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EFFECTIVENESS AND COST-EFFECTIVENESS OF DOUBLE READING IN DIGITAL MAMMOGRAPHY SCREENING: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Abstract

Background: Female breast cancer has become the global leading cause of cancer-related mortality. Although digital mammography has been proposed as an effective and cost-efficient screening method, its real performance and cost-benefit value has been debated by several studies especially concerning the available reading methods. Double reading of digital mammography has been said to increase reading sensitivity but often found some challenges in terms of cost and false positive rate. This systematic review and meta-analysis aim to evaluate the effectiveness and cost-effectiveness of double reading for digital mammography screening.

Methods: This review included comparative studies and cost-effectiveness studies from databases such as Pubmed and Cochrane up to April 2023. We excluded non-English studies, cost-effectiveness studies with lacking adequate statistics, single-armed trials, study protocols, earlier meta-analyses, review articles, and studies that merely evaluated double reading of two different methodologies. Study quality was assessed using the QUADAS-2 tool and CHEERS 2022 checklist. Meta-analysis was conducted to evaluate cancer detection and false positive rate of double reading.

Ten studies were included in this review, three of which were obtained from a reference article. Mammograms in this review were obtained from a total of 260,501 women. Double reading had a slightly but significant chance of finding a breast cancer (OR = 1.137; p-value = 0.004). False-positive rate in double reading was also prominent (ER = 0.041; p value = 0.000). Single reading with CAD was still proven to be a more cost-effective method.

Discussion: Studies in this review was generally had low risk of bias and applicability concern. High cost of double reading may be attributed to the high number of false positive result. Integration of CAD with AI or deep learning may enhance the performance of digital mammography single reading.

Conclusion: with consensus and arbitration, double reading strategy present itself as a screening method for breast cancer, however single reading with CAD has proven more superior as a more-cost effective method.

INTRODUCTION

Approximately 2,261,419 new cases of breast cancer were found in 2020 according to the latest data from Global Cancer Observatory (GLOBOCAN) with a mortality rate of 15.4% in female. Female breast cancer has also replaced lung cancer as the global leading cause of cancer with the highest number of incidence in Australia/New Zealand, Western Europe, Northern America, and Northern Europe. The incidence of breast cancer has been increasing in developed Asian countries such as Japan and South Korea.(1) A cross-sectional study in Indonesia found that breast cancer was the second most common cancer in females after cervical cancer. Breast cancer incidence was most found in females above 20 years old, and especially around 50-54 years old. In most cases, patients were present with stage IIIC which has been commonly associated with lower overall survival, poorer prognosis, and higher hazard ratio even with chemotherapy.(2–4) A study from India in a low-socioeconomic area revealed that most women were not aware of breast cancer symptoms and risk factors albeit they have possessed the awareness about the cancer.(5) Breast cancer screening is essential as an early detection to improve breast cancer patients survival.(6) The most common obstacles in performing breast cancer screening are low literacy rate and high cost.(7,8) Digital mammography has been studied as a cost-efficient method of breast cancer screening especially for population < 50 years old and for asymptomatic women with average risk for breast cancer.(9,10) Digital mammography was found to have a 97% sensitivity and 64.5% specificity when compared to histopathology as a gold standard.(11) The latest study in Netherlands stated that the use of biennial digital mammography is still more cost-effective than the use of digital breast tomosynthesis for a certain maximum threshold per life-year gained.(12)

The use of two radiologists to read a same mammogram may lower the chance of a missed cancer. Independent double reading allows two professionals with expertise in perceptual, cognitive, and decision-making to evaluate images and arbitrate disagreements to improve diagnostic performance.(13) Conventional single reading method of a mammography may produce a high false positive result but is more applicable for a resource-poor condition.(14) One study in Japan found that single reading with computer-assisted diagnosis (CAD) costed more than double reading but proved to slightly extend life expectancy.(15) Several other studies have also debated the most efficient and cost-effective method of digital mammography reading (15–19). This systematic review and meta-analysis aim to explore the effectiveness and cost-efficiency of double reading in digital mammography screening.

Methods

Study Design

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guideline.(20)

Search Strategy

We systematically searched for relevant studies from Pubmed and Scopus on April 21st, 2023. Search results were updated once more on April 22nd, 2023. The search strategies were adjusted for each database which included the search term as followed: ("effectiveness" OR "effective") OR ("cost effectiveness" OR "cost-effectiveness") AND ("digital mammography" OR "full-field digital mammography" OR "full field digital mammogram" OR "full-field digital mammogram" OR "digital mammogram" OR "2D mammography" OR "2D mammogram" OR "2D-mammography" OR "2D-mammogram" OR "digital breast tomosynthesis") AND ("double reading" OR "double reader" OR "double-reading" OR "double-reader"). Search results were not limited by language or year. We also expanded our search by looking at the references used by previous systematic reviews and meta-analyses.

Study Selection and Inclusion Criteria

Duplicate articles were removed using an automated tool from Mendeley reference manager. We manually screened 15 reports for eligibility based on the studies' title, abstract, and then the full text. We included studies with the following PICOS eligibility criteria: 1) Population: female patients who underwent mammography for breast cancer screening or screening centre; 2) Intervention: digital mammography examination; 3) Comparison: double reading strategy versus single reading strategy with or without CAD; 4) Outcome: cancer detection rate, incremental cost, incremental effect, incremental cost-effectiveness ratio (ICER), and threshold for cost-effective intervention; 5) Study design: comparative prospective or retrospective studies, cost-effectiveness studies, and cost-consequence studies. Studies that were not in English, cost-effectiveness studies with lacking cost-effectiveness statistics, single-armed trials, study protocols, earlier meta-analyses, review articles, and studies that merely evaluated double reading of two different methodologies were also disregarded.

Data Extraction and Study Evaluation

One reviewer assessed key study characteristics and outcomes. Applicable studies for effectiveness meta-analysis were evaluated with Quality Assessment of Diagnostic Accuracy Studies (QUADAS)-2 tool.(21) Studies appropriate for cost-effectiveness study were assessed using the new Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022 checklist.(22) For effectiveness analysis, we logged the country of origin, study design, population, reading strategy, index tests, comparator tests, and reference standards for each study. Reported costs were converted and displayed in today's (April 2023) United States Dollar (US$) purchasing power parities (PPP). A meta-analysis was conducted to determine the influence of single versus double reading in digital mammography settings with a 95% confidence interval. We used Comprehensive Meta-Analysis software version 3.3.070 for data analysis.

Results

Flowchart of study selection was shown in Figure 1. We managed to obtain 7 studies from Pubmed and 15 studies from Cochrane database. Six records were omitted due to duplicates. We also identified one reference article as a previous systematic review and meta-analysis.(16) After screening all reports, we managed to obtain a total of 10 studies to be included in the review, 3 of which were previously analysed in a past study. All studies were published during or after 2009. Eight studies were identified from the European countries (17,18,23–28) , one study originated from the United Kingdom (19), and another study was from Japan (15). The age range of the participants in each study varied with a study from the Netherlands was followed by women ranged around 20-90 years old (27) and two studies with hypothetical population (15,19). One study had the most participants of 99,031 women (28) from a Dutch breast cancer screening programme. The mammograms in this study were obtained from a total of 260,501 women participated in included studies. Detailed description of each study is provided in Table 1.

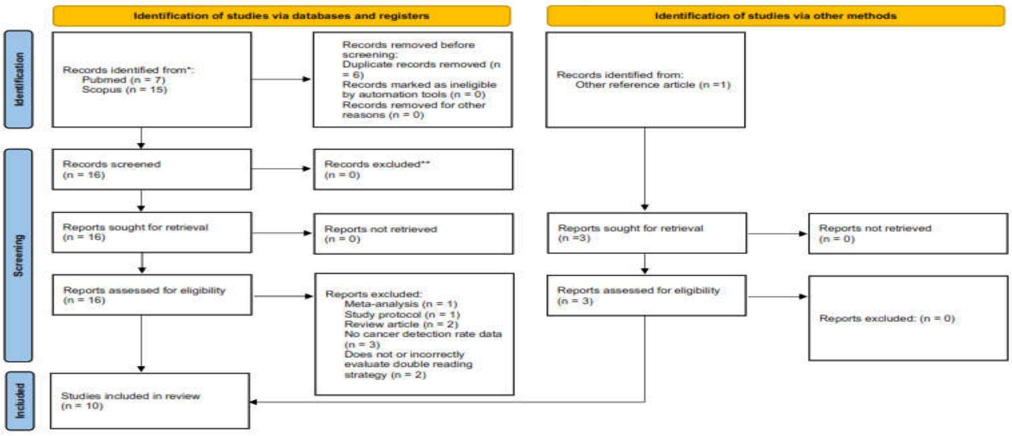

Figure 1. PRISMA 2020 flow diagram

All studies used single reading as the index test with double reading as comparator test. Single reading of digital mammogram was mostly done independently without any additional diagnostic tool. One study (25) compared single reading 3D mammography to double reading of 2D-mammography. Another study (27) compared conventional single reading to a double reading by a radiologist and a technologist with a CAD. Disagreements in double reading would be decided through a consensus (24), arbitration involving a third radiologist (19), or both (17,18). A suspected result of malignancy required a recall for additional examinations such as additional imaging in all studies. Two studies stated that each reader(s) was blinded for the evaluations of other reader(s) (26,27) while one study stated that the second reader was blinded to the previous radiologist's opinion but not to the mammographer's opinion (28).

Table 1. Characteristics of Included Studies

Studies	Country	Design	Population	Readers	Index tests	Comparator test	Reference standard
Houssami, 2017 (25)	Italy	Population screening study based on STORM-2	9,672 women (age 53-63 years)	Radiologists experienced in mammography screening and 3D-mammography	Single reading of 3D-mammography	Double reading of 2D-mammography	Suspected outcome: Additional imaging and excision histology
Posso, 2016a (17)	Spain	Comparative study of digital mammography in a single health centre	57,157 women (age 50-69 years)	Radiologists who read at least 5,000 mammograms per year	Single reader from two blinded radiologists	Double reading with consensus and arbitration	Negative outcome: further mammography screening in two years Suspected outcome: additional imaging and invasive procedure
Martin, 2018 (26)	Spain	Comparative study of first and second digital mammography reading in screening programme	16,067 women (age 50-70 years old)	Radiologists with 3-15 years dedication and experience in breast imaging	Single reading of 2D-mammography	Double reading of 2D-mammography	Suspected outcome: percutaneous biopsy
van der Biggelaar, 2009 (27)	Netherlands	Prospective study comparing conservative reading strategy with computer-aided detection for double reading.	1,048 women (age 20-90 years old)	Radiologists with 5 and 20 years of experience; technologists with one year experience in mammogram interpretation	Conventional single reading strategy by a radiologist	Double reading strategy by a radiologist and a technologist using CAD	Suspected outcome: core needle biopsies and surgical excisions within 12 months follow-up
Weigel, 2016 (24)	Germany	Retrospective study in a single	25,576 women (age	Radiologists who read at least 5,000 mammograms	Independent single reading	Double reading with a consensus	Negative outcome: follow-up screening within 2 years

		digital screening unit	50-69 years old)	screening per year and had more than 5 years of experience in breast radiology			Suspicious outcome: histopathological examination
Houssami, 2014 (23)	Italy	A STORM-based prospective screening study	7,292 women (median age 58 years old)	Radiologists with a median of 1,791 annual screen reading experience (range 1,315-2,370)	Single reading with standard 2D-mammography	Double reading with 2D-mammography	Negative outcome: 13 months follow-up Suspicious outcome: excision histology, work-up imaging, or needle biopsy
Coolen, 2018 (28)	Netherlands	Prospective screening study from multiple screening units	99,013 women (age 50-75 years old)	Radiologists with 10,000 annual mammograms read	Independent single reading	Blinded double reading	Negative outcome: 2 years of follow up. Suspicious outcome: histopathological biopsy
Posso, 2016b (18)	Spain	Cost-effective analysis using decision tree model	28,636 women (age 50-69 years old)	Radiologists who read at least 5,000 mammograms per year	Independent single reading	Independent double reading with consensus or arbitration	Negative outcome: further mammography screening in 12 months Suspicious outcome: pathological examination
Sato, 2014 (15)	Japan	Cost-effective analysis a decision tree and Markov model	16,000 examinees annually (hypothetical population of 50 years old)	Physicians certified in mammogram reading and physicians using CAD	Single reading by a physician using CAD	Double reading by two physicians	Negative outcome: biennial screening Suspicious outcome: fine needle aspiration cytology and core needle biopsy
Taylor, 2010 (19)	United Kingdom	Cost-effective analysis study based on cost of radiologist time	Three hypothetical screening centres	Consultant radiologists and film-reading radiographers	Single reading with CAD	Double reading with arbitration	Suspicious outcome: additional assessment

Studies assessment using the QUADAS-2 tool showed that most studies had relatively low risk of bias. We had relatively low concerns of bias for patient selection, the use of index test, reference standard, and flowing and time. All results from the single reading method were interpreted without knowledge of the second reading. Most studies required screened subjects to join further screening at a certain time interval (15, 17, 18, 23, 24). Applicability concerns on patient selection, index test, and reference standard were mostly low. Most radiologists in this study were stated to have more than at least 1,315 annual screen reading experience except for one study which did not state the radiologists' experience explicitly. Most cost-effectiveness studies had low risk of bias based on the CHEERS 2022 tool. One study (19) had a high risk of bias due to no study perspective stated with cost data from a previous randomized controlled trial and no uncertainty analysis provided.

Table 2. Risk of Bias and Applicability Concerns Based on QUADAS-2 Tool

Studies	QUADAS-2 Risk of Bias				QUADAS-2 Applicability Concerns		
	Patient Selection	Index Test	Reference Standard	Flowing and Time	Patient Selection	Index Test	Reference Standard
Houssami, 2017 (25)	Low	Low	Low	Low	Low	High	Low
Posso, 2016a (17)	Low	Low	Low	Low	Low	Low	Low
Martin, 2018 (26)	Low	Low	Low	Low	Low	Low	Low
van der Biggelaar, 2009 (27)	Low	Low	Unclear	Low	Low	Low	Unclear
Weigel, 2016 (24)	Low	Low	Unclear	High	Low	Low	Low
Houssami, 2014 (23)	Low	Low	Low	Low	Low	High	Low
Posso, 2016b (18)	Low	Low	Low	Low	Low	Low	Low
Coolen, 2018 (28)	Low	Low	Low	Low	Low	High	Low

Table 3. Risk of Bias Based on CHEERS 2022 Tool

Studies	CHEERS 2022
Posso, 2016a (17)	Low risk of bias Design: Cost-consequence analysis from public health perspective. Costs were obtained from a single institution. Cost and health outcomes along with estimated incremental effect were compared between the two reading strategies.
Posso, 2016b (18)	Low risk of bias Design: Cost-effectiveness analysis from public health perspective. Costs were obtained from a single institution. Deterministic sensitivity analysis was done to assess the results' degrees of uncertainty. The variations between the incident and subsequent screen tests were explored.
Sato, 2014 (15)	Moderate risk of bias Design: The analysis was conducted from a societal standpoint from only direct medical expenses. Effectiveness data was provided from a single Japanese city. A deterministic sensitivity analysis was performed to evaluate the data' level of uncertainty.
Taylor, 2010 (19)	High risk of bias Design: Calculation of cost-effectiveness was conducted using a time horizon of 7 years, but study perspective was not reported. Cost data was obtained from a previous multi-centred randomized controlled trial. No test was done to evaluate uncertainty.

Effectiveness of Double Reading

Cancer Detection Rate

We managed to find seven studies which reported the effectiveness of double reading compared to single reading (17,18,23–27). All studies are in concordance regarding the higher odds of finding malignancies in double-reading strategy rather than single reading. In summary, double reading of digital mammography was found to significantly increases the chances of finding a breast cancer (OR = 1.137; p-value = 0.004).

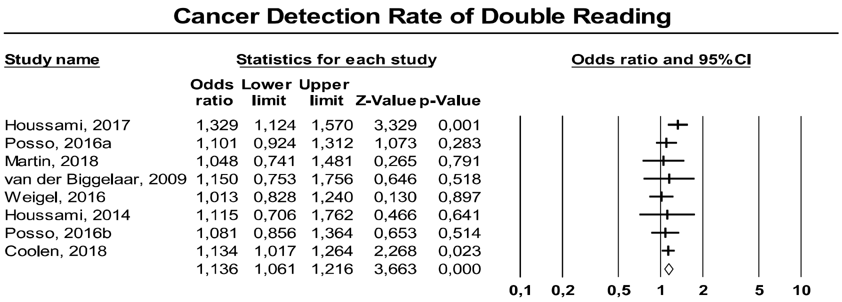

Figure 2. Meta-analysis of Cancer Detection Rate from Double Reading Strategy

False Positive Rate

We found 8 studies with data for false positive rate. We found that double reading had 0.041 more false positive rate than single reading (ER = 0.041; p value = 0.000)

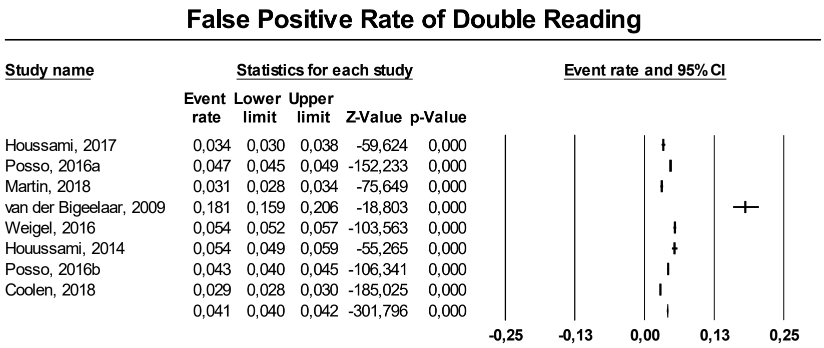

Figure 2. Meta-analysis of False Positive Rate from Double Reading Strategy

Cost-effectiveness of Double Reading

A study by Sato (15) and Posso (18) discovered that single reading with CAD was more cost-effective than double reading of digital mammography. Posso and colleagues (18) found that single reading with CAD had ICER of $22,016,6 per cancer detected. The study by Sato (15) found that despite single reading with CAD cost more ($3,951.77) than double reading ($3,930.98), the ICER was below the threshold of $51,470.94 which was $2,659.65 for each life year. A study by Posso in the same year (17) found that double reading resulted in slightly more cancer detection rate and positive predictive value but followed with a slightly more false positive result. Taylor and colleagues (19) reported that single reading with CAD may be as effective as double reading if the average annual cost is less than the amount of radiologist time spared.

Table 4. Cost-effectiveness of Double Reading Compared to Single Reading Strategy

Reference	Incremental cost	Incremental effect	ICER	Threshold for cost-effective intervention	Reading strategy reported as cost-effective
Posso, 2016a (17)	$319,442.3*	0.4 ‰ more cancer detection rate 0.3% more false positive rate 0.2% more positive predictive value	Not reported	Not reported	Single reading with first reader only
Posso, 2016b (18)	$242,202.5*	11 detected cancers	$22,016,6* per cancer detected	Not reported	Single reading with CAD
Sato, 2014 (15)	$23.12**	0.0087 years of extended life expectancy	$2,659.65** per life year gained	$51,470.94**	Single reading with CAD
Taylor, 2010 (19)	Not reported	60 minutes for time taken per patient assessment and 37% relative increase in recall rate in small, medium, and large unit.	Not reported	$41,962.37^ for 20 minutes per patient and 3% increase in recall at small unit. $63,067.23^ for 20 minutes per patient and 3% increase in recall at medium unit. $91,829.23^ for 20 minutes per patient and 3% increase in recall at large unit.	Single reading with CAD may be more cost-effective than double reading

*Calculation was adjusted based on the inflation rate from 2010 according to the United States' Bureau of Labour Statistics inflation calculator as of March 2023 which has been approximately 22.7%
** Calculation was adjusted based on the inflation rate from 2011 according to the United States' Bureau of Labour Statistics inflation calculator as of March 2023 which has been approximately 12.2%
^Calculation was adjusted based on the inflation rate from 2011 according to the United States' Bureau of Labour Statistics inflation calculator as of March 2023 which has been approximately 23.4%

Discussion
Our systematic review found eight studies (17,18,23–28) which agreed that double reading increases the chance of finding breast cancer compared to that of single reading. Four cost-effectiveness studies, however, stated single reading method with CAD as a more superior cost-effective method than double reading (15,17–19). The risk of bias and applicability of each study based on QUADAS-2 tool assessment was generally low. One cost-effectiveness study (19) did not provide the perspective of the study and incremental cost for double reading and thus had a high risk of bias in this review.

Adding CAD to a single reading strategy may increase sensitivity and cancer detection rate, providing a more or at least, similar performance to that of double reading.(19,29) The use of CAD is intended to help radiologists identify subtle cancers that may not appear to the naked eyes. CAD works by marking suspicious microcalcifications and masses on the mammogram.(29,30) While some studies were sceptical towards the results from CAD (30–32), several others believe that integrating artificial intelligence (33) or deep-learning (34) sequence may help digital mammography to be at least similar as breast tomography. Sato and colleagues (15) explained single reading method with CAD as a cost-effective breast cancer screening method. The results from digital mammography single reading with CAD provided a more extended life expectancy than double reading. Taylor and colleagues (19), however, marked that CAD installation would only be proven as effective as double reading if the average patient appointment time would have been less than 40 minutes or less than 15% recall rate. Our systematic review is in alignment with the previous study which found single reading with CAD as an cost-effective method from an incremental effect.

Double reading technique of digital mammography is often associated with high recall rate and cost due to false positive results.(17,35) Posso et al discovered a mean difference of 511 Euros (equivalent to 676.13 United States dollars in today's value) attributed to false positive recalls. This finding was deemed inconclusive and needed further cost-effective evaluation analysis.(17) In the same year, Posso et al also found that cancer detection rate at double reading should increase by 16% in order to achieve same cost-effectiveness as single reading.(18) Coolen and colleagues (28) found that blinded double reading was associated with higher recall rate and contributes more false positive and true positive outcome.(28) The high recall rate may be due to the second reader recalling the patient after the first reader did the same action. Consensus and arbitration may influence cancer detection and false positive rate and therefore, may be a key in making double reading digital mammography as a cost-effective method for breast cancer screening.(16,35) Our current review has shown that double reading was indeed yielded a higher false positive result which may expose screened women to unnecessary additional tests.

This systematic review has several limitations. Most studies in this review are from the European region (17,18,23,25–27) and only one cost-effective study originated from the Asian region (15). The results from this review may not be well implemented to other countries with very limited radiographers or resources. We were only able to identify a small number of studies through our comprehensive literature search and so, not all studies regarding comparison of double reading and first reading were identified. Some studies in this review had a low quality due to high risk of bias and may affect the overall quality of the systematic review. We also did not include any non-English studies in this review which may provide additional data on double reading effectiveness and cost-effectiveness.

Conclusion
Double reading strategy is a possible effective method for breast cancer screening upon being used with consensus and/or arbitration. Single reading with CAD remains as a more cost-effective method due to lower recall and false positive rate.

References

[1]. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA Cancer J Clin. 2021 May;71(3):209–49.
[2]. Gondhowiardjo S, Christina N, Ngakan ;, Ganapati PD, Hawariy S, Radityamurti F, et al. Five-Year Cancer Epidemiology at the National Referral Hospital: Hospital-Based Cancer Registry Data in Indonesia. JCO Global Oncol. 2021;7:190–203.
[3]. Takahashi R, Toh U, Iwakuma N, Mishima M, Fujii T, Takenaka M, et al. Treatment outcome in patients with stage III breast cancer treated with neoadjuvant chemotherapy. Exp Ther Med. 2013 Nov;6(5):1089–95.
[4]. Deanasa RS, Umar M, Fitri AD. Overall Survival for Stage III Breast Cancer Patients at DR. Mohammad Hoesin General Hospital Palembang and the Influencing Factors. Indonesian Journal of Cancer. 2022 Dec 28;16(4):231.
[5]. Prusty RK, Begum S, Patil A, Naik DD, Pimple S, Mishra G. Knowledge of symptoms and risk factors of breast cancer among women: A community based study in a low socio-economic area of Mumbai, India. BMC Womens Health. 2020 May 18;20(1).

[6]. Guo F, Kuo Y fang, Shih YCT, Giordano SH, Berenson AB. Trends in breast cancer mortality by stage at diagnosis among young women in the United States. Cancer. 2018 Sep 1;124(17):3500–9.
[7]. Taheri M, Tavakol M, Akbari ME, Almasi-Hashiani A, Abbasi M. Relationship of Socio Economic Status, Income, and Education with the Survival Rate of Breast Cancer: A Meta-Analysis. Iran J Public Health. 2019;48(8):1428–38.
[8]. Solikhah S, Perwitasari DA, Rejeki DSS. Geographic Characteristics of Various Cancers in Yogyakarta Province, Indonesia: A Spatial Analysis at the Community Level. Asian Pacific Journal of Cancer Prevention. 2022;23(4):1231–8.
[9]. Icanervilia A V., van der Schans J, Cao Q, de Carvalho AC, Cordova-Pozo K, At Thobari J, et al. Economic evaluations of mammography to screen for breast cancer in low- and middle-income countries: A systematic review. J Glob Health. 2022 Jul 16;12:04048.
[10]. Schünemann HJ, Lerda D, Quinn C, Follmann M, Alonso-Coello P, Rossi PG, et al. Breast cancer screening and diagnosis: A synopsis of the european breast guidelines. Ann Intern Med. 2020 Jan 7;172(1):46–56.
[11]. Zeeshan M, Salam B, Khalid QSB, Alam S, Sayani R. Diagnostic Accuracy of Digital Mammography in the Detection of Breast Cancer. Cureus. 2018 Apr 8;
[12]. Sankatsing VDV, Juraniec K, Grimm SE, Joore MA, Pijnappel RM, de Koning HJ, et al. Cost-effectiveness of digital breast tomosynthesis in population-based breast cancer screening: A probabilistic sensitivity analysis. Radiology. 2020 Oct 1;297(1):40–8.
[13]. Brennan PC, Ganesan A, Eckstein MP, Ekpo EU, Tapia K, Mello-Thoms C, et al. Benefits of Independent Double Reading in Digital Mammography: A Theoretical Evaluation of All Possible Pairing Methodologies. Acad Radiol. 2019 Jun 1;26(6):717–23.
[14]. Gossner J. Digital mammography in young women: Is a single view sufficient? Journal of Clinical and Diagnostic Research. 2016 Mar 1;10(3):10–2.
[15]. Sato M, Kawai M, Nishino Y. Cost-effectiveness analysis for breast cancer screening : double reading versus single + CAD reading. Breast Cancer. 2014;21:532–41.
[16]. Posso M, Puig T, Carles M, Rué M, Canelo-Aybar C, Bonfill X. Effectiveness and cost-effectiveness of double reading in digital mammography screening: A systematic review and meta-analysis. Eur J Radiol. 2017;96:40–9.
[17]. Posso MC, Puig T, Quintana MJ, Solà-Roca J, Bonfill X. Double versus single reading of mammograms in a breast cancer screening programme: a cost-consequence analysis. Eur Radiol. 2016;26(9):3262–71.
[18]. Posso M, Carles M, Rué M, Puig T, Bonfill X. Cost-effectiveness of double reading versus single reading of mammograms in a breast cancer screening programme. PLoS One. 2016;11(7).
[19]. Taylor P, Potts H, Wilkinson L, Given-Wilson R. Impact of CAD with full field digital mammography on workflow and cost. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). 2010. p. 1–8.
[20]. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. Vol. 372, The BMJ. BMJ Publishing Group; 2021.
[21]. Whiting PF, Rutjes AWS, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, et al. QUADAS-2: A Revised Tool for the Quality Assessment of Diagnostic Accuracy Studies. Ann Intern Med. 2011;155(8):1–10.
[22]. Husereau D, Drummond M, Augustovski F, De Bekker-Grob E, Briggs AH, Carswell C, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) statement: Updated reporting guidance for health economic evaluations. Vol. 376, The BMJ. BMJ Publishing Group; 2022.
[23]. Houssami N, Macaskill P, Bernardi D, Caumo F, Pellegrini M, Brunelli S, et al. Breast screening using 2D-mammography or integrating digital breast tomosynthesis (3D-mammography) for single-reading or double-reading – Evidence to guide future screening strategies. Eur J Cancer. 2014;50(May 2012):1799–807.
[24]. Weigel S. Digital mammography screening : sensitivity of the programme dependent on breast density. Eur Radiol. 2016;27:2744–51.
[25]. Houssami N, Bernardi D, Pellegrini M, Valentini M, Fantò C, Ostillio L, et al. Breast cancer detection using single-reading of breast tomosynthesis (3D-mammography) compared to double-reading of 2D-mammography: Evidence from a population-based trial. Cancer Epidemiol. 2017;47:94–9.
[26]. Martín SR, Povedano JLR, García MC, Romero ALS, Garriguet MP, Benito MÁ. Prospective study aiming to compare 2D mammography and tomosynthesis + synthesized mammography in terms of cancer detection and recall. From double reading of 2D mammography to single reading of tomosynthesis. Eur Radiol. 2018;28(6):2484–91.
[27]. van den Biggelaar FJHM, Kessels AGH, van Engelshoven JMA, Flobbe K. Strategies for digital mammography interpretation in a clinical patient population. Int J Cancer. 2009 Dec;125(12):2923–9.
[28]. Coolen AMP, Voogd AC, Strobbe LJ, Louwman MWJ, Tjan-Heijnen VCG, Duijm LEM. Impact of the second reader on screening outcome at blinded double reading of digital screening mammograms. Br J Cancer. 2018 Aug 14;119(4):503–7.
[29]. Henriksen EL, Carlsen JF, Vejborg IMM, Nielsen MB, Lauridsen CA. The efficacy of using computer-aided detection (CAD) for detection of breast cancer in mammography screening: a systematic review. Vol. 60, Acta Radiologica. SAGE Publications Inc.; 2019. p. 13–8.
[30]. Lehman CD, Wellman RD, Buist DSM, Kerlikowske K, Tosteson ANA, Miglioretti DL. Diagnostic accuracy of digital screening mammography with and without computer-aided detection. JAMA Intern Med. 2015 Nov 1;175(11):1828–37.

[31]. Azavedo E, Zackrisson S, Mejàre I, Heibert Arnlind M. Is single reading with computer-aided detection (CAD) as good as double reading in mammography screening? A systematic review. BMC Med Imaging. 2012 Jul 24;12.
[32]. Kohli A, Jha S. Why CAD Failed in Mammography. Vol. 15, Journal of the American College of Radiology. Elsevier B.V.; 2018. p. 535–7.
[33]. Dahlblom V, Andersson I, Lång K, Tingberg A, Zackrisson S, Dustler M. Artificial intelligence detection of missed cancers at digital mammography that were detected at digital breast tomosynthesis. Radiol Artif Intell. 2021 Nov 1;3(6).
[34]. Al-antari MA, Al-masni MA, Kim TS. Deep Learning Computer-Aided Diagnosis for Breast Lesion in Digital Mammogram. In: Lee G, Fujita H, editors. Deep Learning in Medical Image Analysis: Challenges and Applications. Cham: Springer; 2018. p. 59–71.
[35]. Taylor-Phillips S, Stinton C. Double reading in breast cancer screening: considerations for policy-making. Br J Radiol. 2020 Feb;93(1106):20190610.