Journal of Medical Screening

Screening at stationary versus mobile screening units in BreastScreen Norway

Journal:	*Journal of Medical Screening*
Manuscript ID	JMS-18-159.R2
Manuscript Type:	Original Article
Date Submitted by the Author:	18-Aug-2019
Complete List of Authors:	Holen, Åsne; Cancer Registry of Norway Sebuødegård, Sofie; Cancer Registry of Norway Wåde, Gunvor; Oslo Metropolitan University Aase, Hildegunn; Haukeland University Hospital Hopland, Nina-Merete; Haukeland University Hospital Pedersen, Kristin; Cancer Registry of Norway Larsen, Marthe; Cancer Registry of Norway Tsuruda, Kaitlyn; Cancer Registry of Norway Hofvind, Solveig; Cancer Registry of Norway; Oslo Metropolitan University
Abstract:	Objective: To compare breast characteristics, compression parameters, and early performance measures for mammographic screening (rates of recall, screen-detected and interval breast cancer, as well as histopathologic tumor characteristics) at a stationary versus a mobile unit. Methods: Information was available for 92,408 mammographic screening examinations performed at either a stationary (n = 52,620) or mobile (n = 39,788) screening unit in Hordaland county, as part of BreastScreen Norway during 2008-2017. Results were compared for the two units, using descriptive statistics and generalized estimation equations (GEE). A GEE for a binomial regression model was used to estimate crude and adjusted odds ratios with 95% confidence intervals (CI) for the outcome of interest. Adjusted GEE models included age, breast volume and density grade as covariates. Results: Screening at the stationary unit was performed on smaller breasts with higher mammographic density compared with the mobile unit. Lower compression force but higher pressure was used at the stationary unit. Using the stationary screening unit as reference, the adjusted odds of recall was 0.94 (95% CI: 0.88-1.01) for women screened at the mobile unit; screen-detected breast cancer 0.93 (95% CI: 0.78-1.0); and interval breast cancer 1.17 (95% CI: 0.83-1.64). Conclusions: The quality of care did not differ for women screened at the stationary versus the mobile unit, but there were differences between the women who attended the two units. Sociodemographic factors should be included in future analyses to fully understand the risk of

Holen, Å. S., Sebuødegård, S., Wåde, G. G., Aase, H. S., Hopland, N., Pedersen, K., Larsen, M., Tsuruda, K., Hofvind, S. Screening at stationary versus mobile units in BreastScreen Norway. Journal of Medical Screening, Vol 27, Issue 1, , page(s): 31-39.
DOI: https://dx.doi.org/10.1177/0969141319875158

	breast cancer among women residing in urban versus rural areas.

Screening at stationary versus mobile units in BreastScreen Norway

Åsne Holen[1], Sofie Sebuødegård[1], Gunvor Wåde[2], Hildegunn Aase[3], Nina-Merete Hopland[3], Kristin Pedersen[1], Marthe Larsen[1], Kaitlyn Tsuruda[1], Solveig Hofvind[1,2]

1. Cancer Registry of Norway, PO 5313 Majorstuen 0304 Oslo, Norway
2. Oslo Metropolitan University, Oslo 0130, Akershus, Norway
3. Haukeland University Hospital, Bergen, Norway

Corresponding author: Solveig Hofvind, Cancer Registry of Norway, PO 5313 Majorstuen 0304 Oslo, Norway. solveig.hofvind@kreftregisteret

ABSTRACT

Objective: To compare breast characteristics, compression parameters, and early performance measures (rates of recall, screen-detected and interval breast cancer, and histopathologic tumour characteristics) for mammographic screening at a stationary versus a mobile screening unit.

Methods: Results from 92,408 mammographic screening examinations, performed as part of BreastScreen Norway during 2008-2017 at either a stationary (n=52,620) or mobile (n=39,788) unit in Hordaland county, were compared using descriptive statistics and generalized estimation equations. A generalized estimation equation for a binomial regression model was used to estimate crude and adjusted odds ratios with 95% confidence intervals (CI) for the outcome of interest. Adjusted generalized estimation equation models included age, breast volume, and density grade as covariates.

Results: Screening at the stationary unit was performed on smaller breasts with higher mammographic density, using lower compression force but higher pressure than screening at the mobile unit. Using the stationary screening unit as reference, for women screened at the mobile unit the adjusted odds were: for recall 0.94 (95% CI: 0.88-1.01), screen-detected breast cancer 0.93 (95% CI: 0.78-1.0), and interval breast cancer 1.17 (95% CI: 0.83-1.64).

Conclusions: The quality of care did not differ for women screened at the stationary versus the mobile unit, but there were differences between the women who attended the two units. Sociodemographic factors should be included in future analyses to fully understand the risk of breast cancer among women residing in urban versus rural areas.

Keywords: Mammography, cancer screening, mass screening, breast cancer, socioeconomic factors, early detection of cancer, health service, urban/rural, breast compression, early performance measures, breast characteristics

INTRODUCTION

The BreastScreen Norway program, administered by the Cancer Registry of Norway, offers biennial, population-based mammographic screening to women aged 50-69[1] at stationary and mobile screening units. In 2017, the BreastScreen Norway target population was 650,000 women, of whom approximately 17% were offered screening at a mobile unit. The attendance rate among women invited to mobile units was higher than that among women invited to stationary units (80% versus 75%).

Early performance measures are quality indicators for breast cancer screening programs, and are usually given for a screening program as a whole.[2,3] Sociodemographic factors, including residential area, have been shown to affect both the incidence and risk of breast cancer, and could affect early performance measures.[4-8] Because mobile units usually service rural areas with different sociodemographic characteristics from urban populations, it may be useful to stratify the evaluation of early performance measures. A higher rate of recall, screen-detected, and interval breast cancer has been observed among women screened in BreastScreen Norway at stationary compared with mobile units.[1] Characteristics of women residing in rural and urban areas could, therefore, hold potential for stratification of early performance measures and of mammographic screening stratified screening. To our knowledge, no research in this area has been undertaken to date.

In mammographic imaging, the breast is compressed to improve image quality and to reduce radiation dose.[9] Breast compression parameters can be affected by breast characteristics, including breast volume, and mammographic density.[10] High mammographic density is an independent risk factor for breast cancer, and affects early performance measures, as well as histopathologic tumour characteristics.[11,12] We are not aware of any research addressing

whether there are systematic differences in breast characteristics and breast compression parameters between women screened at stationary versus mobile units.

About 17% of women attending BreastScreen Norway in Hordaland County were offered screening at a mobile unit in 2017.[1] Using data from digital mammographic screening examinations performed during 2008-2017 we investigated breast characteristics, breast compression parameters, and early performance measures for women screened at the stationary versus the mobile screening unit in Hordaland County.

METHODS

The requirement to obtain written informed consent for this retrospective analysis of de-identified data from BreastScreen Norway was waived under the Cancer Registry Regulations. Institutional review board approval was not required.[13]

Between 1 January 2008 and 31 December 2017 199,260 screening examinations were performed among 63,655 women aged 50-71 residing in Hordaland County (Figure 1). Standard two-view digital mammography (cranio-caudal and medio-lateral oblique views) was performed by a team of two radiographers, either at a stationary unit in the city of Bergen, or at a mobile unit. The mobile unit was stationed at eight central locations during one screening round until 2013, when three of the locations were ceased and the women were invited to the stationary unit. Mammography equipment from GE Health Care was used at the stationary unit (GE Senographe DS™ from 2008-2014 and GE Senographe Essential™ from 2014-2017), and the mobile unit (GE Senographe Essential™). Images acquired at the stationary unit were stored directly in the Picture Archiving and Communication System at the breast centre. Images taken at the mobile unit were stored on an encrypted memory stick and taken to the breast centre, where they were transferred to the Picture Archiving and Communication System. All mammograms were read at a GE workstation (Seno Advantage or Image Diagnost International). All radiographers and radiologists in this study were employed by the breast centre at Haukeland University Hospital and served both the stationary and the mobile units. The same pool of radiologists performed screen-reading and recall assessment on all women included in the study. All screening examinations were independently double read by two radiologists, giving a score of 1-5 for each breast to indicate the level of mammographic suspicion for breast malignancy.[1] All examinations given

a score of 2 or higher by one or both radiologists were discussed, and a consensus reached on whether to recall the woman for further assessment due to mammographic findings, hereafter referred to as recall.

Screening examinations were used as the unit of analysis. Women could be included in the study population more than once if they attended several screening examinations during the study period. We excluded 14,689 examinations performed with digital breast tomosynthesis as part of the Tomosynthesis Trial in Bergen in 2016 and 2017[14] (Figure 1). To ensure the validity of breast compression parameters, we excluded examinations of women who attended both the mobile and the stationary unit (stationary n=7494; mobile n= 11,516), as well as examinations by radiographers who performed <100 examinations during the study (stationary n=33,473; mobile n=162). We also excluded examinations where mammographic density and compression data from Volpara®Density™ was not available (stationary n=15,001; mobile n=5179), examinations that did not include exactly four standard mammographic images (left/right cranio-caudal view and left/right medio-lateral oblique view) (stationary n=12,155; mobile n=6919), and examinations where the women were recalled due to symptoms reported at screening, or technically unsatisfactory images (stationary n=173; mobile n=91). The final study population included 92,408 screening examinations performed among 44,702 women - 52,620 at the stationary and 39,788 at the mobile unit.

In this study, breast characteristics were defined as breast volume (cm^3), mammographic density measured as volumetric breast density (VBD, %) and fibroglandular volume (cm^3). VBD was classified into Volpara Density Grade (VDG) as follows: VDG1 (VBD <4.49%); VDG2 (VBD 4.5-7.49%); VDG3 (VBD 7.5-15.49%) and VDG4 (VBD ≥15.5%).[15] These

categories are analogous to the BI-RADS 5th edition density categories a-d.[16] Breast compression parameters were defined as compression force (Newton [N]), compression pressure (kilopascal [kPa]), and compressed breast thickness (mm). Compression force was defined as the force applied by the radiographer during the examination and is measured in kilogram (kg) or Newton (N). Compression pressure was defined as the force divided by the area of the breast in contact with the compression paddle and is measured in kilopascal (kPa). Compressed breast thickness was measured in mm and defined as the thickness of the compressed breast.

Early performance measures included the rate of recall, screen-detected and interval breast cancer, and the positive predictive value of recalls and needle biopsies, as well as histopathologic tumour characteristics (tumour diameter, histologic grade, lymph node involvement, estrogen and progesterone receptor status, and human epidermal growth factor receptor 2 status). The definition of screen-detected and interval breast cancer included ductal carcinoma in situ and invasive breast cancer. The recall rate was calculated as the proportion of recalls due to abnormal mammographic findings, biopsy rate as the proportion of needle biopsies performed at recall assessment, and rate of screen-detected breast cancer as the number of breast cancers diagnosed after recall, among the screening examinations. The rate of interval breast cancer was defined as the number of breast cancers diagnosed 0-24 months after a negative screening examination or 6-24 months after a false-positive screening examination, divided by the number of screening examinations. Positive predictive value of recalls was defined as the percentage of screen-detected breast cancer cases detected among recalls, and positive predictive value of needle biopsies as the percentage of screen-detected breast cancer detected among needle biopsies performed at recall assessments. Histopathologic tumour characteristics for invasive tumours included tumour diameter (≤10

mm, >10-≤20 mm and >20 mm), histologic grade (1, 2 and 3), lymph node involvement (positive/negative), and estrogen receptor, progesterone receptor, and human epidermal growth factor receptor 2 status (positive/negative).

Information about breast characteristics and breast compression parameters was derived by an automated software for breast density assessment, Volpara®Density™ (version 15.1; Volpara Health Technologies Ltd, Wellington, NZ).[15] BreastScreen Norway supplied information about screening examinations, including recall, biopsies, cancer detection, and histopathologic tumour characteristics.

Descriptive statistics were used to compare distributions of age, breast characteristics, breast compression parameters, and early performance measures, including histopathologic tumour characteristics, by screening unit. We presented means and standard deviation or median and interquartile range, depending on the nature of the variable being described. We calculated 95% exact (Clopper-Pearson) confidence intervals (CI) for the proportions associated with the histopathologic tumour characteristics.

Analyses of early performance measures and histopathologic tumour characteristics of screen-detected and interval breast cancer were presented as rates per 100 screening examinations. The independency assumption for standard regression models was violated because more than one screening examination could be included per woman, and as some variables changed over time. Univariable generalized estimating equations (GEE) for binary outcomes with log link function were therefore used to analyze crude differences in the two units.

Using a multivariable GEE for continuous outcomes, we modelled the relationship between compression force and pressure (outcomes of interest), and screening unit (stationary or mobile), adjusted for age (two-year groups), mean values of breast volume and VBD. Using a uni- and multivariable GEE for a binomial regression model with a log link function, we estimated the crude and adjusted odds ratios (OR) and 95% CIs for the outcome of interest, recall, screen-detected, and interval breast cancer when screening at a mobile versus a stationary unit (reference). Covariates in the adjusted models included five-year age groups (<55, 55-59, 60-64 and >64), quartiles of breast volume, and VDG (1-4).

We used STATA version 15 (Stata Corp, TX) for all statistical analyses. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean ages of women screened at the stationary unit and at the mobile unit were 59 and 60 respectively ($p<0.01$, Table 1). The mean breast volume was statistically lower for those screened at the stationary versus mobile unit (780 cm^3 versus 886 cm^3), while the mean volumetric breast density (5.4% versus 4.5%) and fibroglandular volume (41.1 cm^3 versus 39.5 cm^3) were higher at the stationary unit ($p<0.01$ for all). The mean compression force and compressed breast thickness were statistically lower at the stationary unit than the mobile unit (115.5 N versus 116.6 N and 57.1 mm versus 60.0 mm, respectively), while the mean compression pressure was higher (12.0 kPa versus 11.5 kPa) at the stationary unit ($p<0.01$ for all).

The unadjusted recall and biopsy rates were higher among women screened at the stationary versus the mobile unit (3.7% versus 3.2%; and 1.8% versus 1.5%, respectively), although the unadjusted rates of screen-detected and interval breast cancer did not differ statistically (Table 2). Based on the CI for the estimated proportions, we did not observe any statistical differences in histopathologic tumour characteristics for women diagnosed with screen-detected breast cancer after screening at the stationary versus the mobile unit (Table 3). Interval breast cancer diagnosed after screening at a stationary unit was more likely to be ≤10mm (21.0% versus 6.8%) and less likely to be grade 2 (23.4% versus 42.6%) than interval breast cancer detected after screening at mobile units (Table 3). No other tumour histopathology differed between these two groups.

The adjusted odds of recall, screen-detected breast cancer, and interval breast cancer did not differ between the two units (OR 0.94, 95% CI: 0.88-1.01; OR 0.93, 95% CI: 0.78-1.09; and OR 1.17, 95% CI: 0.83-1.64 respectively; $p=0.02$; Table 4).

After adjusting for breast volume and VBD, the estimated compression force increased by age, while pressure decreased by age. Compression force was higher and the compression pressure was lower for women of all ages screened at the stationary unit compared with the mobile unit (Figure 2a and 2b).

DISCUSSION

This study is, to our knowledge, the first to compare breast characteristics, breast compression parameters, and early performance measures for screening at a stationary and mobile unit in a population-based breast cancer screening program. We observed that women screened at the stationary unit had smaller breasts, with higher mammographic density, than women screened at the mobile unit. Lower compression force and higher compression pressure was used at the stationary unit. The adjusted ORs for recall, screen-detected, and interval breast cancer did not differ between the two units. Histopathologic tumour characteristics did not differ between the two groups, except for less prognostically favourable tumour diameter and histologic grade for interval breast cancer among women screened at the mobile unit. Given that the mobile unit primarily serves the rural population, sociodemographic factors might be useful to consider as future stratification variables for early performance measures and personalized mammographic screening.

Studies have shown that women living in urban areas have a higher incidence of breast cancer than those in rural areas.[7,17,18] Our study does not corroborate these findings, as we failed to observe a statistical difference in the rates of screen-detected interval breast cancer among women screened at a stationary (urban) or mobile (rural) unit. Women attending the stationary unit in our study had smaller and more mammographically dense breasts than women attending the mobile unit, which indicates that they have different risk for breast cancer, however, small breast volume is also associated with low body mass index (decreased risk of breast cancer in post-menopausal women) and high mammographic density (increased risk of breast cancer).[11,19] These two effects may counterbalance each other. Additionally, more accessible mammographic screening has been proposed as a possible explanation for higher

breast cancer incidence in urban populations.[20] In our population-based screening program, all invited women receive an offer for screening with a fixed place and time for examination. The screening location is based on residential addresses, and the program aims to keep the one-way travel time to the screening unit below one hour. The criteria for the assigned location for examination might thus reflect sociodemographic differences among women invited to stationary versus mobile units in Norway. In 2019, the average travel time from a central point in the womens' residential locales is 25 minutes to the stationary unit and 16 minutes to the mobile unit in Hordaland. For those recalled for further assessment, travel time to the breast centre are 25 minutes and 2 hours, respectively. Access to screening is similar for the women invited to the stationary or mobile units, which may also explain why we did not observe any statistical difference in cancer detection between these two groups. However, women screened at the mobile unit had interval breast cancer with larger tumour diameter and a higher histologic grade compared with those screened at the stationary unit. This might indicate a higher threshold to seek clinical mammography for women living in the rural area.

Several studies have shown that different lifestyle and distributions of sociodemographic factors among women living in urban versus rural areas are associated with breast cancer risk.[7,21,22] A Norwegian study from 2005 reported a lower risk of breast cancer in women residing in rural compared with urban areas, even after adjusting for sociodemographic factors[4], however, this study included women aged 30-62 and the study period was before the startup of BreastScreen Norway. Our results, based on screened women, did not support these findings. BreastScreen Norway is administered centrally and ensures that all women have equal access to screening, follow-up, and treatment, independent of residential area and baseline risk factors. Our study showed that women living in urban and rural areas had similar risk for screen-detected and interval breast cancer, which we attribute to the implementation

of the screening program. Other studies have reported more advanced breast cancer among those screened at mobile units[17], which was partly observed for interval breast cancer in our study.

By offering screening at mobile units, BreastScreen Norway reaches women in their local area, which results in a higher attendance rate than for those invited to stationary units.[1] However, screening at a mobile unit faces some difficulties. In BreastScreen Norway, obtaining image storage and reading stations compatible with the systems at stationary locations has been a challenge. The costs of procuring, maintaining, administering, and driving the unit to strategic locations based on the average journey for women in those areas must be considered in relation to the benefits. Locations for the mobile unit require access to electricity and washroom facilities, amongst other considerations. In addition, access to and the expenses associated with trained radiographers who are willing to travel and stay away from home for longer periods can also be problematic.

Our study found that the compression force increased by age, while the pressure decreased. This could be explained by increased breast volume by age.[23] We also found that lower compression force and higher pressure was applied to women screened at the stationary unit, compared with the mobile unit. Women at the stationary unit has smaller breasts. This supports previous findings that breast characteristics influence breast compression parameters.[10] Continuous surveillance of early performance measures, stratified by screening unit (as a proxy for urban and rural areas) might, therefore, advance our knowledge about early performance measures in mammographic screening. This type of analysis can also improve knowledge about breast cancer risk factors, which is relevant in the progress and development of stratified screening for breast cancer. Stratified breast cancer screening based

on breast cancer risk factors has been proposed to improve breast cancer screening effectiveness.[24] Mammographic density is one of the primary candidates to stratify screening protocols, but this study shows that residential areas might also be a useful candidate for stratified screening. However, stratified screening is a complex issue due to the vast number of factors that must be considered, including the practical consequences.[25]

Our study was based on data from one county in Norway and had stringent exclusion criteria. For example, we only included examinations with four standard images, even though women with larger breasts can require additional exposures to image the entire breast when a standard-sized detector is used. The mammographic equipment used at the stationary unit from January 2008 to October 2014 only had a standard-sized image detector, while the equipment used at the mobile unit for the whole study period, and at the stationary unit from November 2014 to December 2017, offered the standard and a larger image detector. Women with larger breasts who obtained more than four images per examination were excluded, which would result in a lower average breast volume.

To ensure validity of the data, we only included screening examinations performed by radiographers with experience from both the stationary and mobile unit (more than 100 examinations per unit). Several radiographers had performed a high number of examinations at the stationary unit, but had never worked at the mobile unit, and so a larger proportion of examinations performed at the stationary versus the mobile unit was excluded, although this probably had a negligible effect on the outcomes of this study. In addition, due to an administrative change in the invitation process, we also excluded women who attended both the stationary and mobile units during the study period.

Because radiologists are aware that women screened at the mobile unit experience longer travel times, they may increase their screening sensitivity to avoid undue inconvenience among women living in more rural areas. We observed a lower recall rate for women screened at the mobile unit, but this effect disappeared in adjusted analyses, suggesting that women receive comparable care independent of residential area.

CONCLUSIONS

This is the first study comparing breast characteristics, breast compression parameters, and early performance measures for women screened at a stationary versus a mobile unit in a population-based screening program for breast cancer. Women screened at the stationary unit had a lower mean breast volume and higher VBD than women screened at the mobile unit. Early performance measures were comparable for the two units, except for two parameters related to histopathologic characteristics of interval breast cancer. Despite this, we consider that the results indicate comparable quality of care for women screened at the two units. Our results could be relevant for personalized screening protocols in the future. Further research on this topic should include data from other counties, and examine sociodemographic factors in depth, to fully understand the effects of mammographic screening in women residing in urban versus rural areas.

Declaration of conflicting interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Solveig Hofvind has permanent employment as a researcher at the Cancer Registry of Norway, independent of her job as the administrative leader of BreastScreen Norway.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sector.

REFERENCES

1. Hofvind S, Tsuruda K, Mangerud G, et al. The Norwegian Breast Cancer Screening Program, 1996-2016: Celebrating 20 years of organised mammographic screening. In: Cancer in Norway 2016 - Cancer incidence, mortality, survival and prevalence in Norway. Oslo: Cancer Registry of Norway, 2017
2. European Commission Initiative on Breast Cancer. http://ecibc.jrc.ec.europa.eu/recommendations/. Cited July 2019.
3. Perry N, Broeders M, deWolf C, Tönberg S, Holland R, von Karsa L. European guidelines for quality assurance in breast cancer screening and diagnosis. 2006; Brussels, Belgium: European Communities. ISBN 92-79-01258-4
4. Robsahm TE, Tretli S. Weak associations between sociodemographic factors and breast cancer: possible effects of early detection. *European journal of cancer prevention : the official journal of the European Cancer Prevention Organisation (ECP)* 2005; 14(1): 7-12.
5. Faggiano F, Zanetti R, Costa G. Cancer risk and social inequalities in Italy. *Journal of epidemiology and community health* 1994; 48(5): 447-52.
6. Pukkala E, Weiderpass E. Time trends in socio-economic differences in incidence rates of cancers of the breast and female genital organs (Finland, 1971-1995). *International journal of cancer* 1999; 81(1): 56-61.
7. Robert SA, Strombom I, Trentham-Dietz A, et al. Socioeconomic risk factors for breast cancer: distinguishing individual- and community-level effects. *Epidemiology (Cambridge, Mass)* 2004; 15(4): 442-50.
8. Ewertz M, Duffy SW, Adami HO, et al. Age at first birth, parity and risk of breast cancer: a meta-analysis of 8 studies from the Nordic countries. *International journal of cancer* 1990; 46(4): 597-603.
9. Kopans B. Breast imaging (3th ed). . *Philadelphia: Lippincott Williams & Wilkins a Wolters Kluwer business ISBN 0-7817-4768-6* 2007.
10. Moshina N, Roman M, Waade GG, Sebuodegard S, Ursin G, Hofvind S. Breast compression parameters and mammographic density in the Norwegian Breast Cancer Screening Programme. *European radiology* 2018; 28(4): 1662-72.
11. McCormack VA, dos Santos Silva I. Breast density and parenchymal patterns as markers of breast cancer risk: a meta-analysis. *Cancer epidemiology, biomarkers & prevention : a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 2006; 15(6): 1159-69.
12. Wanders JOP, Holland K, Karssemeijer N, et al. The effect of volumetric breast density on the risk of screen-detected and interval breast cancers: a cohort study. *Breast cancer research : BCR* 2017; 19(1): 67.
13. Kreftregisterforskriften. https://lovdata.no/dokument/SF/forskrift/2001-12-21-1477. Cited July 2019.
14. Hofvind S, Holen AS, Aase HS, et al. Two-view digital breast tomosynthesis versus digital mammography in a population-based breast cancer screening programme (To-Be): a randomised, controlled trial. *The Lancet Oncology* 2019; 20(6): 795-805.
15. VolparaSolution. https://www.volparasolutions.com/our-products/volparadensity/. Cited July 2019.
16. ACR BI-RADS Atlas® 5th Edition. https://www.acr.org/Clinical-Resources/Reporting-and-Data-Systems/Bi-Rads. Cited July 2019.

17. Nguyen-Pham S, Leung J, McLaughlin D. Disparities in breast cancer stage at diagnosis in urban and rural adult women: a systematic review and meta-analysis. *Annals of epidemiology* 2014; 24(3): 228-35.
18. Stamenic V, Strnad M. Urban-rural differences in a population-based breast cancer screening program in Croatia. *Croatian medical journal* 2011; 52(1): 76-86.
19. Hjerkind KV, Ellingjord-Dale M, Johansson ALV, et al. Volumetric Mammographic Density, Age-Related Decline, and Breast Cancer Risk Factors in a National Breast Cancer Screening Program. *Cancer epidemiology, biomarkers & prevention : a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 2018; 27(9): 1065-74.
20. Lynge E, Braaten T, Njor SH, et al. Mammography activity in Norway 1983 to 2008. *Acta oncologica (Stockholm, Sweden)* 2011; 50(7): 1062-7.
21. van den Brandt PA, Spiegelman D, Yaun SS, et al. Pooled analysis of prospective cohort studies on height, weight, and breast cancer risk. *American journal of epidemiology* 2000; 152(6): 514-27.
22. Linos E, Spanos D, Rosner BA, et al. Effects of reproductive and demographic changes on breast cancer incidence in China: a modeling analysis. *Journal of the National Cancer Institute* 2008; 100(19): 1352-60.
23. Waade GG, Sebuodegard S, Hogg P, Hofvind S. Breast compression across consecutive examinations among females participating in BreastScreen Norway. *The British journal of radiology* 2018: 20180209.
24. Desreux J, Bleret V, Lifrange E. Should we individualize breast cancer screening? *Maturitas* 2012; 73(3): 202-5.
25. Rainey L, van der Waal D, Donnelly LS, Evans DG, Wengstrom Y, Broeders M. Women's decision-making regarding risk-stratified breast cancer screening and prevention from the perspective of international healthcare professionals. *PloS one* 2018; 13(6): e0197772.

Figure legends

Figure 1: Number of examinations available for the study, exclusions and final study population

Figure 2: Compression force (A) and compression pressure (B) by screening unit (stationary/mobile) and two-year age groups, adjusted for breast volume and volumetric breast density, for screening examinations performed in BreastScreen Norway (Hordaland County), 2008–2017

N = Newton, kPa = kiloPascal

Table 1: Mean and standard deviation (SD), or median and interquartile range (IQR) for age, breast characteristics and compression parameters, by screening unit (stationary/mobile) for examinations performed in BreastScreen Norway (Hordaland County), 2008–2017

	Stationary unit n = 52,620	Mobile unit n = 39,788	Total n = 92,408	p-value[1]
Age [mean (SD) years]	59.0 (5.8)	60.0 (5.7)	59.4 (5.8)	<0.01
Breast volume [median (IQR) cm^3]	779.9 (534.7- 1062.9)	885.6 (610.4-1208.1)	822.9 (563.7-1125.7)	<0.01
Volumetric breast density [median (IQR) %]	5.4 (3.9-8.4)	4.5 (3.4-6.6)	5.0 (3.5-7.6)	<0.01
Fibroglandular volume [median (IQR) cm^3]	41.1 (31.7-54.8)	39.5 (30.9-51.6)	40.3 (31.3-53.4)	<0.01
Compression force [mean (SD) N]	115.5 (14.5)	116.6 (14.6)	116.0 (14.5)	<0.01
Compression pressure [mean (SD) kilopascal]	12.0 (3.7)	11.5 (3.9)	11.8 (3.8)	<0.01
Compressed breast thickness [mean (SD) mm]	57.1 (12.4)	60.0 (11.8)	58.3 (12.2)	<0.01

[1]Unadjusted GEE

Table 2: Frequencies and rates of early performance measures by screening unit (stationary/mobile) for examinations performed in BreastScreen Norway (Hordaland County), 2008–2017

	Stationary unit n = 52,620		Mobile unit n = 39,788		Total n = 93,408		p-value[2]
	n	Rate[1]	n	Rate	n	Rate	
Recall	1921	3.7	1270	3.2	3191	3.5	< 0.01
Biopsy	921	1.8	599	1.5	1520	1.5	< 0.01
Screen-detected breast cancer							
DCIS[3]	63	0.11	44	0.11	107	0.11	0.69
Invasive	278	0.53	192	0.48	470	0.50	0.33
Total	341	0.64	236	0.59	577	0.61	0.29
PPV-1[4]	-	17.8	-	18.9	-	18.1	0.56
PPV-2[5]	-	37.0	-	39.4	-	38.0	0.35
Interval breast cancer							
DCIS[3]	8	0.02	4	0.01	12	0.01	0.50
Invasive	72	0.13	56	0.14	128	0.12	0.87
Total	80	0.15	60	0.14	140	0.14	0.96

[1]Rate per 100 screening examinations
[2]Unadjusted GEE
[3]Ductal carcinoma in situ
[4]Positive predictive value of recall
[5]Positive predictive value of needle biopsy

Table 3: Distribution (%, 95% confidence intervals, CI) of histopathologic tumor characteristics of invasive screen-detected and interval breast cancer, by screening unit (stationary/mobile) for examinations performed in BreastScreen Norway (Hordaland County), 2008–2017

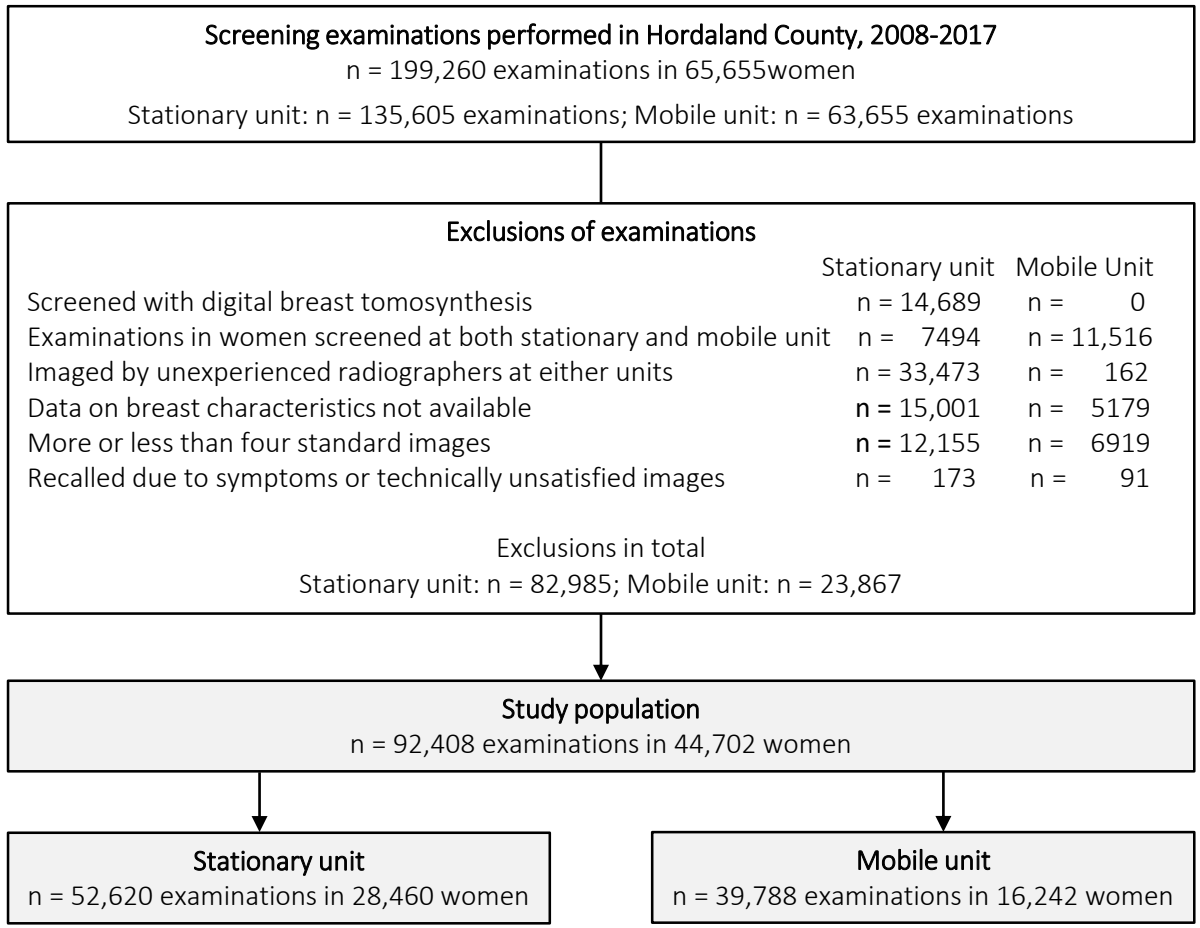
	Screen-detected breast cancer				Interval breast cancer			
	Stationary unit n = 278		Mobile unit n = 192		Stationary unit n = 72		Mobile unit n = 56	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Tumor diameter								
≤10 mm	31.0	(25.5-36.9)	36.0	(29.1-43.3)	21.0	(11.7-33.2)	6.8	(1.4-18.7)
>10 - ≤20 mm	46.1	(40.1-52.3)	45.0	(37.7-52.4)	38.7	(26.6-51.9)	45.5	(30.4-61.2)
>20 mm	22.9	(18.0-28.3)	19.0	(13.7-25.4)	40.3	(28.1-53.6)	47.7	(32.5-63.3)
Info not available (n)	7		3		10		12	
Histologic grade								
1	33.9	(28.3-39.9)	37.8	(30.8-45.2)	21.9	(12.5-34.0)	14.8	(6.2-28.3)
2	44.6	(38.6-50.8)	45.4	(38.1-52.9)	23.4	(13.8-35.7)	42.6	(28.3-57.8)
3	21.4	(16.6-26.8)	16.8	(11.7-22.9)	54.7	(41.7-67.2)	42.6	(28.3-57.8)
Info not available (n)	7		7		8		9	
Lymph node positive	17.5	(13.1-22.5)	12.6	(8.1-18.3)	31.7	(20.6-44.7)	39.6	(25.8-54.7)
Info not available (n)	9		9		9		8	
ER[1] positive	91.5	(87.6-94.6)	89.5	(84.2-93.5)	77.8	(66.4-86.7)	75.0	(61.6-85.6)
Info not available (n)	6		2		0		0	
PR[2] positive	77.6	(72.1-82.4)	72.6	(65.7-78.8)	65.3	(53.1-76.1)	57.1	(43.2-70.3)
Info not available (n)	6		2		0		0	
HER2[3] positive	7.3	(4.4-11.1)	10.9	(6.8-16.3)	16.2	(8.4-27.1)	15.4	(6.9-28.1)
Info not available (n)	16		8		4		4	

[1]Estrogen receptor
[2]Progesterone receptor
[3]Human epidermal growth factor receptor 2

Table 4: Crude and adjusted[1] odds ratios (OR) with 95% confidence interval (CI) of recall, screen-detected and interval breast cancer, by screening unit (stationary/mobile) for examinations performed in BreastScreen Norway (Hordaland County), 2008–2017

	Recall						Screen-detected breast cancer						Interval breast cancer					
	Crude			Adjusted			Crude			Adjusted			Crude			Adjusted		
	OR	95% CI[2]	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Screening unit																		
Stationary	1.00			1.00			1.00			1.00			1.00			1.00		
Mobile	0.87	0.82-0.94	<0.01	0.94	0.88-1.01	0.09	0.92	0.77-1.08	0.30	0.93	0.78-1.09	0.36	0.99	0.71-1.38	0.96	1.17	0.83-1.64	0.37
Age group																		
<55	1.00			1.00			1.00			1.00			1.00			1.00		
55-59	0.51	0.46-0.56	<0.01	0.52	0.48-0.58	<0.01	1.00	0.77-1.29	0.99	1.06	0.82-1.37	0.64	0.87	0.54-1.42	0.59	1.04	0.64-1.70	0.87
60-64	0.55	0.50-0.61	<0.01	0.58	0.53-0.64	<0.01	1.40	1.11-1.78	0.01	1.54	1.21-1.96	<0.01	1.18	0.75-1.86	0.47	1.55	0.98-2.45	0.06
>64	0.56	0.51-0.61	<0.01	0.59	0.54-0.65	<0.01	1.61	1.28-2.03	<0.01	1.82	1.44-2.29	<0.01	1.05	0.66-1.67	0.84	1.48	0.92-2.37	0.11
Breast volume																		
Quartile 1	1.00			1.00			1.00			1.00			1.00			1.00		
Quartile 2	0.92	0.84-1.01	0.08	1.00	0.90-1.10	0.95	0.95	0.76-1.21	0.72	1.09	0.85-1.39	0.50	1.08	0.69-1.70	0.73	1.76	1.10-2.81	0.02
Quartile 3	0.82	0.74-0.90	<0.01	0.95	0.85-1.05	0.32	1.04	0.83-1.31	0.73	1.31	1.02-1.69	0.04	1.00	0.63-1.59	0.99	2.23	1.35-3.69	<0.01
Quartile 4	0.82	0.75-0.91	<0.01	1.06	0.94-1.19	0.33	1.04	0.82-1.30	0.77	1.57	1.19-2.06	<0.01	0.81	0.49-1.31	0.39	2.71	1.55-4.75	<0.01
Volpara Density Grade																		
VDG 1	1.00			1.00			1.00			1.00			1.00			1.00		
VDG 2	1.42	1.28-1.59	<0.01	1.41	1.25-1.58	<0.01	1.66	1.27-2.17	<0.01	1.99	1.50-2.64	<0.01	3.23	1.39-7.48	0.01	4.20	1.78-9.90	<0.01
VDG 3	1.75	1.56-1.97	<0.01	1.60	1.40-1.84	<0.01	1.77	1.32-2.37	<0.01	2.58	1.85-3.60	<0.01	7.62	3.30-17.62	<0.01	14.52	5.93-35.55	<0.01
VDG 4	1.73	1.46-2.05	<0.01	1.47	1.21-1.77	<0.01	2.02	1.35-3.01	<0.01	3.29	2.09-5.18	<0.01	7.92	3.04-20.59	<0.01	19.55	6.89-55.44	<0.01

[1] Adjusted for age (five-year groups), quartiles of breast volume and Volpara Density Grade (VDG)


Screening examinations performed in Hordaland County, 2008-2017
n = 199,260 examinations in 65,655women
Stationary unit: n = 135,605 examinations; Mobile unit: n = 63,655 examinations
Exclusions of examinations
Stationary unit
Mobile Unit
Screened with digital breast tomosynthesis
n = 14,689
n = 0
Examinations in women screened at both stationary and mobile unit
n = 7494
n = 11,516
Imaged by unexperienced radiographers at either units
n = 33,473
n = 162
Data on breast characteristics not available
n = 15,001
n = 5179
More or less than four standard images
n = 12,155
n = 6919
Recalled due to symptoms or technically unsatisfied images
n = 173
n = 91
Exclusions in total
Stationary unit: n = 82,985; Mobile unit: n = 23,867
Study population
n = 92,408 examinations in 44,702 women
Stationary unit
n = 52,620 examinations in 28,460 women
Mobile unit
n = 39,788 examinations in 16,242 women

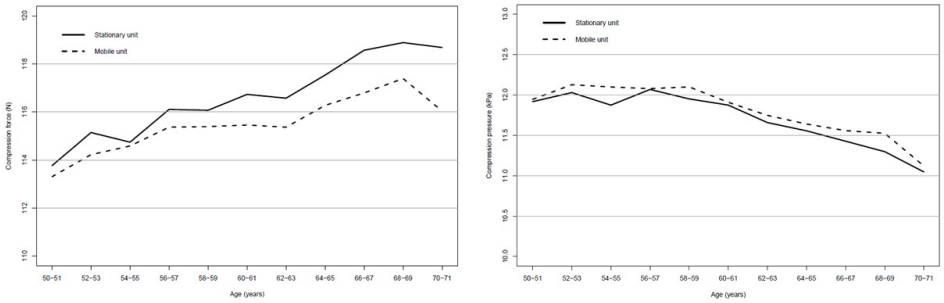


Figure 2: Compression force (A) and compression pressure (B) by screening unit (stationary/mobile) and two-year age groups, adjusted for breast volume and volumetric breast density, for screening examinations performed in BreastScreen Norway (Hordaland County) during 2008–2017

338x190mm (96 x 96 DPI)