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Costs and effects of using specialized breast technologists in prereading mammograms in a clinical patient population

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Objectives: The aim of this study was to assess the costs and effects of using specialized breast technologists in prereading mammograms to reduce the increasing workload of radiologists in daily clinical practice. Mammography is the most widely used imaging modality for early detection and diagnosis of breast cancer.
Methods: A total of 1389 mammograms of consecutive patients were evaluated by two technologists trained in mammogram interpretation. The costs and effects of four different experimental strategies of prereading mammograms by technologists were analyzed by decision analytic modeling and compared with the conventional strategy of standard evaluation by the radiologist on duty.
Results: Overall, the employment of technologists in this patient population resulted in a potential time saving up to 73 percent (1019/1389) for the radiologist. No additional false-negative imaging results were found as compared to the conventional strategy. The total diagnostic costs in the conventional strategy were determined at €150,602. The experimental strategies resulted in cost savings up to 17.2 percent (range, €122,494–€139,781).
Conclusions: The employment of technologists in prereading mammograms in a clinical patient population could be effective to reduce the workload of radiologists without jeopardizing the detection of malignancies. Furthermore, diagnostic costs can be reduced considerably.

Keywords: Breast cancer, Mammography, Costs, Effects, Cost-effectiveness, Radiologist, Technologist

To reduce the increasing workload of radiologists, the employment of radiologic technologists taking over duties previously reserved for radiologists is an upcoming solution.

In breast imaging, mammography is the most widely used modality for early detection and diagnosis of breast malignancies. Deployment of specialized breast technologists in the interpretation of mammograms provides the radiologist the opportunity to devote more time to specialized and complex breast examinations. This is expected to provide cost savings to the healthcare system. Technologists could be involved in two different ways, through double reading and prereading procedures.

In the Dutch breast cancer screening program, mammograms are routinely evaluated by two radiologists. Studies have shown that double reading of screening mammograms by both a radiologist and a technologist could also increase the number of cancers detected (7;9;12;15). With the method of prereading mammograms, a technologist selects those examinations that require further evaluation by a radiologist

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and discharges patients with either negative or clearly benign findings from further evaluation. Haiart and Henderson (5) showed that prereading could not be justified in screening mammograms, neither in terms of performance, nor on economic grounds. However, all studies involving technologists in interpreting mammograms have been performed in a screening setting. Evaluations regarding the deployment of technologists in reading mammograms in a clinical patient population with both diagnostic and screening examinations are found to be lacking (13).

In daily clinical practice, there has been a considerable increase in demand for radiologic services, which has not been met by a commensurate increase in radiologist staffing. Furthermore, it has been demonstrated that, in the Netherlands, more than half the patients who undergo mammography in a clinical setting, are discharged without further imaging workup (3;14). These two facts provide a strong basis for the deployment of technologists in prereading mammograms.

According to evidence-based guidelines in clinical practice (16), approximately 30 percent of women referred for mammography will require additional ultrasonography, fine needle aspiration cytology examination, or core needle biopsy based on their reason for referral, such as a palpable breast mass (3;14). It can be argued to exclude these patients from a preselection interpretation by a technologist, as they need to be seen by a radiologist anyway. In all other patients referred for mammography to a clinical radiology department, technologists are expected to be useful in selecting the cases that require further evaluation based on mammographic findings. This method could reduce the workload of the breast radiologist substantially and could provide cost savings by reducing the time they require to review large numbers of negative mammograms. Moreover, technologists could be helpful in distinguishing mammographic abnormalities that appear clearly benign from those that are suspicious for malignancy. In this strategy, even more patients could be excluded from further assessment by a radiologist, namely those with normal mammograms and those with clearly benign mammographic findings. However, this working procedure has the risk of missing more malignancies as compared to the method of selecting cases that require further workup based on mammographic findings.

To increase the detection of malignancies in a prereading strategy, it could be argued to use two technologists who read all mammograms independently. However, as compared to a strategy with one technologist involved, this strategy has higher personnel costs and more mammograms will be referred to the radiologist which will lower the effect of reducing the workload of the radiologists.

The purpose of this study was to assess the costs and effects of using specialized breast technologists in prereading mammograms in a clinical population without an immediate indication for further testing at referral. Four different experimental prereading strategies were analyzed in terms of costs and effects by decision analytic modeling and were compared with the conventional strategy of standard mammogram evaluation by a radiologist.

METHODS

Study Design

A decision analytic model was designed to compare a conventional strategy of mammogram evaluation by a radiologist with four different experimental strategies of prereading mammographic images by breast technologists. The model was based on a large prospective study in which all consecutive mammography examinations of patients referred to the radiology department of Maastricht University Medical Center between January and August 2007 were included. Patients were informed on the study by written brochures and approved the use of their mammogram images for the purpose of this study. The institutional ethics committee approved the study.

For the purpose of this cost analysis, all patients referred for a palpable breast mass and patients referred with an abnormal mammogram from the national breast cancer screening program, were excluded, as immediate additional ultrasonography examination is recommended according to evidence-based guidelines, which requires the input of a radiologist (14).

All mammograms were performed on a full-field digital system (Giotto Image FFDM, IMS, Bologna, Italy) and read on a digital workstation (Raffaello Review Workstation, IMS, Bologna, Italy), conforming to daily clinical practice. Of each consecutive patient, the radiologist on duty evaluated the mammography examination and recorded the findings in a breast imaging report. For each breast, an imaging conclusion was given as a BI-RADS score which is based on a grading reporting scale for mammography with an increasing degree of suspicion for malignancy: 0, need additional imaging evaluation; 1, negative examination; 2, benign finding; 3, probably benign finding; 4, suspicious abnormality; 5, highly suggestive of malignancy (2). Furthermore, additional imaging workup was initiated when necessary.

In addition, all mammograms were independently evaluated by two technologists, trained in mammogram interpretation during a 500-hour training program under the supervision of breast radiologists. They had full information on the patient characteristics, reason for referral and clinical findings, but had no information on the results of additional imaging tests and were blinded for the evaluations of the other observers. Each technologist registered the mammographic findings on a standardized case report form. Abnormalities were marked on a schematic representation of the breast in craniocaudal and mediolateral oblique views. Furthermore, for each breast a BI-RADS score was assigned. Finally, it was indicated on the case report form whether the technologist advised additional workup.

The reference standard for the presence or absence of breast cancer was determined by the pathologic results from core needle biopsies and surgical excisions during a follow-up of 12 months. Pathology data were retrieved from PALGA, a nation wide network and registry of histopathology and cytopathology in the Netherlands, to which all Dutch hospital pathology departments are linked. Breast cancer status was considered negative when no pathologic condition was reported in the PALGA system within 1 year. Lobular carcinomas in situ were excluded as malignancies.

Strategies and Data Sources

Four different experimental strategies of prereading mammograms by breast technologists were analyzed and compared with a conventional strategy of mammogram evaluation by the radiologist on duty ($n = 6$ well-experienced radiologists). The design of the decision model is shown in Figure 1, in which the different strategies are outlined and each possible clinical pathway is indicated with a branch number (1–22). The evaluations of the mammograms interpreted by the radiologist on duty and two technologists as part of the large prospective study as mentioned above are used in the different strategies.

In the conventional strategy, the numbers of patients in each pathway (1–4) were retrieved from actual data from daily clinical practice. According to clinical guidelines (2), patients were either discharged (BI-RADS 1–2) or referred for additional workup (BI-RADS 0,3–5).

In the experimental strategies, the distribution of patients among the different pathways (5–22) was determined by applying clinical decision rules based on the BI-RADS classification. Strategy 1 represents mammogram evaluation by one technologist, who discharged patients with no mammographic abnormalities (BI-RADS 1), and referred all patients with any mammographic abnormality (BI-RADS 2–5) or requiring additional imaging (BI-RADS 0) to the radiologist. The strategy is subdivided into 1a and 1b, representing the results of the two separate technologists participating in the study.

In experimental strategy 2, two technologists read all mammograms independently. When mammographic abnormalities (BI-RADS 2–5) were reported by at least one technologist or at least one technologist recommended additional imaging evaluation (BI-RADS 0), the mammogram was referred to the radiologist for re-evaluation. Patients without abnormalities (BI-RADS 1) were discharged.

Summarizing, in strategy 1 and 2 a cut-off point between BI-RADS 1 and 2 was used for referral of patients to the radiologist. Additionally, in strategy 3 and 4, a cut-off point between BI-RADS 2 (benign finding) and 3 (probably benign finding) was used for referral. Furthermore, the assumptions regarding the different readers were similar in strategy 3 and 4 to those in strategy 1 and 2 respectively, resulting in strategy 3a and 3b reporting the results of the two separate technologists, and strategy 4 reporting the results of both technologists.

In all strategies, it was assumed that the classification of a technologist would never overrule the classification of the radiologist.

Cost Data

The costs of all radiological breast procedures were acquired according to 2008 national reimbursement rates which contain hospital facility charges and a fee for the physician(s) involved (1).

In the conventional strategy, the costs of a mammogram were equal to the reimbursement rate for mammography (€86.80), consisting of €59.20 for hospital facility charges and €27.60 for radiologists' fee. To assess the costs of the evaluation of a mammogram by a technologist, equal hospital facility charges were assumed and physician's fees were replaced by a proportional fee for technologists.

According to the Dutch guidelines for economic evaluations (8), an hourly rate of €160 for a physician and €33 for a technologist could be counted. Assuming an equal time unit needed for the evaluation of one mammogram, the costs for a technologist evaluating a mammogram were determined at €5.70 ((€33 / €160) * €27.60). Consequently, in strategy 1 and 3 the total costs of a mammogram evaluated by one technologist followed by discharge were established at €64.90 (€59.20 + €5.70). When the technologist recommends a re-evaluation by the radiologist, the costs of a mammogram increase with the fee for the radiologist, leading to €92.50 (€59.20 + €5.70 + €27.60).

In strategy 2 and 4, two technologists are involved, resulting in costs of a mammogram of €70.60 (€59.20 + €5.70 + €5.70) in case of discharge of the patient, and €98.20 (€59.20 + €5.70 + €5.70 + €27.60) when referring the patient to a radiologist. Costs of additional mammography examinations in patients with recommendation for short-term follow-up of a probably benign lesion were charged at the reimbursement rate for mammography (€86.80). In Table 1, an overview is given of the different cost items.

Furthermore, treatment costs for breast cancer were assessed. Probabilities and direct medical costs of surgery, adjuvant therapy, local recurrence, palliative care, and follow-up care in disease-free patients were adapted from Flobbe et al. (4). In Figure 2, probabilities and costs are shown for all branches in a decision tree for surgery of lesions. Surgery of a lesion could reveal a true-positive (probability of 0.983) or false-positive imaging result (probability of .017). Further distinction was made between cases with a bad prognosis leading directly to palliative care, surgery with and without adjuvant chemotherapy and hormonal therapy, and occurrence of a local or systemic recurrence. All costs in the decision tree are presented as year-2003 Euros, whereas the mean costs of a malignancy were discounted at an annual

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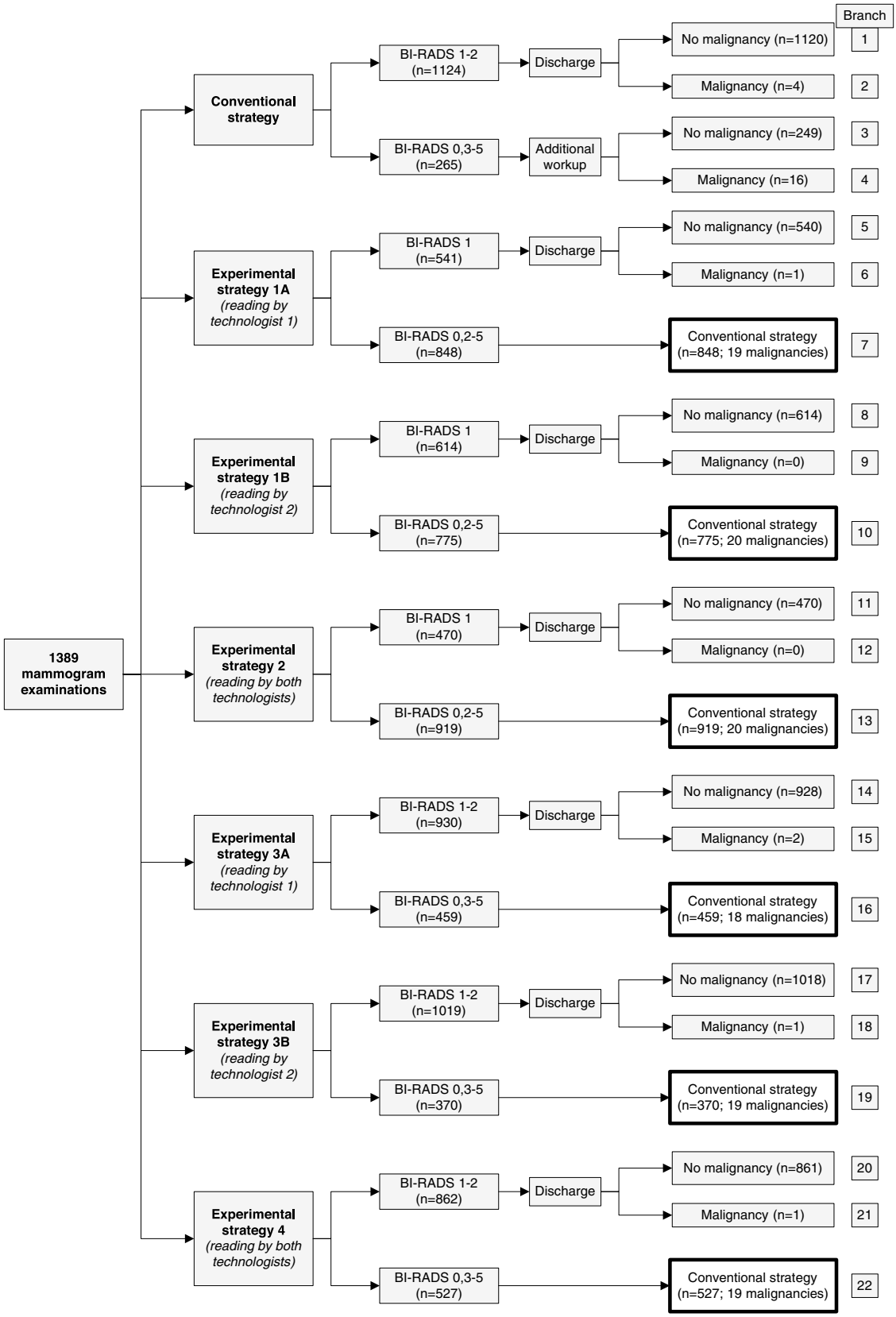

Figure 1. Pre-reading strategies by technologists.

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Table 1. Costs of Diagnostic Procedures (in euros)

Diagnostic procedure	Costs (€)
Mammography[a]	
By radiologist (conventional strategy and short-term follow-up)	86.80
By one technologist (strategy 1 and 3, discharging patient)	64.90
By two technologists (strategy 2 and 4, discharging patient)	70.60
By one technologist and a radiologist (strategy 1 and 3, re-evaluation by radiologist)	92.50
By two technologists and a radiologist (strategy 2 and 4, re-evaluation by radiologist)	98.20
Ultrasound examination[a]	84.00
Fine needle aspiration cytology[a]	114.40
Core needle biopsy[a]	164.20

[a] National reimbursement rates from ctg.bit-ic.nl/Nzatarieven/top.do.

rate of 4 percent and presented in year-2008 Euros as well. Only direct medical costs were calculated; direct nonmedical costs and indirect costs were excluded from analyses, as these were assumed to be the same in each strategy. The mean costs of a malignancy resulted in €17,565 (year-2008 Euros).

For the purpose of this study, it was assumed that the costs of malignancy resulting from the discharge groups (pathways 6, 9, 12, 15, 18, and 21) are comparable to the costs of malignancies resulting from the patients re-evaluated by the radiologist (pathways 7, 10, 13, 16, 19, and 22).

Outcome Measures

The main outcome measure was the number of malignancies failed to be detected by the technologists in each experimental strategy, as compared to the number of malignancies failed to be detected in the conventional strategy (false-negative imaging results).

Furthermore, for the cost analysis the main outcome measures included the total costs of each experimental strategy and the proportion of costs in relation to the conventional strategy.

Threshold Analysis

As prereading of mammograms will increase the responsibilities of technologists, it can be assumed that this will result in wage advance for the technologists. To evaluate the influence of the personnel costs of the technologist on the costs of the different experimental strategies, a threshold analysis was performed. In each experimental strategy, the hourly rate for the radiologist was assumed to be constant (€160), whereas the rate for the technologist was raised to identify the values at which total costs of the experimental strategy was equal to the total costs of the conventional strategy.

RESULTS

General

In the prospective clinical study that formed the basis of this decision analysis, 2034 consecutive mammography examinations were assessed for eligibility. Thirty-five exams (2 percent) were excluded because data were not complete. Another five patients with a proven breast malignancy at the time of performing the study mammogram were excluded as well. Furthermore, patients were excluded from the present study because they were referred for a palpable breast mass

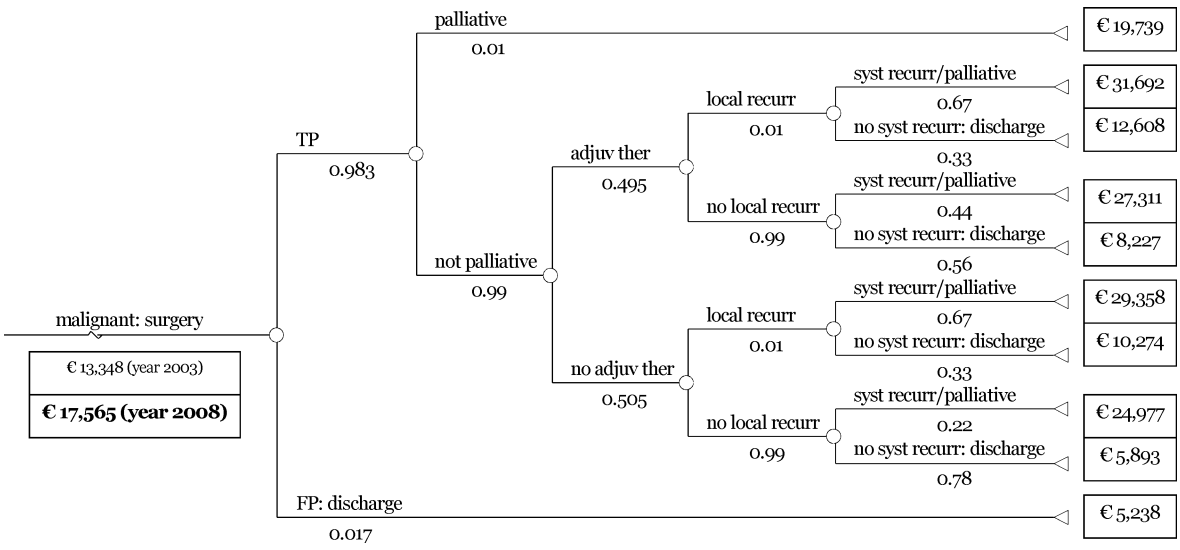

Figure 2. Decision tree for surgery of malignancies. TP, true-positive; FP, false-positive; palliative, palliative care; adjuv ther, adjuvant chemotherapy; recur, recurrence; syst recur, systemic recurrence. Adapted from Flobbe et al., 2004.

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($n = 524$) or an abnormal screening mammogram ($n = 81$). Consequently, 1389 patients were analyzed in this study.

The mean age of the study population was 53 years (range, 21–90 years). Diagnostic mammography was performed in 967 patients (70 percent), whereas 422 women (30 percent) were referred for screening mammography. Indications for referral for diagnostic breast imaging were: follow up of prior breast malignancy ($n = 533$; 38 percent), including 325 examinations after lumpectomy and 208 after mastectomy, symptomatic complaints like pain or nipple abnormalities ($n = 342$; 25 percent) and follow up of a prior benign abnormality ($n = 92$; 7 percent). Indications for screening mammography were family history of breast cancer, including BRCA gene mutation ($n = 319$; 23 percent), and other asymptomatic reasons for referral (n = 103, 7 percent).

After a follow-up of 12 months during which pathology results from core needle biopsies and surgical excisions were retrieved, a total of twenty malignancies have been detected, leading to a breast cancer prevalence of 1.4 percent (20/1389) in this population.

Effects

In the decision model represented in Figure 1, the distribution of patients over the different pathways in the decision model is shown. In the conventional strategy of mammogram evaluation by the radiologist on duty (branch 1–4), additional diagnostic workup was performed in 265 patients (19 percent), whereas 1124 patients (81 percent) were discharged. Four malignancies were detected in the group of patients who were discharged initially (branch 2), and returned for further imaging or surgical procedure in a later stage of the follow up (after 2, 4, 7, and 12 months, respectively). Furthermore, 16 malignancies were detected in the group referred for additional work up (branch 4).

In experimental strategy 1 (branch 5–10), 541 (39 percent) and 614 (44 percent) patients were discharged by the technologists in strategy 1a and 1b, respectively. Another 848 (61 percent) and 775 (56 percent) patients were referred to the radiologist. Using the BI-RADS classifications of both technologists in experimental strategy 2 (branch 11–13) resulted in a discharge of 470 patients (34 percent) and re-evaluation by the radiologist in 919 patients (66 percent). Using a cut-off point between BI-RADS 2 and 3, the patients referred to the radiologist, decreased to 459 (33 percent) in strategy 3a (branch 14–16), 370 (27 percent) in strategy 3b (branch 17–19) and 527 (38 percent) in strategy 4 (branch 20–22).

In the conventional strategy and in the experimental strategies 1a, 3a, 3b, and 4, a few patients were discharged who were proven to have breast cancer later (branch 2, 6, 15, 18, and 21). The malignancies that were not detected in the experimental strategies were also not identified in the conventional strategy. Therefore, no additional false-negative results were reported in the experimental strategies compared with the conventional strategy.

Costs

Table 2 shows the diagnostic procedures and costs of each strategy. For each experimental strategy, the total number of patients referred for further evaluation by the radiologist and the total number of patients discharged are shown. Furthermore, the total number of each diagnostic procedure performed is given per strategy.

In the conventional strategy, a total of 1399 mammograms (1389 initial and 10 short-term follow up mammograms), 268 ultrasonography examinations, 18 fine-needle aspiration cytology, and 28 core needle biopsies were performed. In the experimental strategies, the number of diagnostic procedures was lower, due to the discharge of many patients after mammography. In particular, the number of ultrasound examinations decreased in the experimental strategies (range, 184–236) as compared to the conventional strategy (268 examinations).

Table 2. Diagnostic Procedures and Costs

	Convent.	Exp. 1a	Exp. 1b	Exp. 2	Exp. 3a	Exp. 3b	Exp. 4
Diagnostic procedures (n)							
Mammogram examination by radiologist	1389	–	–	–	–	–	–
Mammogram examination by technologist(s)	–	541	614	470	930	1019	862
Mammogram examination by radiologist and technologist(s)	–	848	775	919	459	370	527
Mammogram examination for short-term follow-up	10	10	10	10	10	8	10
Ultrasound examination	268	226	214	236	203	184	216
Fine needle aspiration cytology	18	17	17	18	16	15	17
Core needle biopsy	28	27	27	27	26	26	27
Costs (€)							
Total costs per strategy	150,602	139,781	136,758	150,612	126,834	122,494	137,999
Mean costs exp. 1a/1b and 3a/3b		*138,270*			*124,664*		
Difference compared with convent. strategy	–	10,821	13,844	−10	23,768	28,108	12,603
Mean difference exp. 1a/1b and 3a/3b		*12,332*			*25,938*		
% of conventional strategy	–	7.2	9.2	0	15.8	18.7	8.4
Mean % exp. 1a/1b and 3a/3b		*8.2*			*17.2*		

Table 3. Results of Threshold Analysis

Experimental strategy	Hourly rate technologist (€)	% of hourly rate radiologist (€160)
2	33	21%
4	59	37%
1	84	53%
3	141	88%

The total diagnostic costs in the conventional strategy were determined at €150,602. Strategies 1a, 1b, 3a, 3b, and 4 were cheaper than the conventional strategy (range, €122,494–€139,781), because fewer mammogram re-evaluations and fewer ultrasonography examinations by a radiologist were needed. Strategy 2 was slightly more expensive (€150,612), which was caused by a relatively high number of patients referred to the radiologist for further evaluation as well as the high costs for personnel, as two technologists were involved in the preselection procedures.

The total number of malignancies was equal in each strategy ($n = 20$). As no differences were assumed between the breast cancers in the different strategies in terms of staging, prognosis, and surgical interventions, the total costs of breast cancer treatment resulted in €351,300 for each strategy. As these costs were the same for each strategy, they were not included in Table 2.

Threshold Analysis

Table 3 shows the results of the threshold analysis in which the hourly rates for technologists were varied, given a constant hourly rate for the radiologist of €160.

The total costs in experimental strategy 2 were equal to the total costs in the conventional strategy, resulting in an hourly rate of the technologist of €33 as threshold value, which was 21 percent of the hourly rate of the radiologist. The costs of experimental strategy 4 were equal to the costs of the conventional strategy at an hourly rate of €59 (37 percent of the rate of the radiologist), whereas the costs of experimental strategy 1 were equal at a rate of €84 (53 percent). In experimental strategy 3, the threshold value was determined at €141 (88 percent of the hourly rate of the radiologist).

DISCUSSION

This study shows that the employment of specialized breast technologists in the preselection of mammograms in a clinical patient population can be an effective tool, which reduces diagnostic costs. Although the number of diagnostic procedures was decreased, no additional false-negative results were recorded in the experimental strategies compared with the conventional strategy. Savings are largest in the strategy in which one technologist separates the normal and benign mammograms (BI-RADS 1–2) from mammograms with suspicious and malignant abnormalities (BI-RADS 3–5) or examinations requiring additional imaging (BI-RADS 0), leading to a cost reduction of 17.2 percent compared with the conventional strategy. Using two technologists in prereading mammograms was only less expensive in strategy 4 (cutoff point between BI-RADS 2 and 3), resulting in cost savings of 8.4 percent.

Strength of this cost-analysis is that it was based on empirical data collected in a prospective, clinical study. Radiologists on duty evaluated all 1389 mammograms according to daily clinical practice. Additionally, the two technologists in this study read the images in another room on a separate workstation, but under similar viewing conditions as the radiologists.

The results showed that, in 470 to 1019 patients (in strategy 2 and 3b, respectively), the technologists decided that re-evaluation of the mammogram by a radiologist would not be necessary, resulting in a time saving up to 73 percent (1019/1389) for the radiologist in this patient population. Furthermore, some of the additional imaging tests that are performed regularly in the conventional strategy were not recommended in the experimental strategies. The number of advised ultrasonography examinations was 268 in the conventional strategy compared with 184 to 236 in the experimental strategies. The number of additional mammograms, fine needle aspiration cytology, and biopsies would be reduced by one to three in different strategies. Although it should be noted that the quality of care in these patients could be affected seriously as potential pathology may be missed, no breast cancers were found in these specific group of mammography examinations and the effect on the quality of care seems to be minimal here.

However, in experimental strategies 1a, 3, and 4, the technologists would have discharged patients that were diagnosed with breast cancer at a later stage. As these malignancies were also not diagnosed by mammography in the conventional strategy, these procedures would not lead to further delay in diagnosis in daily clinical practice. Although there is concern that delay by providers in the diagnosis of breast cancer would result in a significant progress of the malignancy, studies also show that this delay has no significant effect on stage, treatment, or survival (6;10;11). Nevertheless, delay in diagnosis does distress patient and clinician, and must be avoided as much as possible. Our data suggest that technologists are well able to assist radiologists in avoiding oversights whereby decreasing the miss rate in detecting malignancies.

To evaluate the cost savings of prereading mammograms by technologists, only integral diagnostic costs were used, including costs for personnel, material, capacity, and departmental overhead. As it was assumed that nonmedical costs and indirect costs were comparable for all strategies, these were excluded. Furthermore, the number of malignancies was equal in all strategies and it was assumed that the costs of breast cancer treatment were comparable among the

strategies. Therefore, these costs were excluded in the calculations of cost savings.

In addition to the integral diagnostic costs, some other cost items should be taken into consideration in the decision to use technologists in reading mammograms. First, before the start of the prospective study, the technologists underwent a 500-hour training program in 9 months in mammogram reading under the supervision of well-experienced breast radiologists. Training consisted of evaluation of up-to-date literature on mammography and anatomy and pathology of the breast, daily reading of diagnostic mammograms and evaluation of difficult clinical cases with a specialized breast radiologist. Furthermore, the technologists participated in pathology and oncology meetings, attended at mammography symposia and received practical and theoretical training in other medical centers. The total costs of the training program were estimated to be €47,500, including personnel costs of technologists and radiologists, costs for material and costs for symposia and training elsewhere.

Second, it needs to be taken into account that attending refresher courses are needed for regular preservation of interpretation skills of the technologists which will result in persistent costs.

Third, incorporating the task of prereading of mammograms into the job description of breast technologists will increase their responsibilities and, as a consequence, will probably lead to an increase in salary.

Finally, there are also potential costs of organizational effects, such as costs of patient information, increased staff management, and administrative costs. However, the determination of costs of implementation and application of prereading mammograms by technologists in daily clinical practice was not subject of this study.

Because in strategies 3 and 4, the technologists need to discriminate the certainly benign (BI-RADS 2) from the probably benign (BI-RADS 3) lesions, it could be argued that these are also the strategies in which the required performance and confidence of the technologists is highest. Furthermore, it illustrates the need for a good and proper training program to reach this level of expertise and knowledge.

In addition, these findings suggest the feasibility of incorporating the performance of breast ultrasonography into the task responsibilities of breast technologists. Doing so, even more patients could be discharged based on a negative mammogram and negative ultrasonography examination, which would reduce the workload of the breast radiologist even further. Finally, the mammograms of the groups of patients that were excluded from the current analysis because of their direct indication for breast ultrasonography, could then be seen by technologists as well. However, as in the Netherlands, independent performance of ultrasonography by technologists will fall outside their legal scope of practice, adaptation of legislation should be considered.

Concluding, the results of this study indicate that the employment of breast technologists in prereading mammograms in a clinical patient population could be an effective tool to reduce the workload of radiologists without jeopardizing the detection of breast malignancies. In addition to its effect on the clinical pathways of the patients referred for mammography, diagnostic costs can be reduced considerably.

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