Cost-Effectiveness Analysis of a Mobile Mammography Unit for Breast Cancer Screening to Reduce Geographic and Social Health Inequalities

Rémy de Mil, Elodie Guillaume, Ludivine Launay, Lydia Guittet, Olivier Dejardin, Veronique Bouvier, Annick Notari, Guy Launoy, Célia Berchi

Cost-effectiveness analysis of a mobile mammography unit for breast cancer screening to reduce geographic and social health inequalities

Rémy De Mil, M.D, MS[1,2], Elodie Guillaume, Ph.D[1], Ludivine Launay, MS[1], Lydia Guittet, M.D, Ph.D[1,2], Olivier Dejardin, Ph.D[1,2], Véronique Bouvier, M.D[1,2], Annick Notari, M.D[3], Guy Launoy, M.D, Ph.D[1, 2], Célia Berchi, Ph.D[1]

[1]U1086 INSERM-UCN, “ANTICIPE”, BP 5026, 14076 Caen Cedex 05, France

[2]University Hospital of Caen, 14033 Caen Cedex 9, France

[3]P.S.S. de l’Orne, 61016 Alençon, France

Correspondence to: R. DE MIL, “ANTICIPE” U1086 INSERM-UCN, Pôle Recherche CHU CAEN, Centre François Baclesse, 3 Avenue du Général Harris, BP 5026, 14076 Caen Cedex 05, France.

Tel: +33 2 31 45 82 91; E-mail: remy.demil@unicaen.fr

No funding

Keywords: Cost-effectiveness analysis; mobile mammography; breast cancer screening; social inequalities; geographic inequalities.

Running title: Economic evaluation of a mobile mammography

Summary: This article documents the issue of the efficiency of a mobile mammography unit to reduce geographic and social inequalities in breast cancer screening.

Word count: 3,987

Abstract word count: 238

Number of

- **Manuscript pages:** 21
- **Supplementary file :** 1
- **References:** 41
- **Tables:** 5
- **Figures:** 1

Cost-effectiveness analysis of a mobile mammography unit for breast cancer screening to reduce geographic and social health inequalities

ABSTRACT

Objectives: To determine the cost-effectiveness of a mobile mammography program to increase participation in breast cancer screening and reduce geographic and social inequalities. **Methods:** A cost-effectiveness analysis from retrospective data was conducted from the payer perspective, comparing an invitation to a mobile mammography unit or to a radiologist's office (MM or RO group) with an invitation to a radiologist's office only (RO group) (n=37,461). Medical and nonmedical direct costs were estimated. Outcome was screening participation. The mean incremental cost and effect, the incremental cost-effectiveness ratio, and the cost-effectiveness acceptability curve were estimated. **Results:** The mean incremental cost for invitation to MM or RO was estimated to be EUR 23.21 (95% CI, 22.64 to 23.78) compared with RO only, and with a point of participation gain of 3.8% (95% CI, 2.8 to 4.8), resulting in an incremental cost per additional screen of EUR 610.69 (95% CI, 492.11 to 821.01). The gain of participation was more important in women living in deprived areas and for distances exceeding 15 km from an RO. **Conclusion:** Screening involving a mobile mammography unit can increase participation in breast cancer screening and reduce geographic and social inequalities while being more cost-effective in remote areas and in deprived areas. Because of the retrospective design, further research is needed to provide more evidence of the effectiveness and cost-effectiveness of using a MM unit for organized breast cancer screening and to determine the optimal conditions for implementing it.

Keywords: Cost-effectiveness analysis; mobile mammography; breast cancer screening; social inequalities; geographic inequalities.

HIGHLIGHTS

- Adding an invitation to a mobile mammography unit to the usual invitation for breast cancer screening can increase participation and reduce geographic and social inequalities while being more cost-effective in remote areas and in deprived areas.

- Given the fact that organized screening is structured around radiologists' offices in France, the results have also health policy implications by showing that the deployment of a mobile mammography unit in organized breast cancer screening 15 km away from radiologists' offices can increase participation and reduce geographic and social inequalities while being more cost-effective.

INTRODUCTION

Breast cancer is the second most common cancer in France and the most common in women. It is the third cause of cancer deaths in France and the leading cause of cancer death in women. In 2017, there were an estimated 58 968 new cases and 11 883 deaths owing to breast cancer [1]. Breast cancer can be diagnosed at an early stage by mammography screening [2-5]. Organized screening has been offered in France since 2004 to all women aged 50 to 74 at moderate risk. It is based on a mammography and a breast clinical examination every two years. Recent meta-analyses and systematic reviews on the effectiveness of breast cancer screening report a reduction in breast cancer mortality of around 20% [6-11]. However, although screening mammography is reimbursed 100% by the French health insurance system and at least one screening reminder is sent by mail [12, 13], the national participation rate remains low. It was only 52% over the 2014-2015 period [14], which is much lower than the European guidelines of more than 70% [15], or even the objective of 65% set by the French Cancer Plan 2009-2013 [16].

Moreover, there is a social gradient to participation in breast cancer screening in many countries. A low socioeconomic status in terms of income, level of education, occupational status or health insurance, a low use of health services and belonging to an ethnic minority in some countries are negatively associated with participation in breast cancer screening [17-21]. In France, the odd of participating in breast cancer screening is 29% lower in the most deprived areas compared to the least deprived ones [22]. There are also geographic inequalities in breast cancer screening. Women living in rural areas and / or far away from mammography centers participate less in breast cancer screening [23-28]. In France, women living in rural areas and those living more than 15 minutes away from a screening center are respectively 13% and 9% less likely to participate compared with women living in urban areas or less than 15 minutes from a screening center [29].

Breast cancer screening can be delivered by mobile mammography units (MMU) which were first introduced to increase geographical access but also to reach deprived women. They are now implemented in breast cancer screening programs in several countries [30]. However, few studies have compared mammography screening adherence between MMUs and stationary sites. Results from a randomized controlled trial conducted by Reuben et al showed that the participation rate was significantly increased by 15 percentage points in the MMU group compared to fixed sites [31], whereas another randomized trial and an observational study did not find any difference in the participation rate between mobile and fixed sites [32,33]. Reuben et al also found that the participation rate was higher in participants assigned to the MMU in the subgroup of women with the lowest household income. Women who receive mammography in MMU also have a lower socioeconomic status, are less in contact with health services, live more in rural areas and are less adherent to mammography screening guidelines compared to those who receive it in fixed sites [34, 35].

MM services constitute a means of improving adherence to mammography screening guidelines and reducing geographic and social inequalities in participation in breast cancer screening. We previously reported results for women invited for the first time to undergo breast cancer screening in an MM program in the French department of Orne [36]. MMU was associated with a significant 18% percentage point increase in participation and a 3-fold higher odd of participating compared to fixed sites (60% versus 42%; odds ratio 2.9 (95% CI, 2.7 to 3)). Furthermore, in the population invited to MMU, there was no longer any difference in participation according to the distance to fixed mammography sites, as well as between the most deprived and the least deprived women. The present article reports the cost-effectiveness analysis of this MM program in the French department of Orne conducted from the payer perspective.

METHODS

Setting and population

This was a retrospective study that evaluated the impact of an MM program among the target population for breast cancer screening. The study took place in the French department of Orne in North West France and ran from May 2011 to December 2012, corresponding to screening round number 9 (N = 37,461 women), i.e. a little shorter than the 2-year duration of a screening round. According to the data from INSEE (Institut National de la Statistique et des Etudes Economiques), Orne is a rural department with a population in 2012 comprising 290,015 inhabitants, older than the national population and with a poverty rate 1% higher than the national population.

An MMU has been in use in Orne since 1992. It is parked in 109 different places throughout the department, mostly in rural areas, far from radiologists' offices (RO), and evenly distributed around the department. Screening followed national guidelines whether at certified RO or at the MMU. Every woman aged 50–74 years was invited to receive a free mammogram every 2 years with a reminder sent after 6 months. Breast cancer screening included a breast clinical examination and a double reading of all negative screens with immediate diagnostic assessment in the event of a positive result [12, 13]. The program was implemented at local level by a screening management department.

Invitation to screening offered the choice to women living in an administrative district covered by the parking area of the MMU to perform screening either at the RO or in the MMU (MM or RO group), while the other women were invited only to the RO (RO group). For each woman, information regarding age, address, and modality (RO or MM unit) of the mammography, if performed, was collected. The socioeconomic status of the place of residence of each woman was assessed using an aggregated deprivation index, the French version of the European Deprivation index (EDI) [37], and we calculated the road distance between the participant's place of residence and the nearest RO.

Effect estimation

The primary outcome was participation rate, i.e. mammography performed or not.

Cost estimation

Cost analysis was performed in EUR 2012 from the perspective of the payer of breast cancer screening, which are the French State and the French Health Insurance System. Costs considered in the analysis were medical and nonmedical direct costs and were grouped into one of the following categories: MM unit, renting the screening management premises, staff, mailing of invitation letters and reminders, equipment and operating costs including maintenance, mammograms performed at the RO, and other costs. Table 1 shows the unit cost for the main cost components. Cost data were estimated retrospectively from the accounting file of the year 2012 of the screening management department and from literature data. Costs in US dollars from literature data were converted into Euro of the same year and then inflated to EUR 2012 using the consumer price index. Further details about cost estimation and sensitivity analyses are presented in the supplementary material (Appendix 1).

Mobile mammography unit

Costs relative to the MMU included the van, the digital mammograph, and a radiology laser imager. The one-time cost of the van was EUR 460,000, EUR 190,000 for the digital mammograph, and estimated at EUR 19,105 for the radiology imager [38]. The van and the mammography equipment were considered capital purchases, and only the depreciation time over a 7-year period was incorporated into the analysis.

Staff

The MMU worked 47 weeks a year, 4 or 5 days a week, i.e. between 188 and 235 days a year. Inside the MMU, staff included a full-time equivalent (FTE) secretary, 2.8 FTE radiographers , a physician to perform breast clinical examination, usually a retired gynecologist or general practitioner, and a driver. The MMU also required personnel outside the MM van for screening management: a FTE secretary, radiologists' fees for the first and second reading of mammograms, and a 0.2 FTE physician responsible for screening management. The cost of women invited only to RO involved the following: a 0.8 FTE secretary in screening management, radiologists' fees for the second reading only of mammograms, and a 0.4 FTE physician responsible for screening management (Table 1).

Equipment and operating costs

Equipment and operating costs for both the MMU and the screening management department included renting computers and software, office supplies, maintenance of computers, electricity, and telecommunication costs. There was also supplementary expenditure for the MMU: films, medical supplies, annual insurance for the MM van, renting of a garage, fuel, maintenance of the MM van and radiology equipment, and a car to take the staff from the screening management department to the MMU and then bring them back. Annual electricity costs for the MMU were estimated at EUR 3,730 [38]. Cost of fuel was estimated on the basis of an annual distance of 16,000 kilometers. Cost of the car transporting the staff was considered a capital purchase, and only the depreciation time over a 7-year period was incorporated into the analysis.

Mammography performed in radiologist's office

The act of mammography in RO included the mammography itself, the first reading and the breast clinical examination. Since 2005, the unit cost has been EUR 66.42.

Incremental cost-effectiveness ratio (ICER)

A cost-effectiveness analysis of invitation to MM or RO versus invitation to RO (usual screening) was conducted from the payer perspective. The time horizon was approximately 2 years, i.e. the duration of a screening round. The incremental cost-effectiveness ratio (ICER) represents the incremental cost per additional screen of the invitation to MM or RO compared with invitation to RO only. The ICER was computed by dividing the incremental cost per woman invited by the incremental effect (percentage increase in participation).

We also performed a subgroup analysis to assess whether the invitation to MM or RO was more cost-effective for the women the most distant from an RO (≥ 15 km versus < 15km) and for women living in the most deprived areas (Q4Q5 versus Q1Q2Q3).

Sensitivity analysis

Sensitivity of the ICER was assessed by evaluating the impact of variations in some factors that could modify the estimation of costs or effectiveness. The following sensitivity analysis (SA) were performed: change in the incremental effectiveness (SA 1, bounds of the 95% CI), change in the incremental cost (SA 2, bounds of the 95% CI; SA 3, +/- 20% in MMU-related costs), change in staff number (SA 4 , 1.8 FTE radiographer because after December 2012, the number of FTE of radiographers decreased from 2.8 to 1.8 in the MMU without disrupting its functioning), change in equipment and operating costs (SA 5, +/- 20%), change in time horizon (SA 6, because the screening round didn't last exactly 24 months but only 20 months and since cost components were measured over 24 months except mammograms performed at RO, we increased proportionally the number of women invited and we similarly proportionally increased this cost , assuming that the screening rate over 24 months was the same as the one observed on 20 months), and finally change in the percentage of women invited to RO or MM who chose to receive screening in the MMU (SA 7, 100% and 80%).

Statistical analysis

All variables except cost data were categorized. Age was divided into five-year age groups, EDI score into quintiles (Q1 least deprived, Q5 most deprived), and distance to RO into 5-kilometers groups. Baseline characteristics and participation rate were compared between the two groups with a chi-square test for homogeneity. In each group, we also performed a Cochran-Armitage trend test and/or chi-square test for homogeneity on the participation rate according to the deprivation and the distance.

Because of the large sample size in each group, the mean cost per woman invited to each modality was compared with a Student t-test. Comparison was also performed with a nonparametric percentile bootstrap as a statistical sensitivity analysis.

Two-tailed tests were used with an alpha level set at 0.05.We obtained a 95% confidence interval (CI) for the ICER and a cost-effectiveness acceptability curve (CEAC) using a nonparametric percentile bootstrap technique, a method that requires no assumptions about the sampling distribution of the ICER. Bootstrapped cost and effectiveness were obtained and plotted in the cost-effectiveness plane by sampling 10,000 samples of the same size as the study sample with replacement, and by determining the cost and effectiveness of each one [39]. Analyses were conducted with the use of R statistical software, version 3.4.4, and Microsoft Excel 2010. The 'bcea package' was used for the CEAC.

RESULTS

Study population

37,461 women were invited to breast cancer screening from May 2011 to December 2012. 20,968 (56.0%) were invited only to RO and 16,493 (44.0%) to RO or MM. Table 2 shows that women invited to MMU were older ($p<0.001$), lived more in areas with a deprivation quintile of 3 or 4 ($p<0.001$) and farther from an RO ($p<0.001$).

Effectiveness

Table 3 presents outcomes for both groups. Overall 58.2 % of women invited to breast cancer screening received mammography screening. Invitation to MM or RO was associated with a significant 3.8 % percentage point increase in participation ($p<0.001$ and 95% CI, 2.8% to 4.8%) (60.4% in MM or RO group versus 56.6% in RO group). In the MM or RO group, 93.8% of women chose to receive screening in the MMU.

Participation in the RO group decreased significantly and linearly with both an increase in deprivation and an increase in the distance to RO (p-trend < 0.001 for both). A 9 % difference in participation was observed between women living in the least deprived areas and those living in the most deprived areas (61.2% versus 52.2%). For remoteness, participation was higher for women living between 5 and 10 kilometers from an RO and lower in women living between 20 and 25 kilometers (61.4% versus 48.7%). In the MM or RO group, there was no longer a significant trend (p-trend = 0.481 for deprivation and 0.863 for remoteness), but there was a significant association between participation and both deprivation and remoteness (p for homogeneity respectively 0.002 and 0.001). Participation was higher in women living in areas with a deprivation quintile of 3 or 4. The relationship between distance to the nearest RO and participation was non-monotonic, with a moderate travel distance of 10-15 km associated with lower participation.

Costs

Table 4 presents the use of resources in both groups. The total cost for the screening round was EUR 1,053,174.70 and EUR 1,211,151.00 respectively for the RO group and the MM or RO group. In the RO group, mammograms performed in RO accounted for 75% of the total cost. In the MM or RO group, about 30 women per day came to the MMU and 65% of the total cost was related to staff and 16% to the MMU. Individual cost ranged from EUR 9.83 for women invited to RO who did not receive screening to EUR 135.85 for women invited to MM or RO who received it in an RO, and was EUR 64.41 for women invited to MM who did not receive screening, EUR 75.63 for women invited to MM who received screening in the MMU and EUR 81.27 for women invited to RO who received screening. Mean cost per woman invited was significantly higher in the MM or RO group by EUR 23.20 (95% CI, 22.64 to 23.78; $p<0.001$) (EUR 73.43 versus EUR 50.23). The result was similar with the nonparametric percentile bootstrap (95% CI, 22.68 to 23.73).

Cost-effectiveness analysis

Table 5 presents estimates of the mean incremental cost and incremental effect (increase in participation rate) and results of the sensitivity analysis. The incremental cost per additional screen of the invitation to MM or RO compared with invitation to RO only was EUR 610.69 (95% CI, 492.11 to 821.01). In terms of uncertainty, 100 % of the cost-effect pairs on the cost-effectiveness plane were located in the north-east quadrant, where the invitation to MM could be estimated to have both a higher mean cost and a higher mean effectiveness (Figure 1). According to the CEAC (Figure 1), the probability that the invitation to MM or RO was more cost-effective than invitation to RO only was 50%, 75%, 90%, more than 99% and 100% respectively at EUR 612, 669, 732, 876 and 1,242 per additional screen. Subgroup analysis also showed that invitation to MM or RO was more cost-effective for women living more than 15 km away from an RO compared with those living less than 15 km (ICER EUR 289.57 versus EUR 923.07 per additional screen), as well as for women living in the most deprived areas (ICER EUR 347.92 versus EUR 15,235.47 per additional screen).

Results were sensitive to the effectiveness of the MMU to increase participation (SA 1; ICER increased by 34% and decreased by 20% respectively for a mean difference of 0.048 and 0.028), to the percentage of women invited to the MM who received screening in the MMU (SA 7) and less to the MMU-related costs (SA 3).

4. DISCUSSION

Main findings

Our results show that an invitation to an MMU led to a significant 3.8 % percentage point increase in participation in breast cancer screening compared with the usual screening procedure inviting women only to a certified RO. Moreover, the MMU contributed to reducing geographic and social inequalities with a gain of participation more important in women living in areas with a deprivation quintile of 4 or 5, and for distances exceeding 15 km from an RO. This result underlines the geographic rationale of operating an MMU away from ROs in order to reach remote women while taking into account the fact that organized screening in France is structured around ROs. Participation also increased in women living less than 5 km from an RO. However, this may be explained by the fact that 58% of women living less than 5 km from an RO lived in a deprived area (Q4 or Q5). Indeed, the increase in participation was greater for these women, and we previously reported that a MMU allowed annulling the difference in participation between the least deprived and the more deprived women independently of the distance [36]. Our findings also show that women invited to MM or RO preferred the MMU in 93.8% of cases. These results were obtained at a mean cost per woman invited that was significantly higher by EUR 23.20 (95% CI, 22.64 to 23.78) compared with invitation to an RO only. The incremental cost per additional screen (ICER) of the invitation to an MM or an RO compared with an invitation only to an RO was EUR 610.69 (95% CI, 490.17 to 813.47). According to the CEAC, there was only a 10% chance at a willingness-to-pay threshold value of EUR 735 per additional screen of making the wrong decision by implementing the MM program. The invitation to MM or RO was also more cost-effective for women living more than 15 km from an RO (ICER EUR 289.57 per additional screen) and for women living in deprived areas (ICER EUR 347.962 per additional screen). These results are due to a greater increase in participation in women living in these areas. This again highlights the value of operating an MMU in areas further than 15 km from the nearest RO and shows that an MMU can reduce geographic and social inequalities while being more cost-effective in remote and deprived areas. The ICER value of 610.69 is probably high. Indeed, sensitivity analysis of the current organization of the MMU in Orne with 1.8 FTE radiographer showed that the ICER decreased by 22%. Likewise, because effectiveness and costs were not measure on the exact same duration, the cost of the mammography performed at the RO was underestimated essentially in the RO group, and the ICER therefore decreased by 42% when we extrapolated effectiveness over 24 months. The MMU was also more cost-effective when the effectiveness increased and when the percentage of women invited to the MMU who received screening in it increased, provided that the maximum number of screenings per day in the MMU was not exceeded. This was not the case since about 30 women per day were screened for a maximum capacity of about 60. Finally, because the MMU-related cost accounted for 16 % of the total cost, a 20% variation of the MMU-related cost impacted moderately the cost-effectiveness of the MMU.

Comparisons with other studies

Only two studies performed an economic evaluation of an MMU, but only one with participation rate as outcome [38, 40]. Naeim et al performed a cost-effectiveness analysis from a randomized trial in the United States comparing health education only with health education plus MMU [38]. For a capacity of 20 participants per day in the MMU and 40 per day in the RO, the mean incremental cost per woman screened was USD 61 (USD 102 in the mobile group and USD 41 in ROs), the incremental effect of 15 participation points in favor of MMU and the ICER of USD 264 per additional screen. In sensitivity analysis, the ICER decreased to USD 78 per additional screen with a volume of 40 participants per day, i.e. the maximum capacity of the MMU. The incremental cost per additional screen we found is globally higher due to a lower incremental effect, and was close to it for women living more than 15 km from an RO. We also found that MMU was more cost-effective when all women invited to MM or RO performed screening in the MMU.

Strengths and limitations

The main strength of this study is that very few economic evaluations of MMUs exist to date and none in France to our knowledge.

There are also some limitations. First, using retrospective cost data from the accounting file of the screening management department and from literature data could have led to some imprecision in estimating some cost components. Second, the relatively short study period did not allow us to consider overall survival as an outcome, as recommended by current guidelines [41].

Nevertheless, screening adherence can be considered a good intermediate endpoint because increase in participation in breast cancer screening is associated with a reduction in breast cancer mortality [6-11]. Third, the cost-effectiveness analysis was conducted from the perspective of the payer of the breast cancer screening in order to measure the extra resources required for implementing alternative methods in screening organization. Direct medical costs for women and indirect costs were therefore not considered in the analysis, even they could be not negligible. Complementary examinations of the immediate diagnostic assessment, if needed, in particular breast ultrasound, are indeed reimbursed only 70%. Finally, the main limitation of the study is its retrospective design and the sociodemographic differences between the two groups compared. Since the aim of the MMU is to offer screening to women who live far from ROs, women invited to it were older, lived more in areas with a deprivation quintile of 3 or 4 and farther from an RO. Such an imbalance between groups could lead to a bias in estimating the mean incremental effect, and consequently the mean incremental cost and the ICER. The model with adjusted ICER was unfortunately non-contributive and insufficiently discriminant (data not shown), so we could only provide a crude ICER. This limitation testifies to the need for a proper randomized study.

Conclusions

This economic evaluation conducted in the general population concerned by breast cancer screening shows that a mobile mammography unit was more effective in terms of screening adherence compared with usual screening in a radiology office, had a higher cost per woman invited to screening, and could reduce geographic and social inequalities in participation in screening while being more cost-effective in remote areas and in deprived areas. The retrospective design of the study makes it necessary to perform further research using an experimental design to provide further evidence of the effectiveness, cost and cost-effectiveness of a mobile mammography unit, as well as to determine the optimal conditions in which a mobile mammography unit may be used for breast cancer screening.

Conflicts of interest

No author has any conflict of interest with respect to the data, results, or their interpretation in the manuscript.

Competing interests

The authors declare that they have no competing interests.

REFERENCES

1. Jéhannin-Ligier K, Dantony E, Bossard N, et al. Projection de l'incidence et de la mortalité par cancer en France métropolitaine en 2017. Rapport technique. Saint-Maurice : Santé publique France, 2017. French.

2. Miller JW, Royalty J, Henley J, et al. Breast and cervical cancers diagnosed and stage at diagnosis among women served through the National Breast and Cervical Cancer Early Detection Program. Cancer Causes Control. 2015;26(5):741-7.

3. Verdial FC, Etzioni R, Duggan C, et al. Demographic changes in breast cancer incidence, stage at diagnosis and age associated with population-based mammographic screening. J Surg Oncol. 2017;115(5):517-522.

4. Seneviratne S, Lawrenson R, Harvey V, et al. Stage of breast cancer at diagnosis in New Zealand: impacts of socio-demographic factors, breast cancer screening and biology.BMC Cancer. 2016; 16:129.

5. Hofvind S, Lee CI, Elmore JG. Stage-specific breast cancer incidence rates among participants and non-participants of a population-based mammographic screening program Breast Cancer Res Treat. 2012;135(1):291-9.

6. Nelson HD, Cantor A, Humphrey L, et al. Screening for Breast Cancer: A Systematic Review to Update the 2009 U.S. Preventive Services Task Force Recommendation. Agency for Healthcare Research and Quality (US); 2016 Jan. Report No.: 14-05201-EF-1.U.S.

7. Marmot MG1, Altman DG, Cameron DA, et al. The benefits and harms of breast cancer screening: an independent review. Br J Cancer. 2013; 108(11):2205-40.

8. Breast Cancer Screening IARC Handbook of Cancer Prevention Volume 15 [Internet]. 2016 [accessed December 20, 2018]. Available from: http://publications.iarc.fr/Book-And-Report-Series/Iarc-Handbooks-Of-Cancer-Prevention/Breast-Cancer-Screening-2016.

9. Tabár L, Yen AM, Wu WY, et al. Insights from the breast cancer screening trials: how screening affects the natural history of breast cancer and implications for evaluating service screening programs. Breast J. 2015;21(1):13-20.

10. Gøtzsche PC1, Jørgensen KJ. Screening for breast cancer with mammography. Cochrane Database Syst Rev. 2013 Jun 4;(6):CD001877.

11. Myers ER, Moorman P, Gierisch JM, et al. Benefits and Harms of Breast Cancer Screening: A Systematic Review. JAMA. 2015;314(15):1615-34.

12. Haute Autorite de Santé (France). Dépistage et prévention du cancer du sein. Actualisation du référentiel de pratiques de l'examen périodique de santé (EPS) [Internet]. 2015 Feb [accessed December 20, 2018]. Available from: https://www.has-sante.fr/portail/jcms/c_2024559/fr/depistage-et-prevention-du-cancer-du-sein.

13. Journal officiel de la république française. Arrêté du 29 septembre 2006 relatif aux programmes de dépistage des cancers. [Internet].2006 Sep. [accessed December 20,

2018].Available
from:https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000460656.

14. Santé Publique France (France).[Internet]. 2018 [accessed December 20, 2018]. Available from: http://invs.santepubliquefrance.fr/Dossiers-thematiques/Maladies-chroniques-et-traumatismes/Cancers/Donnees-par-localisation/Cancer-du-sein.

15. Perry N, Broeders M, de Wolf C, et al. European guidelines for quality assurance in breast cancer screening and diagnosis fourth edition [internet]. 2006 [accessed December 20, 2018]. Available from: http://www.euref.org/european-Guidelines.

16. Institut national du cancer (France). Plan cancer 2014-2019 [Internet]. 2015 Feb [accessed December 20, 2018]. Available from: https://www.e-cancer.fr/Plan-cancer/Plan-cancer-2014-2019-priorites-et-objectifs.

17. Damiani G, Basso D, Acampora A, et al The impact of level of education on adherence to breast and cervical cancer screening: Evidence from a systematic review and meta-analysis. Prev Med. 201;81:281-9.

18. Ahmed AT, Welch BT, Brinjikji W, et al. Racial Disparities in Screening Mammography in the United States: A Systematic Review and Meta-analysis. J Am Coll Radiol. 2017;14(2):157-165.

19. Dailey AB, Brumback BA, Livingston MD, et al. Area-level socioeconomic position and repeat mammography screening use: results from the 2005 National Health Interview Survey. Cancer Epidemiol Biomarkers Prev. 2011;20(11):2331-44.

20. Wilf-Miron R, Peled R, Yaari E, et al. The association between socio-demographic characteristics and adherence to breast and colorectal cancer screening: analysis of large sub populations. BMC Cancer. 2011 25;11:376.

21. Henry KA, McDonald K, Sherman R, et al. Association between individual and geographic factors and nonadherence to mammography screening guidelines. J Womens Health (Larchmt). 2014;23(8):664-74.

22. Pornet C, Dejardin O, Morlais F, et al. Socioeconomic and healthcare supply statistical determinants of compliance to mammography screening programs: a multilevel analysis in Calvados, France.. Cancer Epidemiol. 2010;34(3):309-15.

23. Leung J, McKenzie S, Martin J, et al. Effect of rurality on screening for breast cancer: a systematic review and meta-analysis comparing mammography. Rural Remote Health. 2014;14(2):2730.

24. St-Jacques S, Philibert MD, Langlois A, et al. Geographic access to mammography screening centre and participation of women in the Quebec Breast Cancer Screening Programme. J Epidemiol Community Health. 2013;67(10):861-7.

25. Jensen LF, Pedersen AF, Andersen B, et al. Distance to screening site and non-participation in screening for breast cancer: a population-based study. J Public Health (Oxf). 2014;36(2):292-9.

26. Onitilo AA1, Engel JM, Liang H, et al. Mammography utilization: patient characteristics and breast cancer stage at diagnosis. AJR Am J Roentgenol. 2013;201(5):1057-63.

27. Bulliard JL, de Landtsheer JP, Levi F. Profile of women not attending in the Swiss Mammography Screening Pilot Programme. Breast. 2004;13(4):284-9.

28. McDonald JT, Wang Y, Liu Z. Participation and retention in the breast cancer screening program in New Brunswick Canada. Prev Med Rep. 2017 23;6:214-220.

29. Ouédraogo S, Dabakuyo-Yonli TS, Roussot A, et al. European transnational ecological deprivation index and participation in population-based breast cancer screening programmes in France. Prev Med. 2014;63:103-8.

30. Altobelli E, Rapacchietta L, Angeletti PM, get al. Breast Cancer Screening Programmes across the WHO European Region: Differences among Countries Based on National Income Level. Int J Environ Res Public Health. 2017;14(4).

31. Reuben DB, Bassett LW, Hirsch SH, et al. A randomized clinical trial to assess the benefit of offering on-site mobile mammography in addition to health education for older women.AJR Am J Roentgenol. 2002;179(6):1509-14.

32. Coronado GD, Beresford SA, McLerran D, et al. Multilevel Intervention Raises Latina Participation in Mammography Screening: Findings from ¡Fortaleza Latina!Cancer Epidemiol Biomarkers Prev. 2016;25(4):584-92.

33. Maheswaran R, Pearson T, Jordan H, et al. Socioeconomic deprivation, travel distance, location of service, and uptake of breast cancer screening in North Derbyshire, UK. J Epidemiol Community Health. 2006;60(3):208-12.

34. Vyas A, Madhavan S, Kelly K, et al. Do Appalachian women attending a mobile mammography program differ from those visiting a stationary mammography facility?. J Community Health. 2013;38(4):698-706.

35. Stanley E, Lewis MC, Irshad A, et al. Effectiveness of a Mobile Mammography Program. AJR Am J Roentgenol. 2017 Dec;209(6):1426-1429).

36. Guillaume E, Launay L, Dejardin O, et al. Could mobile mammography reduce social and geographic inequalities in breast cancer screening participation? Prev Med. 2017; 100:84-88.

37. Pornet C, Delpierre C, Dejardin O, et al. Construction of an adaptable European transnational ecological deprivation index: the French version. J Epidemiol Community Health. 2012;66(11):982-9.

38. Naeim A, Keeler E, Bassett LW, et al. Cost-effectiveness of increasing access to mammography through mobile mammography for older women. J Am Geriatr Soc. 2009; 57(2):285-90.

39. Briggs AH, Wonderling, De Mooney CZ. Pulling cost-effectiveness analysis up by its bootstraps: a non-parametric approach to confidence interval estimation. Health Econ. 1997;6(4):327-40.

40. Zelle SG, Vidaurre T, Abugattas JE, et al. Cost-effectiveness analysis of breast cancer control interventions in Peru. PLoS One. 2013 10;8(12).

41. Haute Autorite De Sante (France). Choices in Methods for Economic Evaluation [Internet]. 2011 [accessed December 20, 2018]. Available from: http://www.has-sante.fr/portail/jcms/r_1499251/en/choices-in-methods-for-economic-evaluation.

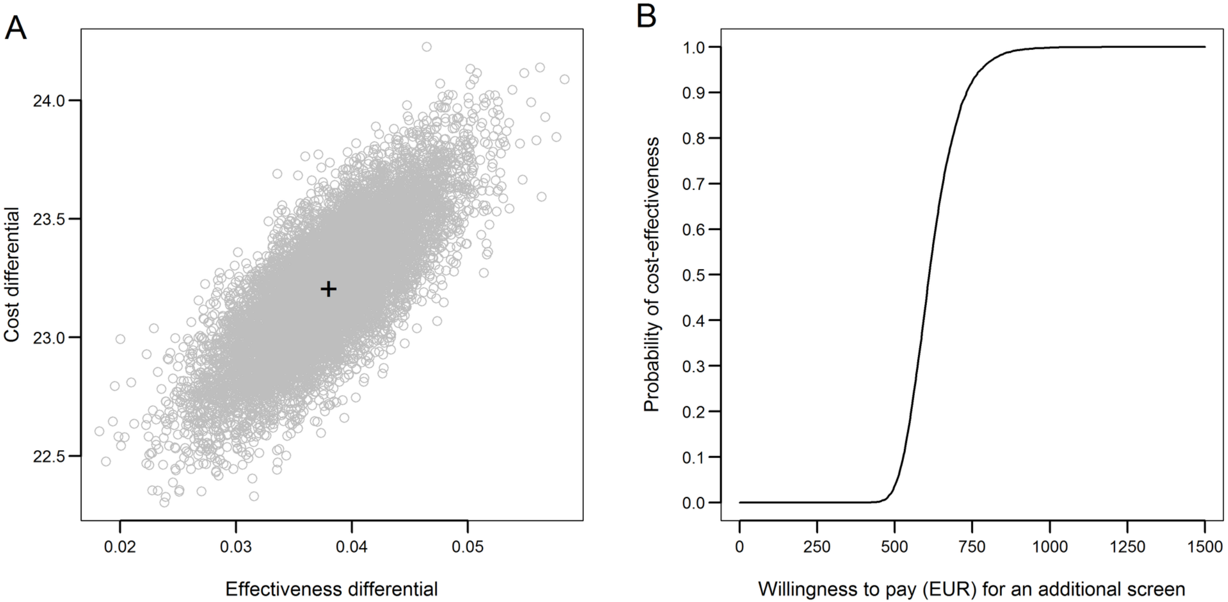
A
Cost differential
24.0
23.5
23.0
22.5
0.02
0.03
0.04
0.05
Effectiveness differential
B
Probability of cost-effectiveness
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
250
500
750
1000
1250
1500
Willingness to pay (EUR) for an additional screen

Table 1. Unit costs

Cost component[a]	Cost	unit
Mobile mammography unit		
Van	460,000	1 unit
Digital mammograph	190,000	1 unit
Radiology laser imager	19,105	1 unit
Staff		
Secretary	36,374.72	1 FTE
Physician of screening structure	76,680.00	1 FTE
Driver	25,000	1 year
Physician for breast clinical examination	560.00	1 day
Radiographer	42,600.00	1 FTE
Radiologist’s first reading	6.20	1 mammography
Radiologist’s second reading	5.02	1 mammography
Mammography performed at radiologist’s office	66.42	1 mammography
Mailing	1.01	1 woman invited
Rental of screening management premises	6,717.90	1 year

[a] In Euro
Abbreviation: FTE, full time equivalent.

Table 2. Baseline characteristics of study population

Characteristic	RO (n=20,968)	MM or RO (n=16,493)	Total (n=37,461)	p-value
Age (years) – n (%)				<0.0001
≤ 54	5,584 (26.6)	3,519 (21.3)	9,103 (24.3)	
55-59	4,726 (22.5)	3,661 (22.2)	8,387 (22.4)	
60-64	4,758 (22.7)	3,795 (23.0)	8,553 (22.8)	
65-69	3,259 (15.5)	2,753 (16.7)	6,012 (16.1)	
≥ 70	2,641 (12.6)	2,765 (16.8)	5,406 (14.4)	
Deprivation quintile – n(%)				<0.0001
Q1 (least deprived)	2,949 (14.1)	853 (5.2)	3,802 (10.2)	
Q2	3,611 (17.2)	2,607 (15.8)	6,218 (16.6)	
Q3	3,682 (17.6)	4,073 (24.7)	7,755 (20.7)	
Q4	5,134 (24.5)	5,459 (33.1)	10,593 (28.3)	
Q5 (most deprived)	5,592 (26.7)	3,501 (21.2)	9,093 (24.3)	
Distance to RO (km) – n (%)				<0.0001
[0-5[	12,589 (60.0)	583 (3.5)	13,172 (35.2)	
[5-10[	3,414 (16.3)	2,213 (13.4)	5,627 (15.0)	
[10-15[	1,839 (8.8)	3,573 (21.7)	5,412 (14.5)	
[15-20[	1,329 (6.3)	3,501 (21.2)	4,830 (12.9)	
[20-25[	838 (4.0)	3,052 (18.5)	3,890 (10.4)	
[25-30[	716 (3.4)	2,569 (15.6)	3,285 (8.8)	
[30 + [	243 (1.2)	1,002 (6.1)	1,245 (3.3)	

Abbreviations: RO, Radiologist’s Office; MM, Mobile Mammography; km, kilometer.

Table 3. Participation rates

Characteristic	RO (n=20,968)			MM or RO (n=16,493)			Mean difference (95% CI)
	n	Participation n (%)	p-value	n	Participation n (%)	p-value	
Total	20,968	11,858 (56.6)		16,493	9,954 (60.4)		0.038[a] (0.028 to 0.048)
Deprivation quintile - n (%)			<0.001[b]			0.481[b] 0.002[c]	
Q1 (least dep.)	2,949	1,805 (61.2)		853	479 (56.2)		
Q2	3,611	2,216 (61.4)		2,607	1,544 (59.2)		
Q3	3,682	2,143 (58.2)		4,073	2,521 (61.9)		
Q4	5,134	2,774 (54.0)		5,459	3,350 (61.4)		
Q5 (most dep.)	5,592	2,920 (52.2)		3,501	2,060 (58.9)		
Distance to RO (km) - n (%)			<0.001[b]			0.863[b] 0.001[c]	
[0-5[	12,589	7,078 (56.2)		583	388 (66.6)		
[5-10[	3,414	2,095 (61.4)		2,213	1,359 (61.4)		
[10-15[	1,839	1,077 (58.6)		3,573	2,071 (58.0)		
[15-20[	1,329	710 (53.4)		3,501	2,133 (60.9)		
[20-25[	838	408 (48.7)		3,052	1,820 (59.6)		
[25-30[	716	362 (50.6)		2,569	1,559 (60.7)		
[30-+ [	243	128 (52.7)		1,002	624 (62.3)		

[a] p-value for chi-square test for homogeneity: <0.001
[b] Cochran-Armitage trend test
[c] Chi-square test for homogeneity
Abbreviations: RO, Radiologist's Office; MM, Mobile Mammography; km, kilometer; dep, deprivation; CI, confidence interval.

Table 4. Cost Components

Cost component[a]	RO (n = 20,968)	MM or RO (n = 16,493)	Mean difference (95% CI)
Mobile mammography unit			
Van	-	131,428.57	
Digital mammograph	-	54,285.71	
Radiology laser imager	-	5,458.58	
Staff			
Secretary	58,199.56	145,498.88	
Physician of screening structure	61,344.00	30,672.00	
Driver	-	50,000.00	
Physician	-	210,560.00	
Radiographer	-	238,560.00	
Radiologist's first reading	-	57,868.04	
Radiologist's second reading	59,513.98	49,958.02	
Mammography performed at radiologist's office	787,608.36	40,981.14	
Mailing	42,160.58	33,162.64	
Rental of screening management premises	7,520.40	5,915.40	
Equipment and operating costs			
Fuel	-	13,070.40	
Garage rental	-	7,500.00	
Van insurance	-	1,557.40	
Car	-	10,667.12	
Computer rental	5,193.60	10,957.60	
Maintenance (computer, van, radiology equipment)	2,493.46	25,129.72	
Film and medical supplies	-	44,023.42	
Office supplies	3,859.78	16,566.72	
Electricity	1,669.18	8,772.94	
Telecommunication	949.56	949.56	
Other costs	22,662.24	17,607.14	
Total cost	1,053,174.70	1,211,151.00	
Mean +/- sd	50.23 +/- 35.41	73.43 +/- 13.44	23.21[b] (22.64 to 23.78)

[a] In Euro
[b] p-value for Student's t-test <0.001
Abbreviations: RO, Radiologist's Office; MM, Mobile Mammography; CI, confidence interval; sd, standard deviation

Table 5. Cost-effectiveness of invitation to mobile mammography unit or radiologist's office in base case analysis, subgroup analysis and sensitivity analysis.

Analysis	Incremental cost (EUR) (95% CI)	Incremental effect (% increase in participation) (95% CI)	ICER (EUR per additional screen) (95% CI)
All Strata	23.21 (22.64 to 23.78)	0.038 (0.028 to 0.048)	610.69 (492.11 to 821.01)
≥ 15 km	26.55 (25.73 to 27.37)	0.092 (0.072 to 0.112)	289.57 (248.40 to 353.75)
< 15 km	23.06 (22.16 to 23.95)	0.025 (0.011 to 0.039)	923.07 (600.52 to 2068.92)
Q4Q5 (most deprived)	25.38 (24.60 to 26.15)	0.073 (0.059 to 0.087)	347.92 (298.47 to 420.63)
Q1Q2Q3 (least deprived)	20.98 (20.14 to 21.82)	0.001 (-0.013 to 0.016)	15,235.47 (-43,264.46 to 42,273.04)
SA 1: Effectiveness difference (%)			
Upper 95% CI	23.43	0.048	488.20
Lower 95% CI	22.98	0.028	820.69
SA 2: Cost difference (EUR)			
Upper 95% CI	23.78	0.038	625.71
Lower 95% CI	22.64	0.038	595.69
SA 3: MMU-related costs (EUR)			
- 20 %	20.89	0.038	549.69
+ 20%	25.52	0.038	671.70
SA 4: Staff			
Radiographer (1.8 FTE)	18.04	0.038	474.76
SA 5: Equipment and operating costs			
+ 20%	24.76	0.038	651.56
- 20%	21.65	0.038	569.83
SA 6: Time horizon			
2 years	13.49	0.038	354.97
SA 7: Percentage of women invited to MM and undergoing screening in MM			
100%	21.27	0.038	559.63
80%	27.53	0.038	724.41

Abbreviations: SA, sensitivity analysis; FTE, Full time equivalent; MM, Mobile Mammography; km, kilometer; Q, quintile; CI, confidence interval; ICER, confidence interval