Original Article

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Association of Retrospective Peer Review and Positive Predictive Value of Magnetic Resonance Imaging-Guided Vacuum-Assisted Needle Biopsies of Breast

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ABSTRACT

Objective: To evaluate the association between retrospective peer review of breast magnetic resonance imaging-guided vacuum-assisted needle biopsies and positive predictive value of subsequent magnetic resonance imaging-guided biopsies

Materials and Methods: In January, 2015, a weekly conference was initiated in our institution to evaluate all breast magnetic resonance imaging-guided vacuum-assisted needle biopsies performed over January 1, 2014-December 31, 2015. During this weekly conferences, breast dynamic contrast-enhanced magnetic resonance imaging findings of 6 anonymized cases were discussed and then the faculty voted on whether they agree with the biopsy indication, accurate sampling and radiology-pathology correlation. We retrospectively reviewed and compared the magnetic resonance imaging indication, benign or malignant pathology rates, lesion types and the positive predictive value of magnetic resonance imaging-guided vacuum-assisted needle biopsy in the years before and after initiating this group peer review.

Results: The number of dynamic contrast-enhanced magnetic resonance imaging and magnetic resonance imaging-guided vacuum-assisted needle biopsies before and after initiating the review were 1447 vs 1596 (p=0.0002), and 253 (17.5%) vs 203 (12.7%) (p=0.04), respectively. There was a significant decrease in the number of benign biopsies in 2015 (n=104) compared to 2014 (n=154, p=0.04). The positive predictive value of magnetic resonance imaging-guided biopsy significantly increased after group review was implemented (Positive predictive value in 2014=%39.1 and positive predictive value in 2015=%48.8) (p=0.03), although the indications (p=0.49), history of breast cancer (p=0.14), biopsied magnetic resonance imaging lesion types (p=0.53) were not different. Less surgical excision was performed on magnetic resonance imaging-guided vacuum-assisted needle biopsy identified high-risk lesions in 2015 (p=0.25).

Conclusion: Our study showed an association between retrospective peer review of past biopsies and increased positive predictive value of magnetic resonance imaging-guided vacuum-assisted needle biopsies in our institution.

Keywords: Breast, dynamic contrast-enhanced magnetic resonance imaging, magnetic resonance imaging-guided vacuum-assisted needle biopsy, positive predictive value

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Introduction

With rising health care costs, recent initiatives have focused on appropriate ordering of tests by physicians, to minimize waste and to improve quality of care (1-7). National campaigns such as 'Choosing Wisely' have gained significant following to improve the utilization of high-cost imaging. Dynamic contrast-enhanced magnetic resonance imaging (MRI) of breast is an important tool for screening high-risk women and for the diagnosis, staging, and evaluation of breast malignancies (8-21). While MRI is highly sensitive (range, 89-100%), it has moderate to low specificity (range, 37-70%) (22-34), resulting in a significant increase in unnecessary needle biopsies (35-37). More than half of MRI detected abnormalities cannot be identified with an MRI directed, or "second-look" ultrasound (38-52), leading to an increased need for MRI-guided biopsies. MRI-guided vacuum-assisted needle biopsy is a costly and time-consuming procedure with a moderate yield of malignancy (range, 14-35%) and can be stressful procedure for patients due to claustrophobia and positioning, even occasionally requiring sedation.

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In an effort to educate and inform our dedicated breast radiology group, a retrospective peer review system was initiated at our institution to evaluate the indication, technical adequacy, and radiology-pathology correlation of previously performed MRI-guided vacuum-assisted needle biopsies and their outcomes. In this study, we present the outcomes of MRI guided biopsies in our tertiary healthcare institution before and after the implementation of our MRI-guided vacuum-assisted needle biopsy peer-review process.

Materials and Methods

This was an institutional review board approved, Health Insurance Portability and Accountability Act (HIPAA) compliant, retrospective case review in which the requirement for patient informed consent was waived. We searched our tertiary imaging center's MRI database for patients who underwent breast MRI-guided vacuum-assisted needle biopsy between January 1, 2014 and December 31, 2014, before initiating the peer review, and between January 1, 2015 and December 31, 2015, after its implementation.

Dynamic contrast-enhanced MRI Technique and MRI-guided vacuum-assisted needle biopsy

All MR imaging studies were performed using a wide bore 3-Tesla MRI unit. (Discovery MR750 GE Healthcare, Waukesha, WI) The protocol consisted of T1-weighted sequence, followed by dynamic contrast-enhanced sequence, T2 weighted sequence and a diffusion weighted imaging sequence. Pulse sequence parameters are outlined in Table 1. Depending on patient size and scanned area, average scan time ranges from 38 minutes to 60 minutes. There is no change in protocol between January 1, 2014 and December 31, 2015. The standard protocol is applied to all patients with a clinical indication to undergo breast MRI for further evaluation between aforementioned dates. MRI-guided vacuum-assisted needle biopsy is recommended for 401 patients.

All MRI-guided vacuum-assisted needle biopsies were performed in a dedicated prone table (*Invivo* Gainsville FL) using a 9-gauge vacuum-assisted needle (ATEC; Hologic, Bedford, Mass). Some of the patients in our study had more than one biopsy performed and each biopsy was considered as a separate entity.

Peer Review Process

In January, 2015, a weekly conference was initiated to evaluate all MRI-guided vacuum-assisted needle biopsies performed over January 1, 2014-December 31, 2015. During each weekly conference, 6 anonymized cases were presented by a breast imaging faculty member of 5-16 years of experience with breast MRI interpretation to an audience of breast imaging faculty comprising our entire group and the breast imaging fellows. The MRI findings and the biopsy indications of the lesions were discussed and then the breast imaging faculty voted on whether they agree with (a) the biopsy indication (b) appropriate sampling (c) radiology-pathology correlation (d) final recommendation.

Below data was collected from the electronic health record of each patient (a) patient age at the time of biopsy, (b) the indication for the study, (c) whether the patient had a new breast cancer or was treated for breast cancer in the past, and if so, whether the cancer was ipsilateral or contralateral to the biopsy site, (d) lesion type (mass or non-mass) and size. The pathology results were reviewed and categorized into benign, high-risk [atypical ductal hyperplasia, atypical lobular hyperplasia, lobular carcinoma in situ, atypical papilloma, and radial scar (including complex sclerosing lesion, complex sclerosing adenosis, and radial sclerosing lesion)] or malignant. Cancers were further classified into invasive or pure ductal carcinoma in situ based on their final surgical histopathology. In our institution, short-term MRI follow up or excision is not performed for lesions revealing benign and concordant results, in line with recent literature (53). Lesions revealing atypia are routinely reviewed in a multidisciplinary Clinical Management Conference, comprised of representatives from breast radiology, pathology, surgery departments and primary care providers who make a consensus management recommendation.

To control for possible radiologist interpretation differences between the two years, MRI-guided vacuum-assisted needle biopsy recommendations of radiologists who joined our group in 2014 and 2015 were excluded, and only the readings and recommendations by the same group of radiologists (n=12) at our institution were included in the analysis.

Statistical Analysis

Total number of MR imaging performed, number of biopsies, patient and tumor characteristics were summarized using frequencies and percentages. Biopsy rate was estimated along with 95% confidence interval (CI) for 2014 and 2015. Fisher's exact test was used to compare MRI-guided vacuum-assisted needle biopsy rates and patient characteristics of biopsied cases between these years. All tests were two-sided and p-values of 0.05 or less were considered statistically significant. Statistical analysis was carried out using SAS version 9 (SAS Institute, Cary, NC).

Table 1. Dynamic contrast-enhanced breast MRI protocol

	Protocol Pulse Sequences				
Pulse Sequence Parameters	**Pre-contrast T1-Weighted**	**DCE (1 pre+5 post contrast)**	**T1-Weighted Sagittal**	**T2-Weighted**	**DWI**
Average scan time (min)	5	10	7	10	6
TR/TE	5.4/2.1ms	5.4/2.2ms	7.5/2.1ms	~5000/100ms	~5000/60ms
Flip Angle	10°	10°	10°	90°	90°
Slice	1.8/-0.9mm	1.8/-0.9mm	2.4/-1.2mm	5/1mm	4/0mm
FOV	~30cm	~30cm	~22cm	~30cm	~36cm
Matrix	384x384	480x384	384x320	384x224	170x224

TR: Repetition Time; TE: Echo Time; FOV: field of view

Results

Of 459 MRI-guided vacuum-assisted needle biopsy procedures performed in the defined two-year time frame, 253 occurred between January 1, 2014-Jan 1, 2015 and 203 between Jan 1, 2015 and December 31, 2015. A single lesion was biopsied in each patient.

In the defined timeframe, significantly more dynamic contrast-enhanced MRIs were performed in 2014 compared to 2015 (1447 vs 1596, p=0.0002) while a lower biopsy rate was observed (17.5% vs 12.7% p=0.04).

There were no significant differences between patient age [median 50 vs 51 years, (p=0.8)], MRI indication (p=0.49), history of ipsilateral or contralateral breast cancer (p=0.14) or MRI lesion types (mass vs non-mass like enhancement, p=0.53) between the two groups. In 2014 there was a significantly higher benign biopsy rate (154 of 253,60.9%) compared to 2015 (104 of 203, 51.2%) (p=0.04). The malignancy rates were similar (26.09% in 2014 and 26.11% in 2015), there was a higher rate of high-risk lesions identified in 2015 (21.7% vs 12.7%) (p=0.03). There was a slight but significant increase in the positive predictive value of MRI-guided vacuum-assisted needle biopsies in 2015 [48.8% (97/203)] compared to those in 2014 [39.1% (98/253) (p=0.04)] (Table 2).

Clinical parameters including breast MRI indication, lesion type on MRI (mass vs non-mass), were not significantly different (Table 3).

Table 2. Pathology results of the biopsied lesions in 2014 and 2015

	MRI Year				
	2014		2015		
	n	%	n	%	*p
Benign	154	60.87	104	51.23	0.046
Cancer	66	26.09	53	26.11	
High Risk	32	12.65	44	21.67	0.03
All	253	100.00	203	100.00	
Positive predictive value	39.13%		48.77%		0.046

Table 3. Breast MRI indications and findings of the biopsied lesions in 2014 and 2015

	MRI Year				
	2014		2015		
	n	%	n	%	*p
Breast Cancer Extent of Disease	131	51.78	115	56.65	0.49
High-risk screening	53	20.95	39	19.21	
Other	15	5.93	12	5.91	
Breast Cancer Surveillance	18	7.11	7	3.45	
¥Problem solving	36	14.23	30	14.78	
MRI finding					
Asymmetry	1	0.40	0	0	0.53
Mass enhancement	107	42.29	94	46.31	

*p-values by Fisher's exact test
¥Problem solving: further evaluation due to abnormal mammography, ultrasonography, nipple retraction

Discussion and Conclusion

Magnetic resonance imaging is an important diagnostic tool for breast cancer and for screening high-risk patients. MRI has a high sensitivity for the detection of breast lesions however its specificity is low (22-34), increasing the false positive results and leading to costly, time and resource consuming interventions like MRI-guided vacuum-assisted needle biopsy. MRI-guided vacuum-assisted needle biopsy can be done in an outpatient office for half of a surgical biopsy cost without the need for anesthesia and hospitalization (54). However, this cost is approximately twice as much as an ultrasound image-guided biopsy or a stereotactic image-guided biopsy (55).

In our study, despite an increase (10.3%, p=0.0002) in the overall number of dynamic contrast-enhanced breast MRIs between pre-PRS and post-PRS periods, there was a significant decrease (p=0.0002) in the overall number of MRI-guided vacuum-assisted needle biopsies recommended by the same group of radiologists, without significant differences in the MRI indication (p=0.49) or MRI lesion type (p=0.53). Less benign biopsies occurred in 2015 compared to 2014 (p=0.0002). There was a statistically significant increase in positive predictive value of MRI-guided vacuum-assisted needle biopsy after the initiation of PRS in January 1, 2015 (p=0.046), although the same group of radiologists made the decision of biopsy.

The overall malignancy rate of breast lesions underwent MRI-guided vacuum-assisted needle biopsy was 26.1% in 2014 and 26.1% in 2015. Our results are similar to the malignancy rates of previous reports, which range between 20-43% (22, 24, 56-60). Our malignancy rate is at the lower end of the spectrum, because all suspicious mass-like enhancements –which are more likely to yield malignancy (48)- undergo MRI-directed ultrasound in our institution.

The upgrade rate for high-risk breast lesions identified at MRI-guided vacuum-assisted needle biopsy ranges between 3-21.5% (28, 61-62). In our study, 62.5% (20/32) of high-risk lesions were excised in 2014, this ratio was 45.5% (20/44) in 2015 (p=0.17). None of these high-risk lesions were upgraded into malignancy upon surgical excision. Surgical excision rate of high-risk lesions decreased in 2015, although the difference was not statistically significant (p=0.25).

Our study has some limitations. First, this is retrospective study performed in a single institution. The small number of patients included decreases the power of the statistical results. Further, for mass-like MR enhancement, we start our work up with MRI-directed ultrasound, and if a correlate is identified, perform ultrasound-guided needle biopsy. Non-mass like enhancement and masses with no ultrasound correlate are subjected to MRI-guided biopsy. MRI-directed ultrasound, and ultrasound guided biopsy rates are not included in this study. However, our primary goal was to investigate the rate of MRI-guided biopsies since ultrasound guided biopsy does not involve contrast or require magnet time, is much better tolerated and less costly compared to MRI-guided vacuum-assisted needle biopsy.

Our weekly all-radiologist review of MRI-guided vacuum-assisted needle biopsies was associated with an increase in positive predictive value of biopsies over time independent of lesion type, indication or history of breast cancer. Peer-review was associated with significantly less surgical excisions for high-risk lesions identified on MRI-guided vacuum-assisted needle biopsy.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of MD Anderson Cancer Center..

Informed Consent: Informed consent was not taken due to retrospective design of the study.

Peer-review: Externally peer-reviewed.

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References

1. American College of Radiology. ACR appropriateness criteria. Reston, VA: American College of Radiology; 2013.
2. Canadian Association of Radiologists. 2012 CAR diagnostic imaging referral guidelines. Saint-Laurent, QC: Canadian Association of Radiologists; 2012.
3. Blackmore CC, Mecklenburg RS, Kaplan GS. Effectiveness of clinical decision support in controlling inappropriate imaging. J Am Coll Radiol 2011; 8: 19-25. (PMID: 21211760) [CrossRef]
4. Cassel CK, Guest JA. Choosing wisely: helping physicians and patients make smart decisions about their care. JAMA 2012; 307: 1801-1802. (PMID: 22492759) [CrossRef]
5. Berger ZD. Appropriate use of screening and diagnostic tests to foster high-value, cost-conscious care. Ann Intern Med 2012; 156: 902. (PMID: 22711089) [CrossRef]
6. Levin DC1, Rao VM, Parker L, Frangos AJ, Sunshine JH. Bending the curve: the recent marked slowdown in growth of noninvasive diagnostic imaging. AJR Am J Roentgenol 2011; 196: 25-29. (PMID: 21178027) [CrossRef]
7. Bautista AB, Burgos A, Nickel BJ, Yoon JJ, Tilara AA, Amorosa JK. Do clinicians use the American College of Radiology Appropriateness criteria in the management of their patients?. AJR Am J Roentgenol 2009; 192: 1581-1585. (PMID: 19457821) [CrossRef]
8. Mainiero MB, Lourenco A, Mahoney MC, Newell MS, Bailey L, Barke LD, D'Orsi C, Harvey JA, Hayes MK, Huynh PT, Jokich PM, Lee SJ, Lehman CD, Mankoff DA, Nepute JA, Patel SB, Reynolds HE, Sutherland ML, Haffty BG. ACR Appropriateness Criteria Breast Cancer Screening. J Am Coll Radiol 2016; 13: 45-49. (PMID: 27814813) [CrossRef]
9. Liberman L. Breast cancer screening with MRI-what are the data for patients at high risk?. N Engl J Med 2004; 351: 497-500. (PMID: 15282358) [CrossRef]
10. Leach MO, Boggis CR, Dixon AK, Easton DF, Eeles RA, Evans DG, Gilbert FJ, Griebsch I, Hoff RJ, Kessar P, Lakhani SR, Moss SM, Nerurkar A, Padhani AR, Pointon LJ, Thompson D. Screening with magnetic resonance imaging and mammography of a UK population at high familial risk of breast cancer: A prospective ulticenter cohort study (MARIBS). Lancet 2005; 365: 1769-1778. (PMID: 15910949)
11. Phi XA, Houssami N, Obdeijn IM, Warner E, Sardanelli F, Leach MO, Riedl CC, Trop I, Tilanus-Linthorst MM, Mandel R, Santoro F, Kwan-Lim G, Helbich TH, de Koning HJ, Van den Heuvel ER, de Bock GH. Magnetic resonance imaging improves breast screening sensitivity in BRCA mutation carriers age = 50 years: Evidence from an individual patient data meta-analysis. J Clin Oncol 2015; 33: 349-356. (PMID: 25534390) [CrossRef]
12. Riedl CC, Luft N, Bernhart C, Weber M, Bernathova M, Tea MK, Rudas M, Singer CF, Helbich TH. Triple-modality screening trial for familial breast cancer underlines the importance of magnetic resonance imaging and questions the role of mammography and ultrasound regardless of patient mutation status, age, and breast density. J Clin Oncol 2015; 33: 1128-1135. (PMID: 25713430) [CrossRef]
13. Evans DG, Kesavan N, Lim Y, Gadde S, Hurley E, Massat NJ, Maxwell AJ, Ingham S, Eeles R, Leach MO, Howell A, Duffy SW. MRI breast screening in high-risk women: Cancer detection and survival analysis. Breast Cancer Res Treat 2014; 145: 663-672. (PMID: 24687378)
14. Chiarelli AM, Prummel MV, Muradali D, Majpruz V, Horgan M, Carroll JC, Eisen A, Meschino WS, Shumak RS, Warner E, Rabeneck L. Effectiveness of screening with annual magnetic resonance imaging and mammography: Results of the initial screen from the Ontario high risk breast screening program. J Clin Oncol 2014; 32: 2224-2230. (PMID: 24934793) [CrossRef]
15. Passaperuma K, Warner E, Causer PA, Hill KA, Messner S, Wong JW, Jong RA, Wright FC, Yaffe MJ, Ramsay EA, Balasingham S, Verity L, Eisen A, Curpen B, Shumak R, Plewes DB, Narod SA. Long-term results of screening with magnetic resonance imaging in women with BRCA mutations. Br J Cancer 2012; 107: 24-30. (PMID: 22588560) [CrossRef]
16. Warner E, Hill K, Causer P, Plewes D, Jong R, Yaffe M, Foulkes WD, Ghadirian P, Lynch H, Couch F, Wong J, Wright F, Sun P, Narod SA. Prospective study of breast cancer incidence in women with a BRCA1 or BRCA2 mutation under surveillance with and without magnetic resonance imaging. J Clin Oncol 2011; 29: 1664-1669. (PMID: 21444874) [CrossRef]
17. Lord SJ, Lei W, Craft P, Cawson JN, Morris I, Walleser S, Griffiths A, Parker S, Houssami N. A systematic review of the effectiveness of magnetic resonance imaging (MRI) as an addition to mammography and ultrasound in screening young women at high risk of breast cancer. Eur J Cancer 2007; 43: 1905-1917. (PMID: 17681781) [CrossRef]
18. Ahern CH, Shih YT, Dong W, Parmigiani G, Shen Y. Cost-effectiveness of alternative strategies for intergrating MRI into breast cancer screening for women at high risk. Br J Cancer 2014; 111: 1542-1551. (PMID: 25137022) [CrossRef]
19. Lee JM, McMahon PM, Kong CY, Kopans DB, Ryan PD, Ozanne EM, Halpern EF, Gazelle GS. Cost-effectiveness of breast MR imaging and screen-film mammography for screening BRCA1 gene mutation carriers. Radiology 2010; 254: 793-800. (PMID: 20177093) [CrossRef]
20. Stout NK, Nekhlyudov L, Li L, Malin ES, Ross-Degnan D, Buist DS, Rosenberg MA, Alfisher M, Fletcher SW. Rapid increase in breast magnetic resonance imaging use: trends from 2000 to 2011. JAMA Intern Med 2014; 174: 114-121. (PMID: 24247482) [CrossRef]
21. Pataky R, Armstrong L, Chia S, Coldman AJ, Kim-Sing C, McGillivray B, Scott J, Wilson CM, Peacock S. Cost-effectiveness of MRI for breast cancer screening in BRCA1/2 mutation carriers. BMC Cancer 2013 10; 13: 339. (PMID: 23837641) [CrossRef]
22. Perlet C, Heywang-Kobrunner SH, Heinig A, Sittek H, Casselman J, Anderson I, Taourel P. Magnetic resonance-guided, vacuum- assisted breast biopsy: results from a European multicenter study of 538 lesions. Cancer 2006; 106: 982-990. (PMID: 16456807) [CrossRef]

23. Lehman CD, Deperi ER, Peacock S, McDonough MD, Demartini WB, Shook J. Clinical experience with MRI-guided vacuum-assisted breast biopsy. AJR Am J Roentgenol 2005; 1846: 1782-1787. (PMID: 15908530) [CrossRef]
24. Liberman L, Bracero N, Morris E, Thornton C, Dershaw DD. MRI-guided 9-gauge vacuum-assisted breast biopsy: initial clinical experience. AJR Am J Roentgenol 2005; 1851: 183-193. (PMID: 15972421) [CrossRef]
25. Orel SG, Rosen M, Mies C, Schnall MD. MR imaging-guided 9-gauge vacuum-assisted core-needle breast biopsy: initial experience. Radiology 2006; 238: 54-61. (PMID: 16304093) [CrossRef]
26. Fischer U, Schwethelm L, Baum FT, Luftner-Nagel S, Teubner J. Effort, accuracy and histology of MR-guided vacuum biopsy of suspicious breast lesions-retrospective evaluation after 389 interventions. Rofo 2009; 1818: 774-781. (PMID: 19582655) [CrossRef]
27. Rauch GM, Dogan BE, Smith TB, Liu P, Yang WT. Outcome analysis of 9-gauge MRI-guided vacuum-assisted core needle breast biopsies. AJR Am J Roentgenol 2012; 1982: 292-299. (PMID: 22268171) [CrossRef]
28. Strigel RM, Eby PR, Demartini WB, Gutierrez RL, Allison KH, Peacock S, Lehman CD. Frequency, upgrade rates, and characteristics of high-risk lesions initially identified with breast MRI. AJR Am J Roentgenol 2010; 195: 792-798. (PMID: 20729462) [CrossRef]
29. Liberman L, Mason G, Morris EA, Dershaw DD. Does size matter? Positive predictive value of MRI-detected breast lesions as a function of lesion size. AJR Am J Roentgenol 2006; 186: 426-430. (PMID: 16423948) [CrossRef]
30. Arponen O, Masarwah A, Sutela A, Taina M, Könönen M, Sironen R, Hakumäki J, Vanninen R, Sudah M. Incidentally detected enhancing lesions found in breast MRI: analysis of apparent diffusion coefficient and T2 signal intensity significantly improves specificity. Eur Radiol 2016; 26: 4361-4370. (PMID: 27114285) [CrossRef]
31. Nogueira L, Brandão S, Matos E, Gouveia Nunes R, Ferreira HA, Loureiro J, Ramos I. Improving malignancy prediction in breast lesions with the combination of apparent diffusion coefficient and dynamic contrast-enhanced kinetic descriptors. Clin Radiol 2015; 70: 1016-1025. (PMID: 26135541) [CrossRef]
32. Menezes GL, Knuttel FM, Stehouwer BL, Pijnappel RM, van den Bosch MA. Magnetic resonance imaging in breast cancer: a literature review and future perspectives. World J Clin Oncol 2014; 5: 61-70. (PMID: 24829852) [CrossRef]
33. Heywang-Köbrunner SH, Hacker A, Sedlacek S. Magnetic resonance imaging: the evolution of breast imaging. Breast 2013; 22: 77-82. (PMID: 24074797) [CrossRef]
34. Marino MA, Helbich T, Baltzer P, Pinker-Domenig K. Multiparametric MRI of the breast: a review. J Magn Reson Imaging. J Magn Reson Imaging 2018; 47: 301-315. (PMID: 28639300) [CrossRef]
35. Rauch GM, Dogan BE, Smith TB, Liu P, Yang WT. Outcome analysis of 9-gauge MRI-guided vacuum-assisted core needle breast biopsies. AJR Am J Roentgenol 2012; 198: 292-299. (PMID: 22268171) [CrossRef]
36. Jung HN, Han BK, Ko EY, Shin JH. Initial experience with Magnetic resonance-guided vacuum-assisted biopsy in Korean women with breast cancer. J Breast Cancer 2014; 17: 270-278. (PMID: 25320626) [CrossRef]
37. Eby PR, Lehman CD. Magnetic resonance imaging-guided breast interventions. Top Magn Reson Imag 2008; 19: 151-162. (PMID: 18941395) [CrossRef]
38. Trop I, Labelle M, David J, Mayrand MH, Lalonde L. Second-look targeted studies after breast magnetic resonance imaging: practical tips to improve lesion identification. Curr Probl Diagn Radiol 2010; 39: 200-211. (PMID: 20674767) [CrossRef]
39. Leung JW. Utility of second-look ultrasound in the evaluation of MRI-detected breast lesions. Semin Roentgenol 2011; 46: 260-274. (PMID: 22035668) [CrossRef]
40. Demartini WB, Eby PR, Peacock S, Lehman CD. Utility of targeted sonography for breast lesions that were suspicious on MRI. AJR Am J Roentgenol 2009; 192: 1128-1134. (PMID: 19304724) [CrossRef]
41. Meissnitzer M, Dershaw DD, Lee CH, Morris EA. Targeted ultrasound of the breast in women with abnormal MRI findings for whom biopsy has been recommended. AJR Am J Roentgenol 2009; 193: 1025-1029. (PMID: 19770325) [CrossRef]
42. Abe H, Schmidt RA, Shah RN, Shimauchi A, Kulkarni K, Sennett CA, Newstead GM. MR-directed ("second-look") ultrasound examination for breast lesions detected initially on MRI: MR and sonographic findings. AJR Am J Roentgenol 2010; 194: 370-377. (PMID: 20093598) [CrossRef]
43. Candelaria R, Fornage BD. Second-look US examination of MR-detected breast lesions. J Clin Ultrasound 2011; 39: 115-121. (PMID: 21387324) [CrossRef]
44. LaTrenta LR, Menell JH, Morris EA, Abramson AF, Dershaw DD, Liberman L. Breast lesions detected with MR imaging: utility and histopathologic importance of identification with US. Radiology 2003; 227: 856-861. (PMID: 12773685) [CrossRef]
45. Carbognin G, Girardi V, Calciolari C, Brandalise A, Bonetti F, Russo A, Pozzi Mucelli R. Utility of second-look ultrasound in the management of incidental enhancing lesions detected by breast MR imaging. Radiol Med (Torino) 2010; 115: 1234-1245. (PMID: 20574702) [CrossRef]
46. Hsu HH, Chang TH, Chou YC, Peng YJ, Ko KH, Chang WC, Lin YP, Hsu GC, Yu JC. Breast non-mass enhancement detected with MRI: uility and lesion characterization with second-look ultrasonography. Breast J 2015; 21: 579-587. (PMID: 26390913) [CrossRef]
47. Lee SH, Kim SM, Jang M, Yun BL, Kang E, Kim SW, Park SY, Ahn HS, Chang JH, Yoo Y, Song TK, Moon WK. Role of second-look ultrasound examinations for MR-detected lesions in patients with breast cancer. Ultraschall Med 2015; 36: 140-148. (PMID: 25750138) [CrossRef]
48. Spick C, Baltzer PA. Diagnostic utility of second-look US for breast lesions identified at MR imaging: systematic review and meta-analysis. Radiology 2014; 273: 401-409. (PMID: 25119022) [CrossRef]
49. Aracava MM, Chojniak R, Souza JA, Bitencourt AG, Marques EF. Identification of occult breast lesions detected by magnetic resonance imaging with targeted ultrasound: a prospective study. Eur J Radiol 2014; 83: 516-519. (PMID: 24440492) [CrossRef]
50. Fiaschetti V, Salimbeni C, Gaspari E, Dembele GK, Bolacchi F, Cossu E, Pistolese CA, Perretta T, Simonetti G. The role of second-look ultrasound of BIRADS-3 mammary lesions detected by breast MR imaging. Eur J Radiol 2012; 81: 3178-3184. (PMID: 22417393) [CrossRef]
51. Luciani ML, Pediconi F, Telesca M, Vasselli F, Casali V, Miglio E, Passariello R, Catalano C. Incidental enhancing lesions found on preoperative breast MRI: management and role of second-look ultrasound. Radiol Med 2011; 116: 886-904. (PMID: 21293943) [CrossRef]
52. Park VY, Kim MJ, Kim EK, Moon HJ. Second-look US: how to find breast lesions with a suspicious MR imaging appearance. Radiographics 2013; 33: 1361-1375. (PMID: 24025929) [CrossRef]
53. Huang ML, Speer M, Dogan BE, Rauch GM, Candelaria RP, Adrada BE, Hess KR, Yang WT. Imaging-concordant benign MRI-guided vacuum-assisted breast biopsy may not warrant MRI follow-up. AJR Am J Roentgenol 2017; 208: 916-922. (PMID: 28140609) [CrossRef]
54. Uchida M, Pizzolon F, Pinochet MA, Durán M, Galleguillos C, Wenzel H, Horvarth E, Gálvez J. MRI-guided breast biopsies, preliminary experience. Rev Chil Radiol 2014; 20: 13-18. [CrossRef]
55. Gebauer B, Bostanjoglo M, Moesta KT, Schneider W, Schlag PM, Felix R. Magnetic Resonance-guided biopsy of suspicious breast lesions with a handheld vacuum biopsy device. Acta Radiologica 2006; 47; 907-913. (PMID: 17077039) [CrossRef]
56. Han BK, Schnall MD, Orel SG, Rosen M. Outcome of MRI-guided breast biopsy. AJR Am J Roentgenol 2008; 191: 1798-1804. (PMID: 19020252) [CrossRef]
57. Spick C, Schernthaner M, Pinker K, Kapetas P, Bernathova M, Polanec SH, Bickel H, Wengert GJ, Rudas M, Helbich TH, Baltzer PA. MR-guided vacuum-assisted breast biopsy of MRI-only lesions: a single center experience. Eur Radiol 2016; 26: 3908-3916. (PMID: 26984430) [CrossRef]

58. Heller SL, Elias K, Gupta A, Greenwood HI, Mercado CL, Moy L. Outcome of high-risk lesions at MRI-guided 9-gauge vacuum- assisted breast biopsy. AJR Am J Roentgenol 2014; 202: 237-245. (PMID: 24370150) [CrossRef]
59. Lehman CD, Isaacs C, Schnall MD, Pisano ED, Ascher SM, Weatherall PT, Bluemke DA, Bowen DJ, Marcom PK, Armstrong DK, Domchek SM, Tomlinson G, Skates SJ, Gatsonis C. Cancer yield of mammography, MR, and US in high-risk women: prospective multi-institution breast cancer screening study. Radiology 2007; 244: 381-388. (PMID: 17641362) [CrossRef]
60. Heller SL, Moy L. Imaging features and management of high-risk lesions on contrast-enhanced dynamic breast MRI. AJR Am J Roentgenol 2012; 198: 249-255. (PMID: 22268165) [CrossRef]
61. Liberman L, Holland AE, Marjan D, Murray MP, Bartella L, Morris EA, Dershaw DD, Wynn RT. Underestimation of atypical ductal hyperplasia at MRI-guided 9-gauge vacuum-assisted breast biopsy. AJR Am J Roentgenol 2007; 188: 684-690. (PMID: 17312054) [CrossRef]
62. Lourenco AP, Khalil H, Sanford M, Donegan L. High-risk lesions at MRI-guided breast biopsy: frequency and rate of underestimation. AJR Am J Roentgenol 2014; 203: 682-686. (PMID: 25148176) [CrossRef]