Breast Imaging Modalities in Clinical Practice

A Breast Radiologist’s Perspective

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Disclosures

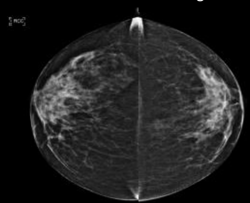
- Nothing to disclose

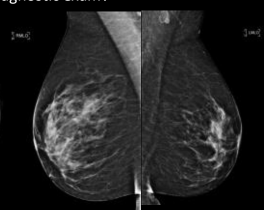
Outline

- Screening vs Diagnostic Indications
- Discuss Risk Assessment
- Breast Cancer Epidemiology
- Screening Mammography
- Focused Clinical Update on Breast Imaging Modalities
  - Digital Breast Tomosynthesis (DBT)
  - Synthetic Mammography (SM)
  - Contrast Enhanced Digital Mammography (CEDM)
  - Stereotactic vs. DBT guided core biopsies
- Future of Breast Imaging

Definitions

Screening vs. diagnostic exam?



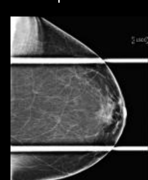


Screening Exam

- Asymptomatic

Diagnostic Exam

- Symptomatic
- Abnormal screening exam
- Follow up of a BI-RADS 3 finding



How does a patient's risk of developing breast cancer influence the recommendation for screening?

Average risk women: annual mammography

High risk women: annual mammography **AND annual breast MRI** recommended

High Risk is defined as those with a:

- Lifetime risk (LTR) of developing breast cancer ≥ 20-25%
- Disease-causing genetic mutation(s) (e.g. BRCA, p53, PTEN, STK11)
- First-degree relative with a known disease-causing mutation (but who are themselves untested)
- History of prior chest radiation therapy before age 30
- Hereditary or genetic syndrome associated with an increased risk for developing breast cancer (Li-Fraumeni, Cowden, or Bannayan-Riley-Ruvalcaba Syndromes)
- Personal history (pHx) of breast cancer and dense breast tissue and/or those with a pHx of breast cancer diagnosed before the age of 50

How is breast cancer risk assessed?

Risk Assessment Models

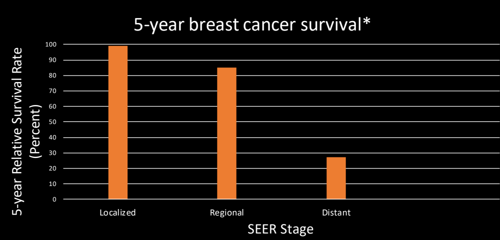
- Statistical models that combine known major risk factors
- Predict:
  - Risk of developing invasive breast cancer
  - Risk of pathogenic mutation
  - Both
- Stratify pts into risk categories to personalize screening and surveillance plans

How are the models used?

To identify women who:
- Meet criteria for high-risk screening breast MRI
- May carry a pathogenic mutation and benefit from genetic risk assessment
- May benefit from risk-reducing medications

Breast Cancer

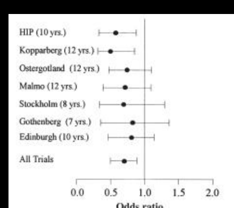
- Approximately 12 % of women (1/8) will be diagnosed with breast cancer at some point during their lifetime
- Second leading cause of cancer death among women



*Based on the SEER (Surveillance, Epidemiology, and End Results) database, maintained by the National Cancer Institute (NCI), available on the ACS website. The data displayed is based on women diagnosed with breast cancer between 2008 and 2014.

Screening Mammography

- Multiple randomized control trials (RCTs) since the 1960s
- Mortality reduction 25-30%
- Smaller and more node-negative tumors

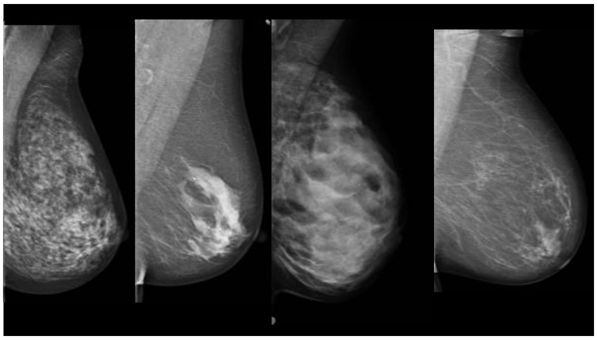


Kopans, D. B. (2005). *Breast Imaging*. Chapter 4 p152

Mammography RCT Data

Trial (year)	Age at Entry	# of views	Frequency of Mammography (mo)	Rounds (n)	F/U (yrs)	RR (95% CI)	Mortality Reduction (%)
HIP trial (1963-1969)	40-64	2	12	4	18	0.78 (0.61-0.97)	22
Malmo, Sweden (1976-1986)	46-69	1-2	18-24	5	20	0.78 (0.65-0.95)	22
Two-County Swedish (1979-1988)	40-74	1	23-33	4	30	0.68 (0.54-0.80)	32
Edinburgh, Scotland (1979-1988)	45-64	1-2	24	4	14	0.78 (0.62-0.97)	22
Stockholm, Sweden (1981-1988)	40-64	1	28	2	16	0.90 (0.63-1.28)	10
Gothenburg, Sweden (1982-1988)	40-59	2	18	4	14	0.79 (0.58-1.08)	21
UK Age trial (1991-2005)	39-41	1-2	12	8	10	0.83 (0.66-1.04)	17

Modified from: Feig *Radiol Clin N Am* 2014



Challenges with Mammography

- Heterogeneity of a normal mammogram
- FFDM is limited
  - Overlapping tissue can simulate disease
  - Overlapping tissue can obscure cancers

Digital Breast Tomosynthesis (DBT)

- X-ray tube moves in an arc
- Multiple low dose projection images obtained
- Mathematical reconstruction of imaging planes from a set of projection images obtained through a limited angle

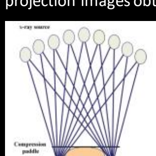


Figure: Peppard HR et al. RadioGraphics 2015

Table 1: Currently FDA-approved DBT Systems

Parameter	Hologic Selenia Dimensions	GE SenoClaire	Siemens Mammomat	Fujifilm Aspire	GE Senographe
X-ray tube					
Anode target	W	Mo/Rh	W	W	Mo/Rh
Filter*	Al (700 μm)	Mo (30 μm)/Rh (25 μm)	Rh (50 μm)	Al (700 μm)/Rh	Mo (30 μm)/ Rh (30 μm)
Tube motion	Continuous	Step and shoot	Continuous	Continuous	Step and shoot
Flat-panel detector					
Detector	Amorphous Se	Amorphous Si/ CsI	Amorphous Se	Amorphous Se	Amorphous Si/ CsI
Pixel size (μm)	140 (2 × 2 binned)	100	85	150 (ST binned 2 × 1), 100 (HR)	100
Grid	No	Yes	No	No	Yes
Acquisition					
Tube motion	Continuous	Step and shoot	Continuous	Continuous	Step and shoot
Sweep angle (degrees)	15	25	50	15 (ST), 40 (HR)	25
No. of projections	15	9	25	15	9
Scanning time (sec)	3.7	10	25	9 (HR), 7 (ST)	7
Reconstruction algorithm	FBP	FBP/ASiR	FBP	FBP	FBP/ASiR

Note.—Al = aluminum, ASiR = adaptive statistical iterative reconstruction, CsI = cesium iodide, FBP = filtered back projection, HR = high resolution, Rh = rhodium, Mo = molybdenum, Se = selenium, Si = silicone, ST = standard mode, W = tungsten.
* Some systems use combinations of targets and filters that are specific to DBT and not used for FFDM.

Tirada, N et al. RadioGraphics 2019

DBT Screening Studies

Author (year)	Vendor	Volumes (n)	Study Type	DM vs. DBT	
				Recall Rate %	Cancer Detection Rate (per 1000)
Skaane (2013)	Hologic	12,631 multi reads	Prospective	6.1 to 5.3% 15% reduction	6.1 to 8.0 27% increase (p<0.001)
Ciatto (2013)	Hologic	7292 DM then DBT	Prospective	4.5 to 3.5 % 17.2% “conditional” reduction	5.3 to 8.1/1000 (cancers overall not by pt) 52.8% increase
Friedewald (2014)	Hologic	454,850 -DBT: 173,663 -DM: 281,187	Retrospective	10.7 to 9.1% 15% reduction (p<0.0001)	4.2 to 5.4 (p<0.001)
Greenberg (2014)	Hologic	59,617 -DBT: 20,943 -DM: 38,674	Retrospective	16.2 to 13.6% 16% reduction (p<0.001)	4.9 to 6.6 (p=0.035)
Lourenco (2015)	Hologic	25,299 -DBT: 12,921 -DM: 12,577	Retrospective	9.3 to 6.4% 31% reduction (p<0.00001)	5.4 to 4.6 (p=0.44)

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Additional Uses of DBT in Screening & Diagnostic Workups

- Characterization of benign breast findings
- Margin characterization
  - DBT obviates need for additional views
  - Enhanced margin characterization
- Localization

DBT vs. FFDM Imaging after Recall

- Fewer mammo views
- More US only
- Fewer combination of mammo views and US

Table 2

Types of Additional Imaging Examinations Performed after Screening Mammography

Additional Imaging Examination	DM ($n = 1175$)	DBT ($n = 827$)	P Value*
Additional mammographic views only	472 (40.2) [37.4, 43.0]	235 (28.4) [25.4, 31.6]	<.0001 [7.5, 16.0]
US only	31 (2.6) [1.8, 3.8]	234 (28.3) [25.3, 31.5]	<.0001 [−29.0, −22.3]
Both additional mammographic views and US	672 (57.2) [54.3, 60.0]	358 (43.3) [39.9, 46.7]	<.0001 [9.4, 18.4]

Note.—Data are numbers of examinations. Numbers in parentheses are percentages. Numbers in brackets are 95% CIs (in percentages).

* All P values were statistically significant, where $\alpha = 0.001$.

Lourenco et al. *Radiology* 2015

DBT vs. Supplemental diagnostic DM views

- 217 lesions / 182 patients
- Mix of benign and malignant lesions assessed with 2D FFDM + DBT
- BI-RADS assessments and a probability-of-malignancy (POM) scores
- FP rate ↓ from 85% to 74% with DBT for cases rated BI-RADS 3 or higher WITHOUT significant change in sensitivity
- With DBT, more cancers were classified as BI-RADS 5 (39% vs. 33%) WITHOUT a decrease in specificity

Zuley et al. *Radiology* 2013

DBT vs. Supplemental diagnostic DM views

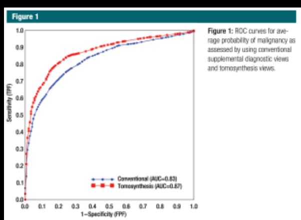


Figure 1: ROC curves for average probability of malignancy as assessed by using conventional supplemental diagnostic views and tomosynthesis views.

- DBT significantly improved diagnostic accuracy for noncalcified lesions compared with supplemental mammographic views.

Zuley et al. *Radiology* 2013

Implementation of DBT

- Triaging patients in hybrid FFDM/DBT practices
  - DBT 37.3% of mammo systems certified by FDA
  - DBT available at 61.9% of certified breast imaging facilities in US
- Reading and acquisition times
- Dose considerations

Entire Screening Cohort	DM	DBT	Change from DM to DBT
CDR (per/1000)	4.6	5.5	+ 19.6 %
Recall Rate (%)	10.4	8.8	- 15.4 %
PPV1 (cancer/recalls)	4.4	6.2	+ 40.9 %

Baseline Subgroup	DM	DBT	Change from DM to DBT
CDR (per/1000)	4.2	5.9	+ 40.5 %
Recall Rate (%)	20.5	16	- 22 %
PPV1 (cancer/recalls)	2	3.7	+ 85 %

If limited resources, women < 50 years with no priors available or undergoing baseline screening may benefit more from DBT than from DM alone.

McDonald ES et al. *AJR* 2015

Effect on Image Interpretation Time

- 10 radiologists read images from screening FFDM/DBT vs FFDM exams
- 1 hr uninterrupted sessions; at least 5 sessions / rad / modality
- Avg # of studies read: 23.8 ± 0.55 for FFDM/DBT vs 34.0 ± 0.55 for FFDM alone
- Avg interp time: 2.8 min ± 0.9 for FFDM/DBT vs. 1.9 min ± 0.6 FFDM
- 47% avg increase interp time per rad - 10 fewer studies/hr for FFDM/DBT
- 9/10 had an increased interp time for DBT despite years of experience

Dang PA et al. *Radiology* 2014

Acquisition and Reading Times

Acquisition Time
- 7 technologists, 20 cases
- Avg FFDM/DBT Combo time: 4 min 3 sec
- Avg FFDM time: 3 min 13 sec (p<0.01)

Reading Time
- 3 radiologists, 100 cases
- Avg FFDM/DBT Combo time: 77 sec
- Avg FFDM time: 33 sec (p<0.01)

Bernardi et al. *Br J Radiol* 2012

Summary of Workflow After Implementing DBT

- ↑ acquisition time
- ↑ interp time

- ↓ recalls
- ↓ diagnostic mammo images

≈

No staffing change

Although the radiation dose is below the MQSA limit of 3 mGy per view, there is over a two-fold (approx 2.25) increase when comparing FFDM with FFDM/DBT

How can we reduce the dose?

Synthetic Mammography (SM)

- Synthetic images reconstructed from DBT dataset
- No additional radiation dose
- FDA approval in 2013

SM/DBT vs FFDM/DBT: Dose

- 15,571 women screened w FFDM/DBT; 5,366 women screened w SM/ DBT
- Average glandular dose (AGD)
  - 4.88 mGy for SM/DBT
  - 7.97 mGy for FFDM/DBT ($p < .001$)
- AGD was reduced by 39% with SM/DBT compared to FFDM/DBT

Zuckerman et al. *Radiology* 2016

Literature Review of SM vs FFDM performance

Study (Year)	Study Conclusions
Zuley et al (2014)	-SM alone has a comparable AOC to DM alone -SM/DBT has a comparable AOC to FFDM/DBT
Skaane et al (2014)	-SM/DBT and FFDM/DBT have comparable CDRs -SM/DBT and FFDM/DBT have comparable FP rates
Gilbert et al (2015)	-No statistically significant difference in sensitivity of SM/DBT and FFDM/DBT -No statistically significant difference in specificity of SM/DBT and FFDM/DBT
Zuckerman et al (2016)	-No statistically significant difference in CDR between SM/DBT and FFDM/DBT -SM/DBT reduces recall rates and dose compared to FFDM/DBT ($p<0.001$)
Aujero et al (2017)	-No statistically significant difference in CDR between SM/DBT and FFDM/DBT -SM/DBT reduces recall rates compared to FFDM/DBT ($p<0.0001$)

Modified from: Ratanaprasatporn L et al. *RadioGraphics* 2017

Synthetic Mammography (SM)

Strengths

- ↓ **radiation dose**
- ↓ **acquisition time**
- ↑ conspicuity of calcifications
- ↑ definition of spiculated margins/distortions

Weaknesses/Artifacts

- Pseudocalcifications
- Foreign-body or metal artifacts
- Difficulty in assessing motion
- Subcutaneous tissue blurring & loss of skin resolution
- ↓ axillary contrast resolution

SM Implementation into Clinical Practice

- 312/2600 SBI respondents
- 96% (299/312) reported DBT capability and 80% (249/312) reported SM capability
- 45% use SM without DM for all DBT screens
- Although SM is utilized by a majority of practices, it has not widely replaced DM

Zuckerman et al. Synthetic Imaging Usage Patterns in Screening Practices with Digital Breast Tomosynthesis Among Members of the Society of Breast Imaging. Presented at the Society of Breast Imaging (SBI) National Meeting. April 4, 2019. Hollywood, FL.

DBT Summary

- ↑ CDR
- ↓ RR
- Diagnostic accuracy of SM/DBT comparable to FFDM/DBT

Incremental CDR

Modality	CDR (per 1000)
Mammography	3-5
+DBT	+1-2
+US*	+4
+MRI**	+15

*Berg, W et al. *JAMA* 2008

**Berg, W et al. *JAMA* 2012

Supplemental Breast MRI Screening in Average Risk Women

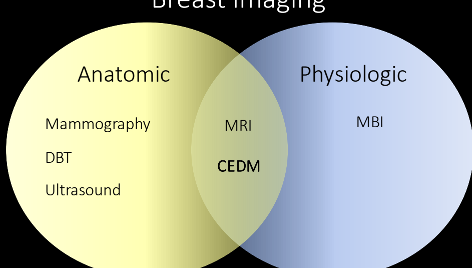
- 2120 women - 3861 screening MRI studies
- Overall supplemental CDR of 15.5 per 1000 cases (22.6/1000 at prevalence screening)
- Of the 61 malignant lesions, 26 (43%) exhibited high nuclear grades (95% CI: 30.0, 55.9) and 20 (33%) (95% CI: 21, 46) ER/PR neg cancers.
- Cancers diagnosed were small (median, 8 mm), node negative in 93.4% of cases, and dedifferentiated (high-grade cancer) in 41.7% of cases at prevalence screening and 46.0% of cases at incidence screening.

Kuhl et al. *Radiology* 2017

Some Limitations of Breast MRI

- Cost
- Metallic implants / devices
- Claustrophobia
- Gadolinium contrast allergy

Breast Imaging



Contrast Enhanced Digital Mammography (CEDM)

- FDA approved October 2011
- GE, Siemens, Hologic have FDA approved units
- DM units adapted to perform low and high energy exposures
- Contrast screening process
  - Nurse or tech interviews pt and starts IV
  - Contrast allergy history
  - Renal function evaluation per same criteria for CT studies

Contrast Enhanced Digital Mammography (CEDM)

- Iodinated contrast administered via IV
  - Approximately 3 ml/s – power injector
  - 300 – 370 mg/mL iodine concentration
  - 1.5 ml/kg body weight → typically 90-150 mL total
- After a delay of at least 90 seconds, pt positioned for mammo views
  - Positioning starts at approx. 2 min 15 sec – 1st exposure 2 min 45 sec

Contrast Enhanced Digital Mammography (CEDM)

- Two images of each breast obtained, dual-energy image pairs in each projection
- Weighted subtraction performed – nonenhancing tissue is eliminated and enhancement/iodine is shown
- Low keV images are identical to standard unenhanced mammo, serve as standard digital mammogram for interpretation
- Typically one time point (no kinetic information)
- Radiation dose 1.2-1.8x of DM*

*Phillips J et al. *AJR* 2018

Table 2 Overview of the diagnostic performance of mammography versus contrast-enhanced spectral mammography (CESM)

	Mammography	CESM
Sensitivity (%)	96.9 (83.7–99.5)	100.0 (89.0–100.0)
Specificity (%)	42.0 (31.1–53.5)	87.7 (78.5–93.9)
Positive predictive value (%)	39.7 (28.8–51.5)	76.2 (60.6–87.9)
Negative predictive value (%)	97.1 (85.0–99.5)	100.0 (94.9–100.0)
Area under the ROC curve	0.779 (0.707–0.851)	0.976 (0.954–0.999)

95 % confidence intervals are in parentheses

Lobbes MB et al. Eur Radiol. 2014

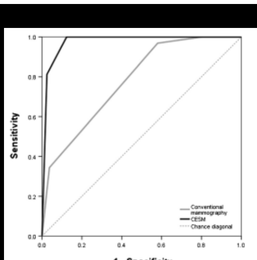


Fig. 4 Receiver operating characteristic (ROC) curve for both conventional mammography (*grey line*) and CESM (*black line*)

Lobbes MB et al. Eur Radiol. 2014

Diagnostic performance of dual-energy contrast-enhanced subtracted mammography in dense breasts compared to mammography alone: interobserver blind-reading analysis

Table 3 Average sensitivity, specificity, PPV, NPV and accuracy of Mx and Mx + CESM

	Mx	Mx + CESM	Difference
Sensitivity	71.5	92.7	21.2
Specificity	51.8	67.9	16.1
PPV	80	88.2	8.2
NPV	41.5	78.9	37.4
Accuracy	65.9	85.8	19.9

PPV positive predictive value, *NPV* negative predictive value, *Mx* conventional mammography, *Mx + CESM* conventional mammography plus contrast-enhanced subtracted mammography

Cheung YC et al. Eur Radiol 2014

CEDM & MRI

	Study (Year)	No. of Subjects	CEDM Result (%)	MRI Result (%)
Sensitivity	Jochelson et al (2017)	307	96	96
	Li et al (2017)	48	100	100
	Jochelson et al (2013)	52	96	96
	Zhu et al (2018)*	2859	89	---
Accuracy (AUC)	Luczynska et al (2015)	102/118	79	73
	Chou et al (2015)	185	88	90
	Zhu et al (2018)*	2859	96	---

*meta-analysis of 18 studies

Research article

Comparison of screening CEDM and MRI for women at increased risk for breast cancer: A pilot study

Maxine S. Jochelson[a,b,*], Katja Pinker[a,b,c], D. David Dershaw[a,b], Mary Hughes[a,b], Girard F. Gibbons[a,b,1], Kareem Rahbar[a,b,2], Mark E. Robson[a,d], Debra A. Mangino[a,d], Debra Goldman[a,e], Chaya S. Moskowitz[a,e], Elizabeth A. Morris[a,b], Janice S. Sung[a,b]

- Prospective screening study
- 307 heavily pre-screened patients
- PPV3 for CEDM 15.4% (95% CI: 1.9–45.43, 2/13) vs. MRI 14.3% (95% CI: 3.0–36.3%, 3/21), p = 0.86.
- Specificity: CEDM 94.7% [91.6–97] and MRI 94.1% [90.8–96.4]
- False positive rates: CEDM 5.3% [3–8.4] and MRI 5.9% [3.6–9.2].

	CEDM	MRI
Specificity	94.7%	94.1%
PPV3	15.4%	14.3%

Utility of CEDM for Breast Cancer Screening

- 1197 CEDM studies performed in high-risk population
- CDR of 18/1000
- PPV of biopsy - 31%

Sung et al. SSA02-04. Science Session with Keynote: Breast Imaging (Contrast Enhanced Mammography). Radiological Society of North America 2017 Scientific Assembly and Annual Meeting, November 26 - December 1, 2017, Chicago IL. archive.rsna.org/2017/17039960.html

How does CEDM compare with DBT?

- 185 patients with BI-RADS 4 or 5 lesions evaluated before bx with DM, DBT, CEDM, CE-DBT and DCE-MRI.
- 81 cancers/144 benign lesions
- Significant differences in AUC were found between the group of contrast enhanced modalities (CEDM, CE-DBT, DCE-MRI) and the unenhanced modalities (all $p < 0.05$).
- No significant differences were found in AUC between DCE-MRI, CET and CEDM (all $p > 0.05$).

Chou et al. *Euro Radiol* 2015

Uses of CEDM

Non-Cancer Patients

- Evaluate abnormal screening examinations
- Problem solving / evaluation inconclusive imaging findings
- Assess pts with clinical symptoms
- Supplemental screening
  - High-risk women
  - Dense breast tissue

Suspected/Known Cancer

- Evaluate extent of disease
- Monitor response of neoadjuvant therapy

*EUSOBI: CEDM can be considered as an alternative to MRI in the case of MRI contraindications

Relative Advantages

CEDM	MRI
Lower cost	No ionizing radiation
Shorter exam time	Chest wall and axillary imaging/visualization
	Less risk of contrast reaction
	Full characterization of enhancement (kinetics)
Detection of calcifications	
No claustrophobia or loud noises	No compression
No MRI-specific contraindications (pacemakers /implanted metal)	MRI-guided biopsy is available
No risk of NSF or gadolinium deposition	

Modified from: Patel B, Lewin J. (2019) 'Comparison of Contrast-Enhanced Mammography and Contrast-Enhanced Breast MRI', in **Lobbes M**, **Jochelson M** (Eds.) *Contrast-Enhanced Mammography*. Switzerland: Springer, p 86.

Workflow Issues for CEDM: Biopsy

- Biopsy mechanism being tested but **not** commercially available yet
- If seen on mammography or ultrasound → biopsy
- If not seen on mammo or US → MRI → MRI biopsy
- If not seen on MRI → 6 month follow up CEDM

Workflow Issues for CEDM: Contrast

- Nurse or tech to obtain history, screen, & place IV
- Contrast allergies/reactions
  - 1.3% of patients*
  - Screen carefully for contrast contraindications
  - Learn to manage contrast allergies/reactions
  - Crash cart in room

*Jochelson et al. *Eur J Radiol* 2017

CEDM Summary

- Superior to unenhanced mammography/DBT
- Comparable to MRI in sensitivity and diagnostic accuracy
- Well tolerated by patients
- CEDM biopsy mechanism being tested
- Additional large prospective studies needed to validate initial data

Stereotactic / DBT guided Biopsy

Indications for Stereotactic/DBT guided Biopsy

- Suspicious calcifications
- Suspicious asymmetry/mass/distortion with no sonographic correlate

Stereotactic/DBT guided Biopsy

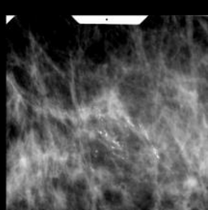
- Typically 9 G vacuum assisted biopsy needle
- Standard size (20 mm trough); Petite (12 mm trough)
- 6-12 samples taken
- Clip placed

Prone Stereotactic VAB

DBT guided VAB

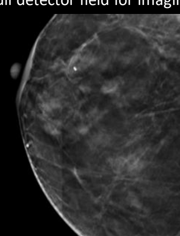
Prone Stereotactic VAB

- Small field of view/biopsy window



DBT guided VAB

- Full detector field for imaging

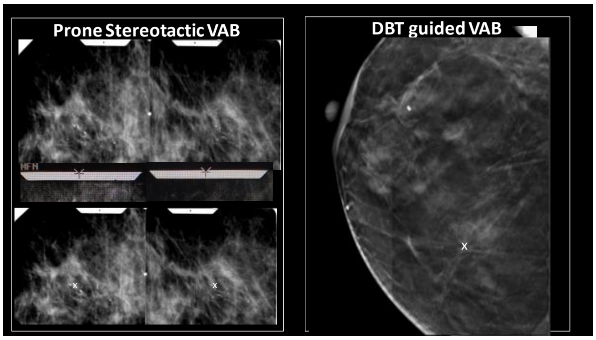


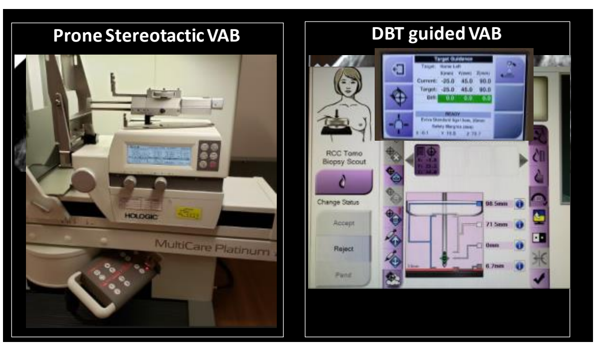
Prone Stereotactic VAB

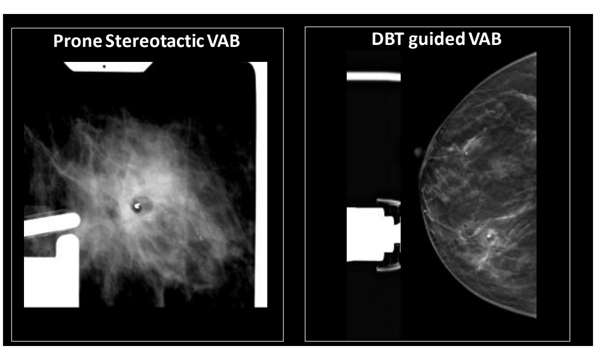
- Triangulation required to produce Z axis/depth info

DBT guided VAB

- Provides immediate lesion depth information (slice # determines Z)


Prone Stereotactic VAB
DBT guided VAB


Prone Stereotactic VAB
DBT guided VAB
HOLOGIC
MultiCare Platinum
RCC Tomo Biopsy Scout
Change Status
Accept
Reject


Prone Stereotactic VAB
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Prone Stereotactic VAB

- Mean biopsy time – 29 ± 10.1 min*
- 93% technical success (154/165)*
  - Inability to visualize lesion in 5 cases

*Schrading et al. *Radiology* 2015

DBT guided VAB

- Mean biopsy time – 13 ± 3.7 min*
- 100% technical success (51/51)*
- Low contrast targets
- DBT only findings

What about calcifications?

Table 2: Studies of Calcification Conspicuity at DBT and SM Compared with that at FFDM

Authors (Reference)	Publication Year	Imaging Modality	Percentage of Cases with Conspicuity Better than or Equal to That at FFDM
Poplack et al (54)	2007	DBT	43
Kopans et al (56)	2011	DBT	92
Svane et al (57)	2011	DBT	92
Destounis et al (55)	2013	DBT	92.2
Hwang et al (52)	2018	SM	83.3
Mariscotti et al (12)	2017	SM	94.2

Horvat et al. RadioGraphics 2019

DBT guided VAB for Breast Calcifications

Advantages	Disadvantages
↓ biopsy time	Rarely, fine calcifications not well visualized by DBT
↑ detection of associated masses/distortions	
Allows for dx of skin calcs	
Better avoidance of blood vessels	
↓ tissue overlap	

What does the future hold?

Tall Order For Breast Imaging

- Detect cancer
- Stage cancer
- Monitor disease / assess response to therapy
- Predict pathologic complete response (pCR)
- Predict recurrence free survival (RFS)
- Predict overall survival (OS)

all while

- ↓ FP
- ↓ FN
- ↓ cost
- ↓ dose
- ↓ time
- ↓ anxiety
- ↓ overtreatment
- ↓ overdiagnosis

Thank You

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