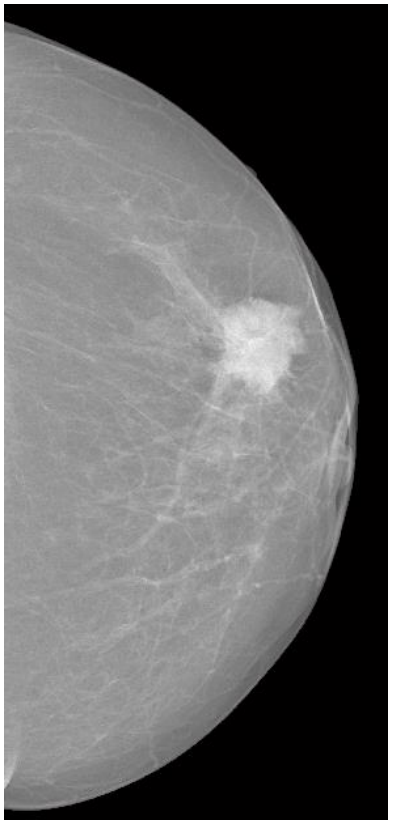
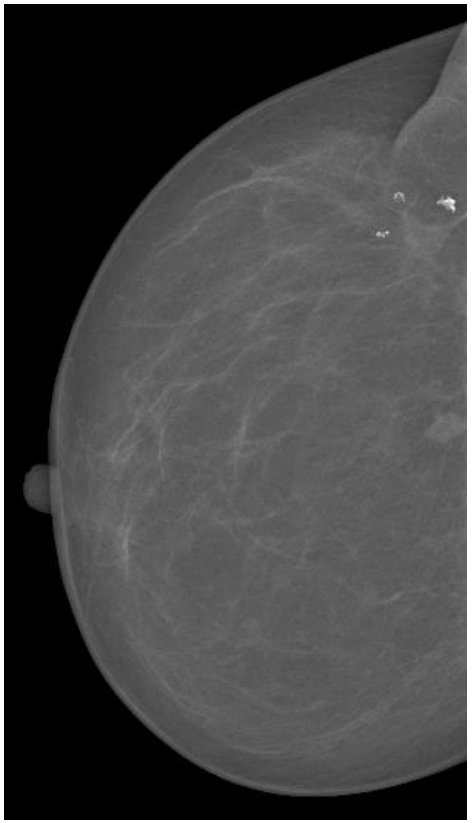
The scale





BI-RADS classification

Motivation

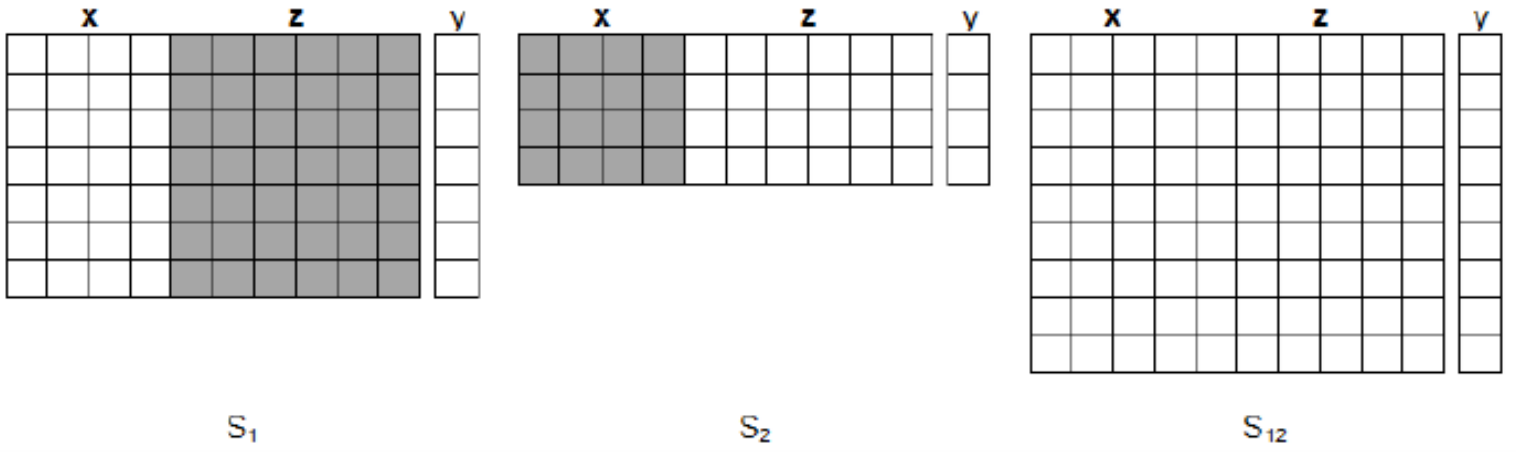




When more than one finding is present in the mammogram, the overall BIRADS in the medical report corresponds to the finding with the highest BI-RADS

BI-RADS classification

Methods

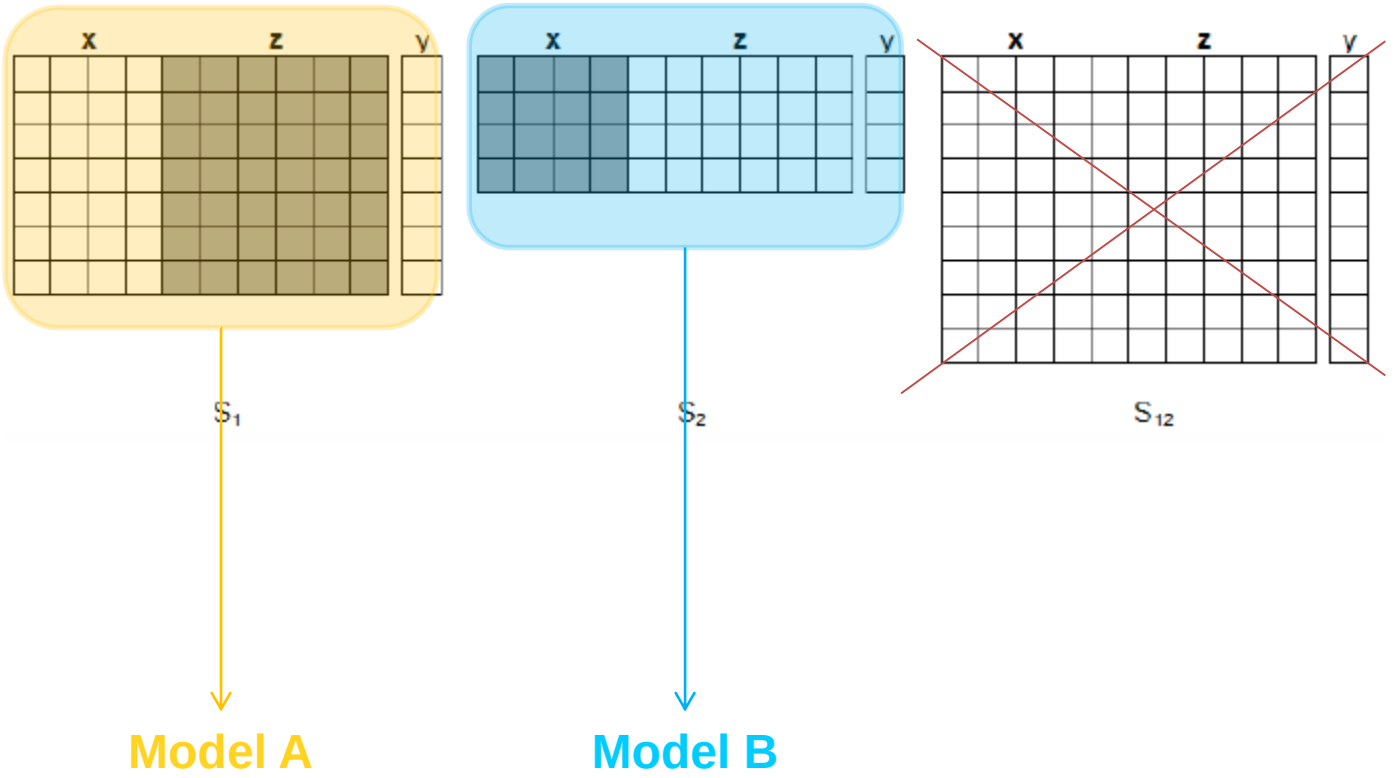
- Max Ordinal Learning (MOL)
  - MOL.LA
  - MOL.CD



Training set illustration
White represents observed and gray not present features

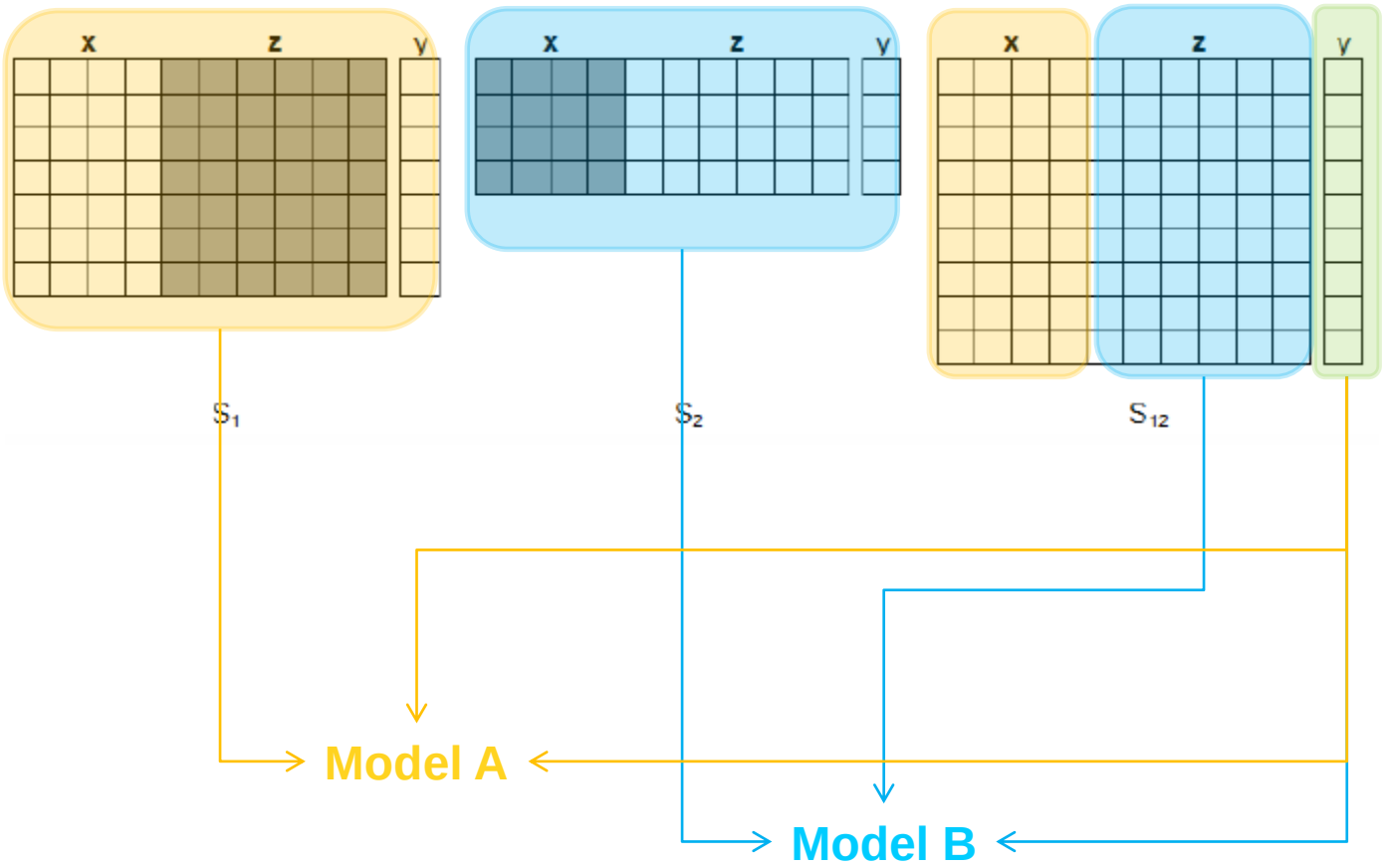
BI-RADS classification

non-MOL



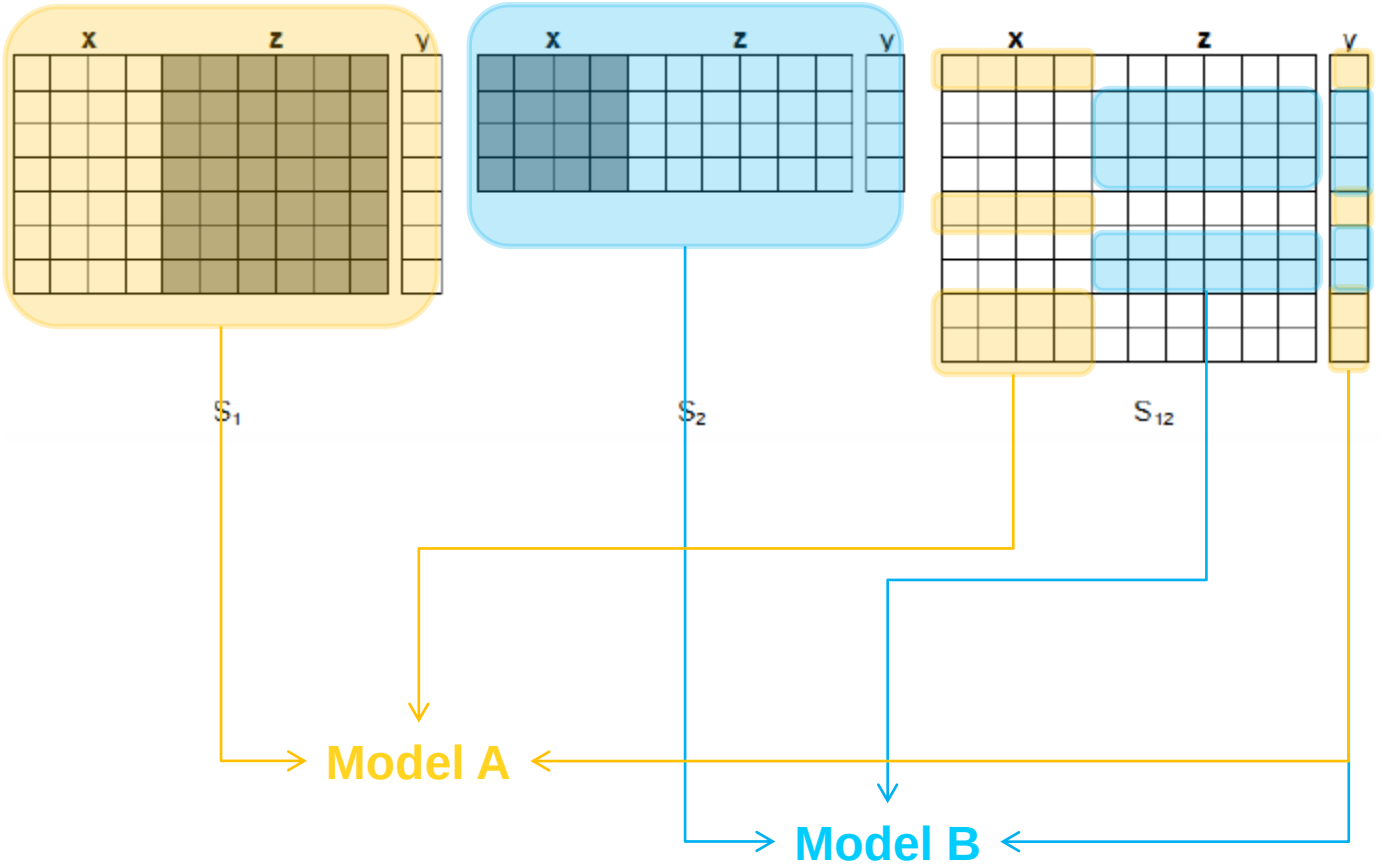
BI-RADS classification

MOL.LA initialization



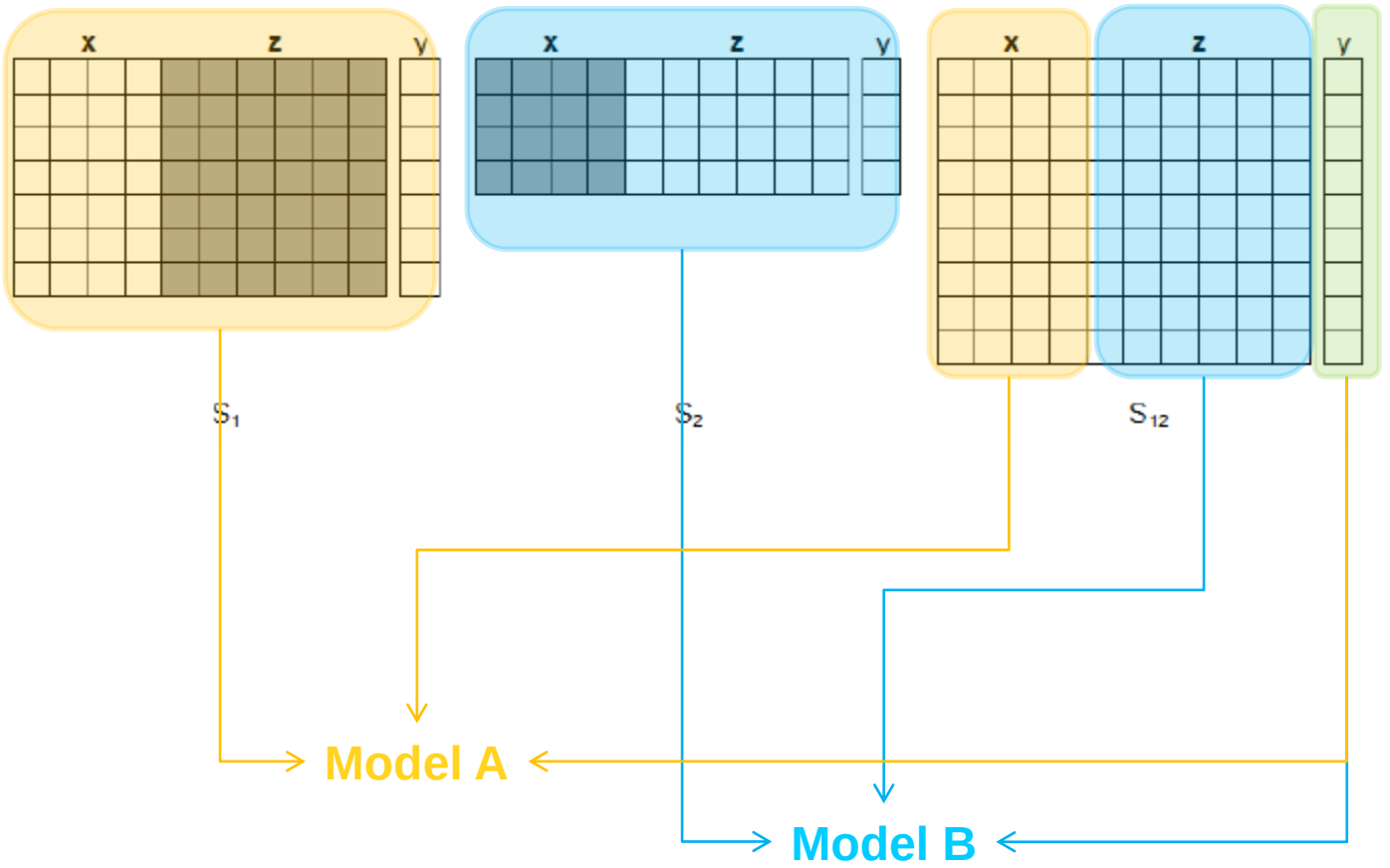
BI-RADS classification

MOL.LA subsequent iterations



BI-RADS classification

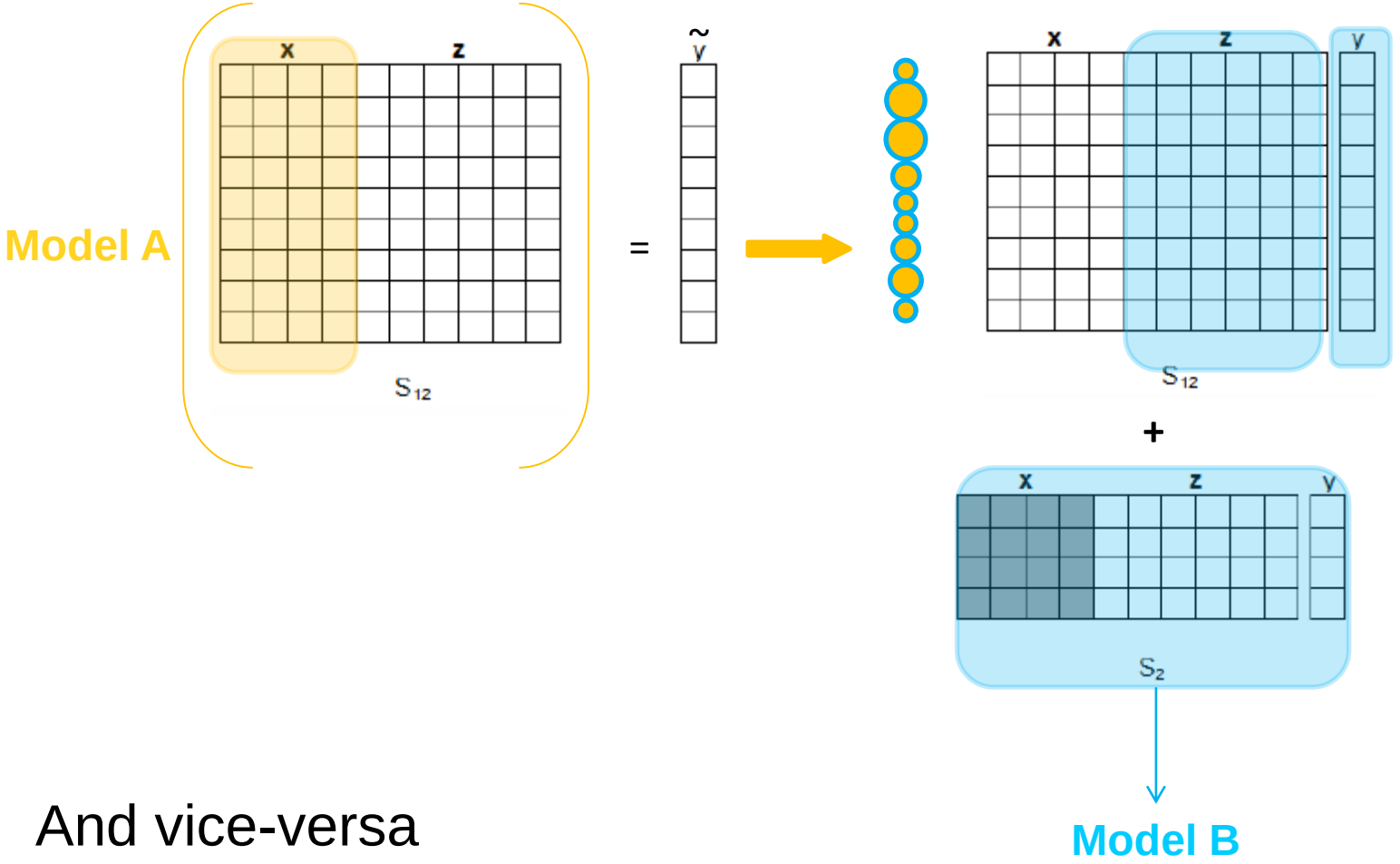
MOL.CD initialization



BI-RADS classification

MOL.CD subsequent iterations

- Consider **Model A** fixed and update **Model B**



- And vice-versa

BI-RADS classification

Experiments

- Two kernels
  - Linear & Radial Basis Function
- Model parameterization selection
  - two-fold cross-validation
- Non-ordinal extension from binary to multi-class
  - one-against-one
    - instantiated with SVMs
- Ordinal methods
  - Frank and Hall
    - instantiated with SVMs
  - Data replication
    - instantiated with SVMs
  - KDLOR
    - instantiated LDA

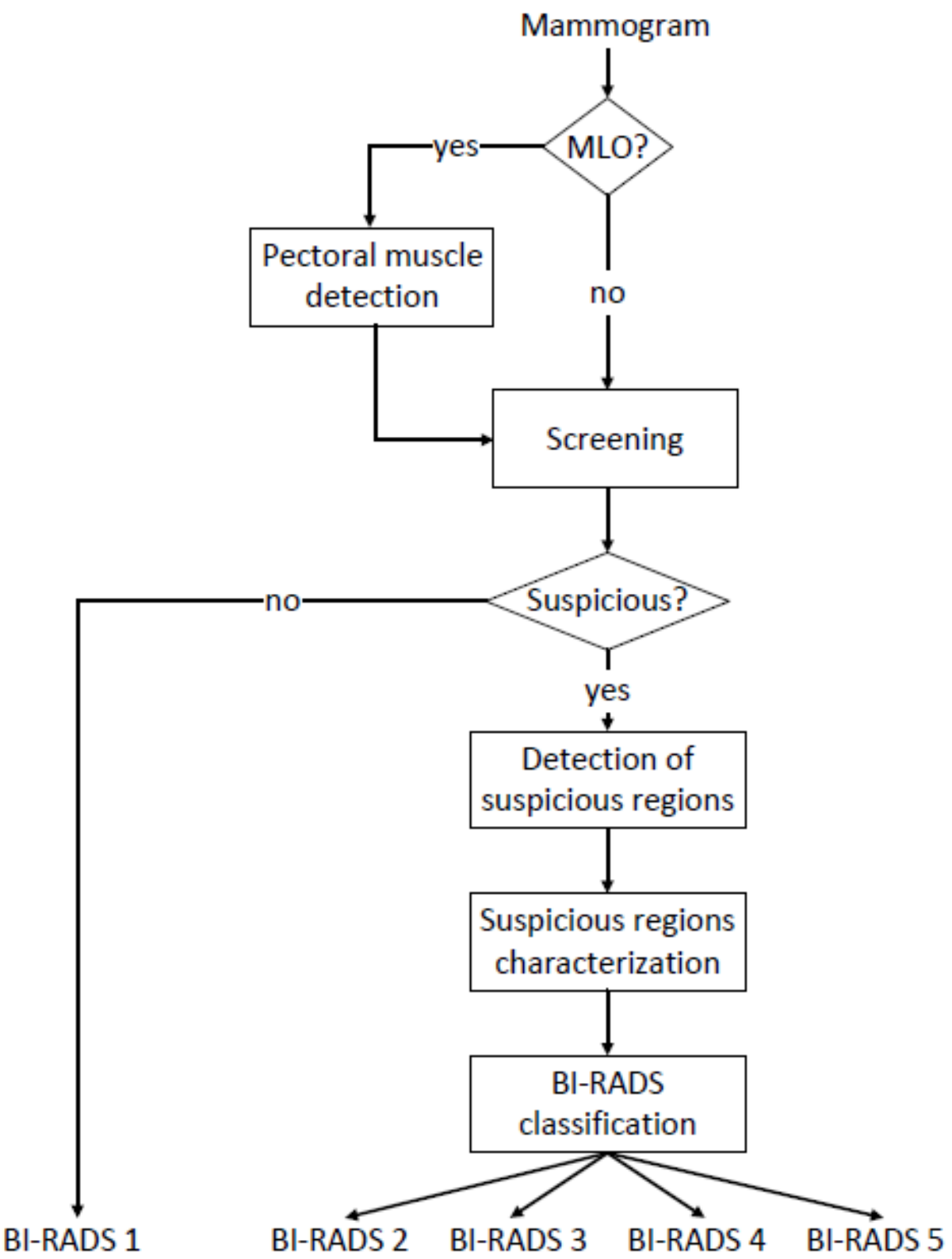
BI-RADS classification

Results

		Mass contorus	
		Ground truth	CaPTOR
Baseline techniques	Standard Model	15	13
	Tri-Training	17	16
	Non-ordinal	10	7
MOL.LA	Frank&Hall	9	7
	Data Replication	7	8
MOL.CD	Frank&Hall	9	7
	Data Replication	9	7

- Automatic segmentation does **not** seem to negatively affect classification results
- Both the MOL.LA and MOL.CD techniques perform better than the standard methods
  - It is sufficient to test and compare MOL.LA and MOL.CD

Outline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Putting all together

Component	Ground truth	Automatic
Pectoral muscle detection	AOM = 0.65	
	CM = 0.77	
	AD = 0.06	
	AMED = 0.07	
	HD = 0.17	
Screening	TPr = 0.92	TPr = 0.82
	TNr = 0.18	TNr = 0.33
	FNr = 0.08	FNr = 0.17
	FPr = 0.82	FPr = 0.67
Calcification detection	Sensitivity = 56.4 %	Sensitivity = 63.8 %
	FP = 47	FP = 49
Mass detection	Sensitivity = 47.6 %	Sensitivity = 48.8 %
	FP = 4	FP = 4
BI-RADS classification	MAE = 10 %	MAE = 88 %

Thank you!

Questions?