

Factors associated with breast screening radiologists' annual mammogram reading volume in Italy

Doralba Morrone¹ · Livia Giordano² · Franca Artuso³ · Daniela Bernardi⁴ · Chiara Fedato⁵ · Alfonso Frigerio⁶ · Daniela Giorgi⁷ · Carlo Naldoni⁸ · Gianni Saguatti⁹ · Daniela Severi¹⁰ · Mario Taffurelli¹¹ · Daniela Terribile¹² · Leonardo Ventura¹³ · Lauro Bucchi¹⁴

Received: 25 August 2015 / Accepted: 23 February 2016
© Italian Society of Medical Radiology 2016

Abstract

Purpose Screening mammogram reading volume (SMRV) and total (screening and clinical) mammogram reading volume (TMRV) per year are strongly associated with the radiologist's diagnostic performance in breast cancer screening. The current article reports the prevalence and correlates of a SMRV and a TMRV ≥ 5000 among Italian breast screening radiologists.

Materials and methods A questionnaire survey was carried out in 2013–2014 by the Italian Group for Mammography Screening (GISMa). The questionnaire included items of information for radiologist's experience-related characteristics and for facility-level factors supposedly associated with SMRV and TMRV. Multivariate analysis was performed using backward stepwise multiple logistic regression models.

Results Data for 235 radiologists from 51 local screening programmes were received. Of the 222 radiologists who were eligible, 133 (59.9 %) reported a SMRV ≥ 5000 and 163 (73.4 %) a TMRV ≥ 5000 . Multivariate factors positively associated with both characteristics included: the number of years of experience reading mammograms; the percentage of total working time dedicated to breast imaging and breast care; the participation in diagnostic assessment; and the availability of digital tomosynthesis at facility. Full-time dedication to breast imaging and breast care was associated with the highest odds ratio for a SMRV and a TMRV ≥ 5000 , i.e. 11.80 and 46.74, respectively, versus a percentage of time ≤ 50 %. An early (<2000) year of implementation of the screening programme and the availability of vacuum-assisted biopsy at facility were associated with a SMRV and, respectively, a TMRV ≥ 5000 .

✉ Lauro Bucchi
lauro.bucchi@irst.emr.it

¹ Senology Unit, Cancer Research and Prevention Institute (ISPO), Florence, Italy

² Epidemiology Unit, Centre for Cancer Prevention (CPO), Turin, Italy

³ Mammography Screening Unit, Centre for Cancer Prevention (CPO), Turin, Italy

⁴ Clinical Senology and Mammography Screening Unit, Local Health Authority, Trento, Italy

⁵ Regional Screening Coordinating Centre, Veneto Region, Venice, Italy

⁶ Regional Reference Centre for Breast Cancer Screening, Turin, Italy

⁷ Epidemiology Unit, Local Health Authority, Lucca, Italy

⁸ Department of Health, Emilia-Romagna Region, Bologna, Italy

⁹ Senology Unit, Local Health Authority, Bologna, Italy

¹⁰ Cancer Prevention Unit, Local Health Authority, Forlì, Italy

¹¹ Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy

¹² Unité de Sénologie Chirurgicale, Hôpitaux Universitaires de Genève, Geneva, Switzerland

¹³ Clinical and Descriptive Epidemiology Unit, Cancer Research and Prevention Institute (ISPO), Florence, Italy

¹⁴ Romagna Cancer Registry, Romagna Cancer Institute (IRST) IRCCS, Meldola, Forlì, Italy

Conclusions Increasing the proportion of radiologists with full-time dedication to breast imaging and breast care qualified as the most effective approach to improve SMRV and TMRV.

Keywords Screening · Mammography · Questionnaire · Survey · Radiologist · Mammogram reading volume

Introduction

The sensitivity of mammogram reading for early-stage breast cancer and its specificity for the unaffected breast are powerful factors for effectiveness, cost-effectiveness, and acceptability of mammography screening. For this reason, the often reported variability in diagnostic accuracy of breast screening radiologists is a matter of concern. This variability depends mostly on the radiologist's experience [1].

In fact, the breast screening radiologist's experience is difficult to define and to measure. The radiologist's performance is a process in which multiple determinants are involved interactively [1–4]. These include several personal characteristics [1–3, 5–11] as well as facility-level factors (for example, the number of interpreting radiologists at facility) [2]. However, because the volume of procedures has been shown to be a strong determinant of quality in numerous medical fields [12], the experience-related factor that has received the most attention in the literature is the annual mammogram reading volume (MRV) [1–3, 6–11]. Expectedly, most studies have consistently demonstrated a close independent association between MRV and radiologist's accuracy [6, 7, 11, 13].

This notion is reflected in the European guidelines for quality assurance in breast cancer screening and diagnosis, which state that each radiologist should: have had specific training both in screening and in clinical mammography; participate in a continuing medical education programme; be involved both in basic screening and in assessment of women with abnormal screening results; and read a minimum of 5000 screening mammograms per year [14]. The more recent European Society of Breast Cancer Specialists (Eusoma) position paper for Specialist Breast Centre certification states that each breast radiologist working in a Centre must read a minimum of 1000 mammography cases per year, which rise to 5000, including both screening and clinical mammograms, if he participates in a screening programme [15].

In 2013–2014, the Italian Group for Mammography Screening (Gruppo Italiano Screening Mammografico, GISMa), the scientific society that promotes communication and dissemination of knowledge across the mammography screening community in the country, carried out a

questionnaire survey aimed (1) at evaluating the distribution of Italian breast screening radiologists by the main experience-related characteristics, and (2) at acquiring a list of screening centres offering training opportunities. In the current study, we used data from the first part of the survey. Our aim was to evaluate the prevalence of radiologists with a MRV ≥ 5000 and the factors significantly associated with it, in order to find clues to improvement in this critical indicator of radiologist's experience.

Materials and methods

Setting

In Italy, mammography screening is implemented on a health care district basis. District screening programmes are served by one or more mammography facilities (also referred to as screening centres), each with or without an assessment clinic. Detailed information on geographic coverage, target population, performance indicators, and impact indicators can be found elsewhere [16–19].

Questionnaire

The questionnaire was developed by two of us (DM and LB) after consultation of the relevant literature, was amended by a third author (LG), and was tested on a randomly selected group of radiologists. The items were divided in two sections: one devoted to the characteristics of the screening centre and of employed radiologists (see “Appendix”), and the other to the offer of training opportunities.

The questionnaire was saved as a Microsoft Excel file with locked cells and, in June 2013, was sent via e-mail to all radiologists enrolled in the GISMa. Telephone and email reminders were sent in October 2013. The deadline for responding was December 31, 2013, although a small number of questionnaires were received in early 2014.

Items of information

We used a subset of items of the questionnaire. From among the radiologist's experience-related characteristics (personal characteristics), we selected the following: number of screening mammograms read per year, calculated as the average of the last 3 years; number of clinical mammograms read per year, calculated as the average of the last 3 years; years of experience in reading both screening and clinical mammograms; percentage of total working time dedicated to breast imaging and breast care, calculated as the average of the last 3 years; and regular participation in diagnostic assessment sessions for women with abnormal screening mammography results.

With respect to the facility-level factors supposedly associated with the MRV, we used the following: geographic area (north, centre, south); year of implementation of the screening programme; number of interpreting radiologists at facility (each single facility in multi-facility screening programmes); availability of digital mammography; availability of digital tomosynthesis; and availability of vacuum-assisted biopsy. The latter two variables were assumed as proxies of a high technological level. For reasons of quality of information, the year of implementation of the screening programme was taken from a set of data that the GISMa and the National Centre for Screening Monitoring (Italian: Osservatorio Nazionale Screening, ONS) collected in 2013 from local screening programmes.

Data analysis

The total number of breast radiologists working in the screening centres in Italy is unknown, because their registration with official bodies is not mandatory. Conversely, all screening programmes should be notified to the ONS, which acts upon a mandate of the Ministry of Health. Under these conditions, we estimated the approximate survey's coverage in two alternative ways: first, as the proportion of respondent radiologists out of the number of radiologists enrolled in the GISMa; and, second, as the proportion of surveyed programmes out of the number of active programmes notified to the ONS [17]. Active programmes were defined as providing (at least) the number of screen-detected cancers.

Continuous variables were dichotomised by the median value. The number of screening and clinical mammograms was rounded to the nearest multiple of 100. The problem of missing data was dealt with using the multiple imputation technique [20].

The endpoint of analysis was twofold. The first was the screening MRV (SMRV), defined according to the European guidelines for quality assurance in breast cancer screening and diagnosis [14], and the second was the total MRV (TMRV), i.e. the sum of screening and clinical mammogram readings, defined according to the Eusoma position paper [15].

Differences in proportions were tested for significance with the Fisher's exact test and the χ^2 test for heterogeneity, and trends in proportions with the χ^2 test for trend. Multivariate analysis was performed using two backward stepwise multiple logistic regression models. Given the skewed distribution of percentages of working time dedicated to breast imaging and breast care, the variable was also categorised into tertiles and both models were run again.

Results

Response

Data for 235 radiologists from 51 health care district screening programmes were received. Averaging over all study variables, 3 % of them had missing information. Thirteen radiologists reported that they participated only in the reading of clinical mammograms and in the diagnostic assessment of women with abnormal screening results. They were excluded, leaving 222 subjects available for analysis. These accounted for 76.6 % of the 290 radiologists enrolled in the GISMa. The 51 surveyed programmes accounted for 46.8 % of the 109 active programmes known to the ONS.

Characteristics of radiologists

The 222 eligible radiologists were mostly (163 or 73.4 %) from northern Italy. The median number of interpreting radiologists at their work facilities was four. Two hundred and two (91.0 %) of them reported that their work facility was equipped with digital mammography. The left part of Table 1 shows the distribution of eligible radiologists by other study variables.

Figure 1 shows their distribution by SMRV and TMRV categories. One hundred and thirty-three radiologists (59.9 %) reported a SMRV ≥ 5000 , and 163 (73.4 %) a TMRV ≥ 5000 . Four (1.8 %) radiologists reached a TMRV $\geq 25,000$. The median number of clinical mammograms read per year was 1400 (range 0–10,000).

Factors associated with a SMRV and a TMRV ≥ 5000

The right part of Table 1 shows the results of univariate and multivariate analysis. Both approaches demonstrated that the geographic area, the number of radiologists at facility, and the availability of digital mammography were not significantly associated either with a SMRV or a TMRV ≥ 5000 .

Factors significantly associated with the probability of a SMRV ≥ 5000 in multivariate analysis included an early year of implementation of the screening programme, a high number of years of experience in reading mammograms, a percentage of working time dedicated to breast imaging and breast care ≥ 75 %, a regular participation in diagnostic assessment sessions, and the availability of digital tomosynthesis at facility. The effect of the number of years of experience was found only in multivariate analysis. This was entirely explained by the fact that the variable was strongly and positively associated ($p = 0.007$) with the year of implementation of the programme (data not shown), that

Table 1 Breast screening radiologist's experience-related characteristics and facility-level factors associated with a screening mammogram reading volume (SMRV) and a total (screening and clinical) mammogram reading volume (TMRV) ≥ 5000 per year

Factor	Total no. of radiologists	Radiologists with a SMRV ≥ 5000		Radiologists with a TMRV ≥ 5000	
		No. (%)	OR (95 % CI)	No. (%)	OR (95 % CI)
Year of implementation of the screening programme					
1990–1999	97	73 (75.3)	1.00 (referent)	84 (86.6)	Variable removed
2000–2012	125	60 (48.0) ^a	0.42 (0.20–0.89)	79 (63.2) ^a	
Number of years of experience in reading mammograms					
1–14	103	57 (55.3)	1.00 (referent)	72 (69.9)	1.00 (referent)
15–40	119	76 (63.9) ^b	2.71 (1.31–5.61)	91 (76.5) ^b	2.58 (1.07–6.20)
Percentage of working time dedicated to breast imaging and breast care					
10–74 %	110	40 (36.4)	1.00 (referent)	54 (49.1)	1.00 (referent)
75–100 %	112	93 (83.0) ^a	5.02 (2.48–10.13)	109 (97.3) ^a	27.28 (7.13–104.43)
Regular participation in diagnostic assessment sessions					
No	40	9 (22.5)	1.00 (referent)	11 (27.5)	1.00 (referent)
Yes	182	124 (68.1) ^a	7.45 (2.67–20.81)	152 (83.5) ^a	29.62 (7.33–119.68)
Availability of digital tomosynthesis at facility					
No	168	91 (54.2)	1.00 (referent)	116 (69.0)	1.00 (referent)
Yes	54	42 (77.8) ^a	5.07 (1.89–13.61)	47 (87.0) ^a	6.09 (1.22–30.40)
Availability of vacuum-assisted biopsy at facility					
No	86	40 (46.5)	Variable removed	48 (55.8)	1.00 (referent)
Yes	136	93 (68.4) ^a		115 (84.6) ^a	3.04 (1.14–8.08)

Continuous variables were dichotomised by the median value

Odds ratios were estimated with two backward stepwise multiple logistic regression models. The variables were removed if the likelihood ratio statistic based on the maximum likelihood estimates had a probability >0.1 . In multivariate analysis, geographic area, number of interpreting radiologists at facility, and availability of digital mammography were not associated either with SMRV or with TMRV

OR odds ratio, CI confidence interval

^a $p < 0.05$

^b $p > 0.05$

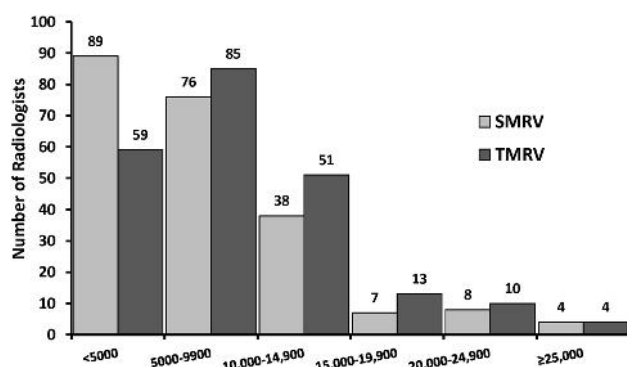


Fig. 1 Frequency distribution of radiologists by screening mammogram reading volume (SMRV) and total (screening and clinical) mammogram reading volume (TMRV) per year. One hundred and thirty-three radiologists (59.9 %) reported a SMRV ≥ 5000 and 163 (73.4 %) a TMRV ≥ 5000 . Note: the annual number of mammograms reported by radiologists was rounded to the nearest multiple of 100

is, an inverse determinant of SMRV. The availability of vacuum-assisted biopsy at facility was significantly associated with the outcome variable in univariate analysis, but not after simultaneous adjustment for confounders.

The pattern of associations with TMRV was similar, but not equal, to that for SMRV. The availability of vacuum-assisted biopsy at facility emerged as a significant independent determinant, whereas the year of implementation of the screening programme was not retained in the multivariate model. More important, a high percentage of working time dedicated to breast imaging and breast care and a regular participation in diagnostic assessment sessions had a much stronger influence on TMRV than on SMRV.

After categorising the percentage of working time dedicated to breast imaging and breast care into tertiles, we ran both models again. As shown in Table 2, using the 10 to 50 % category as a referent, the odds ratio for a

Table 2 Association of the percentage of working time dedicated to breast imaging and breast care, categorised into tertiles, with a screening mammogram reading volume (SMRV) and a total (screening and clinical) mammogram reading volume (TMRV) ≥ 5000 per year

Percentage of working time dedicated to breast imaging and breast care (tertiles) (%)	Total no. of radiologists	Radiologists with a SMRV ≥ 5000		Radiologists with a TMRV ≥ 5000	
		No. (%)	OR (95 % CI)	No. (%)	OR (95 % CI)
10–50	91	32 (35.2)	1.00 (referent)	39 (42.9)	1.00 (referent)
51–99	43	21 (48.8)	0.79 (0.34–1.84)	38 (88.4)	6.21 (1.96–19.66)
100	88	80 (90.9) ^a	11.80 (4.61–30.18)	86 (97.7) ^a	46.74 (9.78–223.45)

Odds ratios were estimated with two backward stepwise multiple logistic regression models also including terms for year of implementation of the screening programme, number of years of experience in reading mammograms, regular participation in diagnostic assessment sessions, number of interpreting radiologists at facility, availability of digital mammography at facility, availability of digital tomosynthesis at facility, and availability of vacuum-assisted biopsy at facility. These variables were removed if the likelihood ratio statistic based on the maximum likelihood estimates had a probability >0.1

OR odds ratio, CI confidence interval

^a $p < 0.05$ (test for trend)

SMRV ≥ 5000 was not significant for a percentage varying between 51 and 99 %, while raising to above 11 among radiologists with full-time dedication. The probability of TMRV being ≥ 5000 was sixfold greater and, respectively, 46-fold greater. Both indicators were above the recommended threshold for more than 90 % of radiologists with full-time dedication.

Discussion

In Italy, there never have been nationwide data on the experience-related characteristics of breast screening radiologists. This provided a strong rationale for the present study.

Since mammography screening and diagnostic breast imaging are increasingly integrated into multidisciplinary Specialist Breast Centres [15], we took both SMRV and TMRV as endpoints of analysis. 59.9 and 73.4 % of respondent radiologists reported a SMRV and, respectively, a TMRV ≥ 5000 . Both figures were roughly in line with expectations, as were most of factors found to influence the probability of reaching either or both standards. Conversely, the finding that the probability of a SMRV ≥ 5000 was lower in those screening programmes that have been implemented in the most recent years was unexpected and disappointing. It suggests that local health care districts where the set-up of the programme has taken longer had a lower background level of mammography services. If so, our observation might predict other unfavourable characteristics of recent programmes.

SMRV and TMRV increased with increasing number of years of experience [1, 3, 7, 10]. Because both associations were adjusted for the working time dedicated to breast imaging and breast care, the most likely interpretation is that the more the years of experience the greater the

reading volume per time unit. In this time of budget difficulties, this finding deserves attention.

An association between the percentage of working time dedicated to breast imaging and breast care and both mammogram reading volumes has already been reported by others [1]. In our data, however, the association with a SMRV ≥ 5000 depended entirely on a markedly increased probability among radiologists with full-time dedication. Although screening authorities in Italy recommend that breast radiologists spend at least half of their time reading mammograms [21], this is not sufficient to reach the standard SMRV. The percentage of working time dedicated to breast imaging and breast care had an even stronger effect on TMRV, with a 47-fold increased probability of reaching a level ≥ 5000 for full-time dedication. As many as 98 % of full-time radiologists were in line with the Eusoma requirement [15].

A high percentage of working time dedicated to breast imaging and breast care was also likely to increase the probability for radiologists to participate in diagnostic assessment sessions [1, 5]. The observed association of the latter variable with SMRV and TMRV, however, was independent of this, because it was adjusted for working time. The explanation we suggest is that reading volumes and participation in diagnostic assessment were both associated with a third radiologist's characteristic, that is, a high degree of commitment to breast imaging and breast care.

In screening centres equipped with digital tomosynthesis, the probability of radiologists reporting a SMRV and a TMRV ≥ 5000 was higher. Digital tomosynthesis is an innovative imaging technique, not yet used for basic screening, that merges digital image capture with conventional radiographic tomography. A plausible interpretation for our finding is that those radiologists who are interested in digital tomosynthesis have high expertise and strong

commitment to breast imaging and breast care. Availability of vacuum-assisted biopsy, conversely, was associated only with TMRV. This technique is used by breast radiologists who spend much working time in the clinical mammography setting, where they are also employed in the assessment of women with abnormal screening results. The fact that these radiologists have a higher TMRV but not a higher SMRV is plausible.

Although a SMRV and a TMRV ≥ 5000 per year remain important targets, a balanced workload allocation is also needed on the other side of the distribution because there could be an upper limit above which the reader's performance deteriorates. In our data, four radiologists—approximately 2 %—reported a SMRV and a TMRV $\geq 25,000$. A study from the UK has demonstrated a lower cancer detection rate in the group of screening radiologists who read $\geq 25,000$ mammograms in a 3-year period [9].

There are two limitations of this study that warrant mention. First, although the proportion of missing values was very low, some study variables were subject to the recall bias and other potential sources of error associated with self-reporting. In order to minimize the adverse effects of related biases, we dichotomised all continuous variables.

Second, the radiologists' participation in the survey was limited. Moreover, we were able to determine the response rate only in an approximate manner using two different approaches. In fact, we do not know whether the true rate is nearer to the proportion of respondent radiologists out of the number of radiologists enrolled in the GISMa, i.e. 76.6 %, or to the proportion of surveyed programmes out of the number of active Italian programmes, i.e. 46.8 %. In any case, the latter figure provides an underestimated measure of response. The reported median number of four radiologists per screening centre, which is above that expected, indicates that the participation was higher among large-staffed centres.

Conclusions

We performed this study with the objective of finding modifiable factors for the likelihood of a SMRV and a TMRV ≥ 5000 , that is, of finding clues to improvement in these major indicators of radiologist's experience. In fact, most of the determinants we identified can be hardly translated into meaningful actions. First, the year of implementation of the screening programme is not modifiable; second, the number of years of experience will inevitably decrease in the next few years because of the projected retirement of a substantial part of the medical workforce of the Italian National Health Service, including numerous experienced radiologists; and third, the complex relationships that link SMRV and TMRV to regular participation in diagnostic

assessment and to technical level of the screening centre do not suggest appropriate actions in an objective manner. Conversely, our results point to an increase in the proportion of radiologists with full-time dedication to breast imaging and breast care as a clear and effective way to improve both mammogram reading volumes.

Acknowledgments The authors thank the radiologists who participated in the survey.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest and that the study has been carried out without any financial support.

Ethical standards This article does not contain any studies with patients or animals performed by any of the authors.

Appendix

Items of the questionnaire. The questionnaire was divided into two sections: one devoted to the characteristics of the screening centre and of employed radiologists, and the other to the offer of training opportunities. The latter was not used for the current study, and its items are not presented here. Except for the name of the health care district and for numerical items, the response option was yes or no. The asterisk indicates the items of the first part that were excluded from analysis.

Characteristics of the screening centre

- Name of the health care district
- Number of women attending the facility per year*
- Number of interpreting radiologists
- Number of radiographers*
- Availability of diagnostic assessment
- Availability of film-screen mammography
- Availability of digital mammography
- Availability of magnetic resonance imaging*
- Availability of digital tomosynthesis
- Availability of fine needle aspiration cytology*
- Availability of core biopsy*
- Availability of vacuum-assisted biopsy

Characteristics of the radiologist

- Number of screening mammograms read per year (as the average of the last 3 years)
- Number of clinical mammograms read per year (as the average of the last 3 years)

- Number of years of experience in reading screening and clinical mammograms
- Percentage of total working time dedicated to breast imaging and breast care (as the average of the last 3 years)
- Regular participation in diagnostic assessment sessions for women with abnormal screening mammography results
- Duration of training in breast imaging (in days)*

References

1. Molins E, Macià F, Ferrer F, Maristany MT, Castells X (2008) Association between radiologists' experience and accuracy in interpreting screening mammograms. *BMC Health Serv Res* 8:91. doi:[10.1186/1472-6963-8-91](https://doi.org/10.1186/1472-6963-8-91)
2. Beam CA, Conant EF, Sickles EA (2003) Association of volume and volume-independent factors with accuracy in screening mammogram interpretation. *J Natl Cancer Inst* 95:282–290
3. Barlow WE, Chi C, Carney PA et al (2004) Accuracy of screening mammography interpretation by characteristics of radiologists. *J Natl Cancer Inst* 96:1840–1850
4. Haneuse S, Buist DS, Miglioretti DL et al (2012) Mammographic interpretive volume and diagnostic mammogram interpretation performance in community practice. *Radiology* 262:69–79. doi:[10.1148/radiol.11111026](https://doi.org/10.1148/radiol.11111026)
5. Elmore JG, Wells CK, Howard DH (1998) Does diagnostic accuracy in mammography depend on radiologists' experience? *J Womens Health* 7:443–449
6. Esserman L, Cowley H, Eberle C et al (2002) Improving the accuracy of mammography: volume and outcome relationships. *J Natl Cancer Inst* 94:369–375
7. Smith-Bindman R, Chu P, Miglioretti DL et al (2005) Physician predictors of mammographic accuracy. *J Natl Cancer Inst* 97:358–367
8. Buist DS, Anderson ML, Haneuse SJ et al (2011) Influence of annual interpretive volume on screening mammography performance in the United States. *Radiology* 259:72–84. doi:[10.1148/radiol.10101698](https://doi.org/10.1148/radiol.10101698)
9. Cornford E, Reed J, Murphy A, Bennett R, Evans A (2011) Optimal screening mammography reading volumes: evidence from real life in the East Midlands region of the NHS Breast Screening Programme. *Clin Radiol* 66:103–107. doi:[10.1016/j.crad.2010.09.014](https://doi.org/10.1016/j.crad.2010.09.014)
10. Rawashdeh MA, Lee WB, Bourne RM et al (2013) Markers of good performance in mammography depend on number of annual readings. *Radiology* 269:61–67. doi:[10.1148/radiol.13122581](https://doi.org/10.1148/radiol.13122581)
11. Théberge I, Chang SL, Vandal N et al (2014) Radiologist interpretive volume and breast cancer screening accuracy in a Canadian organized screening program. *J Natl Cancer Inst* 106:djt461. doi:[10.1093/jnci/djt461](https://doi.org/10.1093/jnci/djt461)
12. Halm EA, Lee C, Chassin MR (2002) Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. *Ann Intern Med* 137:511–520
13. Théberge I, Hébert-Croteau N, Langlois A, Major D, Brisson J (2005) Volume of screening mammography and performance in the Quebec population-based Breast Cancer Screening Program. *CMAJ* 172:195–199
14. Rosselli del Turco M, Hendriks J, Perry N, Azavedo E, Skaane P (2006) Radiological guidelines. In: Perry N, Broeders M, de Wolf C, Törnberg S, Holland R, von Karsa L (eds) *European guidelines for quality assurance in breast cancer screening and diagnosis*, 4th edn. Office for Official Publications of the European Communities, Luxembourg, pp 181–195
15. Wilson AR, Marotti L, Bianchi S et al (2013) The requirements of a specialist Breast Centre. *Eur J Cancer* 49:3579–3587. doi:[10.1016/j.ejca.2013.07.017](https://doi.org/10.1016/j.ejca.2013.07.017)
16. Puliti D, Miccinesi G, Collina N et al (2008) Effectiveness of service screening: a case-control study to assess breast cancer mortality reduction. *Br J Cancer* 99:423–427. doi:[10.1038/sj.bjc.6604532](https://doi.org/10.1038/sj.bjc.6604532)
17. Giorgi D, Giordano L, Ventura L, Frigerio A, Paci E, Zappa M (2012) Mammography breast cancer screening in Italy: 2010 survey. *Epidemiol Prev* 36(Suppl 1):8–27
18. Zappa M, Dardanoni G, Giorgi Rossi P et al (2012) The diffusion of screening programmes in Italy, year 2010. *Epidemiol Prev* 36(Suppl 1):3–7
19. Foca F, Mancini S, Bucci L et al (2013) Decreasing incidence of late-stage breast cancer after the introduction of organized mammography screening in Italy. *Cancer* 119:2022–2028. doi:[10.1002/encr.28014](https://doi.org/10.1002/encr.28014)
20. Rubin DB (1987) *Multiple imputation for nonresponse in surveys*. Wiley, New York
21. Naldoni C, Petrella M, Ciatto S et al (2008) Documento congiunto GISMa-SIRM. Lo screening mammografico organizzato: esigenze dei radiologi coinvolti nello screening ed esigenze del programma di screening nei confronti dei radiologi. http://www.gisma.it/index.php?option=com_content&view=article&id=98:documento-congiunto-gisma-sirm&catid=44:documenti-gisma&Itemid=111. Accessed 5 Mar 2016