BJR
© 2020 The Authors. Published by the British Institute of Radiology

https://doi.org/10.1259/bjr.20190785

Received: 12 September 2019 | Revised: 07 February 2020 | Accepted: 16 February 2020

Cite this article as:
Mariscotti G, Durando M, Pavan LJ, Tagliafico A, Campanino PP, Castellano I, et al. Intraoperative breast specimen assessment in breast conserving surgery: comparison between standard mammography imaging and a remote radiological system. *Br J Radiol* 2020; **93**: 20190785.

FULL PAPER

Intraoperative breast specimen assessment in breast conserving surgery: comparison between standard mammography imaging and a remote radiological system

[1]GIOVANNA MARISCOTTI, [1]MANUELA DURANDO, [1]LUCA JACOPO PAVAN, [2]ALBERTO TAGLIAFICO, [3]PIER PAOLO CAMPANINO, [4]ISABELLA CASTELLANO, [5]RICCARDO BUSSONE, [6]ADA ALA, [7]CORRADO DE SANCTIS, [8]LAURA BERGAMASCO, [1]PAOLO FONIO and [9]NEHMAT HOUSSAMI

[1]Department of Diagnostic Imaging and Radiotherapy, Radiology Institute, University of Turin, A. O. U. Città della Salute e della Scienza di Torino, Presidio Ospedaliero Molinette Via Genova 3, 10126 Torino, Italy
[2]Department of Experimental Medicine, University of Genoa IRCCS AOU San Martino – IST Istituto Nazionale per la Ricerca sul Cancro, 16132 Genoa, Italy
[3]Breast Imaging Service. Ospedale Koelliker.C.so Galileo Ferraris 256 – 10100, Torino, Italy
[4]Department of Medical Sciences, University of Turin, A. O. U. Città della Salute e della Scienza di Torino, Presidio Ospedaliero Molinette, Via Santena, 7, Torino, Italy
[5]Breast Surgery, Presidio Sanitario Ospedale Cottolengo Via S. Giuseppe Benedetto Cottolengo, 9 - 10152, Torino, Italy
[6]Breast Surgery, Department of Surgery, A. O. U. Città della Salute e della Scienza di Torino, Presidio Ospedaliero S. Anna, Via Ventimiglia, 1, 10126, Torino, Italy
[7]Department of Gynecology and Obstetrics, Breast Unit, A.O.U. Città della Salute e della Scienza di Torino, Presidio Ospedaliero S. Anna, Via Ventimiglia, 1, 10126 Torino, Italy
[8]Department of Surgical Sciences, University of Torino, A. O. U. Città della Salute e della Scienza di Torino, Presidio Ospedaliero Molinette, C.so Bramante 88, 10126 Torino, Italy
[9]Screening and Test Evaluation Program, School of Public Health, Sydney Medical School, University of Sydney, Sydney, 2006, NSW, Australia

Address correspondence to: Dr Giovanna Mariscotti
E-mail: *giovanna.mariscotti@libero.it*

Objective: To compare standard specimen mammography (SSM) with remote intraoperative specimen mammography (ISM) assessment in breast conserving-surgery (BCS) based on operative times, intraoperative additional excision (IAE) and re-intervention rates.
Methods and materials: We retrospectively compared 129 consecutive patients (136 lesions) who had BCS with SSM at our centre between 11/2011 and 02/2013 with 138 consecutive patients (144 lesions) who underwent BCS with ISM between 08/2014 and 02/2015.
SSM or ISM were performed to confirm the target lesions within the excised specimen and margin adequacy. The utility of SMM and ISM was evaluated considering pathology as gold-standard, using χ^2 or Fisher's exact tests for comparison of categorical variables, and non-parametric Mann–Whitney test for continuous variables.
Results: The two groups did not statistically differ for age (p = 0.20), lesion size (p = 0.29) and morphology (p = 0.82) or tumor histology type (p = 0.65). Intraoperative time was significantly longer (p < 0.00001) for SSM (132 ± 43 min) than for ISM (90 ± 42 min). The proportions requiring IAE did not significantly differ between SSM group (39/136 lesions (40%)) and ISM group (52/144 lesions (57%)) (p = 0.19), overall and in stratified analysis by mammographic features. Re-intervention rates were not statistically different between the two groups [SSM:19/136 (14%), ISM:13/144 (9%); p = 0.27].
Conclusion: The introduction of ISM in BCS significantly reduced surgical time but did not change IAE and re-intervention rates, highlighting facilitated communication between surgeons and radiologists.
Advances in knowledge: Compared to standard mammography imaging, the use of ISM significantly reduced surgical time.

INTRODUCTION

Breast cancer is the most frequent tumor in females worldwide. Since non-palpable breast cancer is frequently diagnosed through screening services[1,2] and given equivalent survival outcomes for mastectomy and breast conserving surgery (BCS) in early-stage breast cancer, BCS is generally the preferred treatment in these patients.[3,4]The main objective of BCS is the complete removal of cancer with clear surgical margins, the latter being a prognostic factor for tumor recurrence,[5–7] in balance with the best possible aesthetic outcome.

Re-excision is a possible further procedure to obtain negative margins in patients with positive margins after BCS. An additional operative intervention submits the patient to increased treatment burden including risk of anesthesia, increased surgical complications, in addition to increased healthcare costs.[8–10]

For these reasons, obtaining negative tumor margins during initial BCS is important to reduce the risk of local recurrence, whilst also avoiding unnecessary re-operations.[7,11]

Specimen radiography using digital mammography is used to document excision of the targeted lesion but is also one of the strategies used for intraoperative resection margin determination during BCS. When removing non-palpable lesions, an X-ray evaluation of the specimen using two projections can confirm whether the tumor has been adequately excised without apparent involvement of margins, and if not, further tissue may be promptly excised by the surgeon to potentially avoid a further operation.[12] This evaluation is usually completed by physically transporting the specimen to the Radiology unit to perform a standard specimen mammography (SSM). Since this procedure is time consuming, an alternative technique, intraoperative specimen mammography (ISM), has emerged: specimen mammography is performed in the surgical block by the surgeon using an automatic small device and images are remotely evaluated by the radiologist via PACS (picture archiving and communication system, with an expected reduction in intraoperative time.[13]

The aim of this study was to investigate the utility of ISM compared to SSM for the assessment of resection margins in BCS of non-palpable breast cancer. In particular, we compared ISM and SSM based on: (1) operative times, (2) intraoperative additional excision (IAE) and (3) re-intervention rates.

METHODS AND MATERIALS

Study design and population

We performed a retrospective study of patients who underwent BCS at our at our Breast Unit, A.O.U. Citta' della Salute e della Scienza di Torino before and after the introduction of ISM in our hospital in December 2013. Patients were divided in two groups, considering two-time intervals: November 2011 to February 2013, when the standard approach was SSM, and August 2014 to February 2015, when ISM became the standard approach.

Patient eligibility was based on four inclusion criteria: (1) availability of complete pre-operative imaging (mammography, ultrasound and MRI if indicated) and specimen imaging; (2) availability of post-operative pathology reports; (3) malignant lesion (invasive or *in situ* carcinoma) confirmed at pathology; (4) same surgical and radiological team performed the procedures during the study period, to prevent confounding variables related to the staff's ability and team coordination.

Patients, who underwent neoadjuvant chemotherapy treatment and subsequently BCS, were excluded, since the shrinkage of the tumor in responders could represent an additional challenge to identify the lesion on specimen imaging. Lesions that were occult on mammography were also excluded.

SSM and ISM procedure

In all cases, non-palpable lesions were marked with charcoal suspension (2–4 ml, 4%) before BCS, using ultrasound or stereotactic guidance.

Specimens examined with SSM were sent by the surgeon to our Breast Imaging Service for mammography. Suture threads were applied on each surgical specimen in the operating room to identify each resection margins: one thread for the areolar margin; two threads for the antiareolar side; three threads for the superficial or cutaneous margin.

For all specimens, mammograms were obtained in the two orthogonal planes. First, the surgical specimen was positioned on the mammography plate, compressed by the appropriate paddle and oriented as for the craniocaudal view, and then rotated 90° laterally to obtain the laterolateral view. Specimen mammograms were performed on a digital mammography unit (Hologic Dimensions) using the direct magnification technique and appropriate compression.

For ISM evaluation, the excised specimens were placed by the surgeon in the specimen mammography system (BioVision, Faxitron Bioptics®) into plastic bag and examined using the same two projections (two orthogonal views), even though only soft compression was feasible. The acquired images were displayed in real time on a 24" high-resolution 3.7 MP monitor, not intended for definitive evaluation. After the surgeon obtained two correct projections, they were accepted and sent via PACS to the radiologist, who performed the evaluation on a high-resolution screen (5 MegaPixel, Barco®).

For both modalities, specimen images were compared with the baseline (diagnostic) mammogram to assess adequacy of the excision. Parameters considered in the radiological report of the specimen were:

- Presence/absence of the lesion.
- Position of the lesion relative to the resection margins.
- Direction along which to extend the excision in case of close or affected margins, to direct the IAEs (recommended by radiologist).

The radiologist discussed immediately each case by telephone with the surgeon. In cases where the lesion was found to be close to a margin, the radiologist suggested to the surgeon the direction of the IAEs. A formal radiological report was also provided.

Baseline mammography and specimen images were evaluated by two dedicated breast radiologists with more than 10 years of experience. After the mammographic examination, the surgical specimen was sent to the pathologist for histological assessment.

The diagnostic reliability of the SSM and ISM specimen evaluation was assessed by comparing the radiographic and histopathological diagnoses: at histology, the resection margins were considered to be infiltrated if the tumor was located on the sectioned surface (ink on tumor). When the distance between resected border and lesion was <2 mm, we classified margins as "close margin"; margins were considered as free (negative) if more than 2 mm were present between lesion and borders.

According to the Institutional protocol, all cases were finally discussed at multidisciplinary meeting for subsequent treatment (included surgical re-interventions, if necessary).

This retrospective analysis was performed in accordance with the guidelines of the local institutional review board with a waiver of informed consent. Before undergoing surgery, all patients had been informed about the surgical procedures and the possible use of their data for study purposes, and accordingly signed an informed consent form. Patient information was anonymized prior to analysis.

Data collected and statistical analysis

The following variables were collected for both groups: age, lesion mammographic features, lesion size, tumor histology type, operative time, specimen weight, IAEs requested by radiologist and their outcome; and re-intervention rates. Operative time was calculated from the induction of anesthesia to the end of the surgical procedure.

Pathology was considered as gold-standard to determine the presence of malignancy.

A stratified analysis of intraoperative additional excisions and re-intervention rates were calculated, according to mammographic features and histology.

Statistical analysis was carried out using $\chi 2$ or Fisher's test for categorical variables and Mann–Whitney test for continuous variables, with a significance level <0.05.

Table 1. Comparison of patient and tumor characteristics between two groups according to whether SSM or ISM was used during breast conserving-surgery

	SSM		ISM		*p*-value
Study period	Nov 2011 – Feb 2013		Aug 2014 – Feb 2015		-
N. of patients (N. of lesions)	129 (136)		138 (144)		-
Patients' age (mean ± SD)	62 ± 11 years		60 ± 11 years		0.20
Mammographic size (mean ± SD)	17 ± 11 mm		15 ± 9 mm		0.29
		N (%)		N (%)	
Mammographic features of malignant lesion	Masses	88 (65%)	Masses	95 (66%)	0.82
	Microcalcifications	26 (19%)	Microcalcifications	23 (16%)	
	Architectural Distortion	22 (16%)	Architectural Distortion	26 (18%)	
Type of surgery	BCS only	27 (20%)	BCS only	22 (15%)	0.59
	BCS with sentinel lymph node biopsy	87 (64%)	BCS with sentinel lymph node biopsy	96 (67%)	
	BCS with axillary dissection	22 (16%)	BCS with axillary dissection	26 (18%)	
Histologic size (mean ± SD)	18 ± 11 mm		16 ± 11 mm		0.20
Specimen weight (mean ± SD)	70 ± 67 g		60 ± 39 g		0.11
		N (%)		N (%)	
Tumor histologic types	Invasive ductal ca.	64 (47%)	Invasive ductal ca.	73 (51%)	0.65
	Invasive lobular ca.	24 (18%)	Invasive lobular ca.	24 (17%)	
	In Situ ductal carcinoma	27 (20%)	*In Situ ductal* carcinoma	22 (15%)	
	Other invasive types	21 (15%)	Other invasive types	25 (17%)	

BCS: breast conserving surgery;ISM, intraoperative specimen mammography; SD: standard deviation;SSM, standard specimen mammography.

Table 2. Comparison between operative times, intraoperative additional excisions and re-intervention rates

	Standard specimen mammography	Intraoperative specimen mammography	*p*-value
Operative time (mean ± SD)	132 ± 43 min	90 ± 42 min	***<0.00001***
Operative time (mean ± SD) when intraoperative additional excision was recommended by **radiologist**	144 ± 44 min	96 ± 37 min	***<0.00001***
Intraoperative additional excision rate recommended by **radiologist**	39/136 (29%)	53/144 (37%)	0.19
Intraoperative additional excision rate yielding **malignant finding** at pathology examination	9/39 (23%)	18/53 (34%)	0.37
Re-intervention (re-operation) rate	19/136 (14%)	13/144 (9%)	0.27

SD: standard deviation

RESULTS

Patient cohorts

A total of 267 patients with breast cancer were included: 129 in the SSM group and 138 in the ISM group. Table 1 shows and compares the characteristics of the two groups of patients and related imaging, tumor and treatment variables. There were no significant differences between the two groups across all variables.

Intraoperative outcomes

Table 2 reports the comparison of operative times, IAEs and re-intervention rates. In terms of intraoperative time, there was a significant difference between groups: 132 ± 43 min for SSM *vs* 90 ± 42 min for ISM ($p < 0.00001$). The difference in intraoperative time was statistically significant ($p < 0.00001$) also comparing SSM and ISM in the subgroup of cases where the IAE was recommended by the radiologist.

IAE recommended by the radiologist was performed for 39/136 (29%) lesions in the SSM group and on 53/144 (37%) lesions in the ISM group ($p = 0.19$), and there were no significant differences at stratified analysis for each mammographic feature supplementary material 1 (Table A.1) or considering histologic type supplementary material 1 (Table A.2). At pathological examination, 9/39 (23%) IAE specimens in the SSM group were positive for malignancy and 18/53 (34%) in the ISM group, ($p = 0.37$).

There were no statistically significant differences in re-intervention (re-operation) rates between the two groups, respectively 14% for SSM and 9% for ISM ($p = 0.27$).

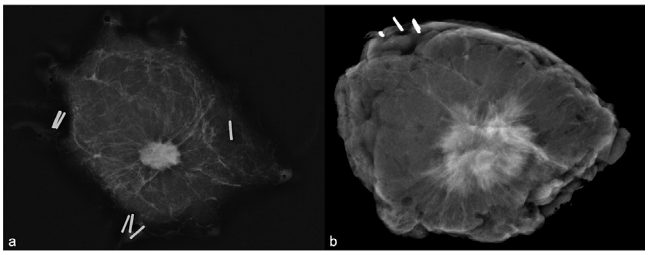
Table 3 reports and compares the margin status of the specimens evaluated by the two different procedures, highlighting that no statistical differences ($p = 0.10$) were found in the percentages of clear, infiltrated or close margins in the two groups (data also

Table 3. Comparison between SSM and ISM based on margin status evaluated with histology

Margin status evaluated with histology (***subgrouped by each mammographic features***)	**SSM (N.136)**	**ISM (N.144)**	*p*-value
Clear (negative)	108 (79%)	114 (79%)	0.10
-Masses	*78*	*74*	
-Microcalcifications	*15*	*18*	
-Architectural distortions	*15*	*22*	
Infiltrated (positive)	19 (14%)	12 (8%)	
-Masses	*7*	*8*	
-Microcalcifications	*6*	*2*	
-Architectural distortions	*6*	*2*	
Close	9 (7%)	18 (13%)	
-Masses	*5*	*12*	
-Microcalcifications	*3*	*3*	
-Architectural distortions	*1*	*3*	

ISM, intraoperative specimen mammography; SSM, standard specimen mammography.

Figure 1. (a, b) Two different example cases of masses with spiculated margins assessed by (a) SSM and (b) ISM, respectively. ISM, intraoperative specimen mammography; SSM, standard specimen mammography.



shown in sub groups according to mammographic features) (Figures 1–3). Sensitivity, specificity, positive predictive value and negative predictive value for the two procedures in the radiological assessment of margin status were not significantly different, estimated respectively as 35.7%, 73.1%, 25.6% and 81.4% for SSM and 56.7%, 68.4%, 32.1% and 85.7% for ISM; the results similarly showed no significant differences at analyses stratified by mammographic features supplementary material 1(Table A.3).

DISCUSSION

Our study shows that following the introduction of the ISM system in our centre we had a significant reduction in the operative time for BCS compared to an earlier time-period when we used SSM for the same procedure. This finding aligns with previous studies.[13–16] The reason for this time saving is likely to be that performing specimen mammography directly in the surgical block, without physically carrying the specimen to the Radiology Department which could be situated in a different location within the hospital (as is the case in some facilities including ours).

The reduction in operative time has multiple consequences, such as decreased anesthetic times, reduced risks for the patients and reduced operating room costs, as well the potential to increase the number of interventions per day, hence decreasing patients' waiting list.

The intraoperative margin assessment methods included non-invasive techniques that applied to the excised tissue or within the surgical cavity can produce results about margin status during surgery to enable further tissue shavings to be taken. Intraoperative pathological assessment (frozen section, touch smear and imprint cytology, gross tissue inspection combined with specimen radiology) had high sensitivity, specificity and accuracy, but these methods add significant time to the operation, often between 20 and 30 min on average.[17] Among the intraoperative imaging methods, intraoperative ultrasound showed sensitivity that ranged from 25 to 100% and specificity from 74 to 95% and can be used to guide surgery in the operating theatre. However, ultrasound works well in dense soft tissue, but it does not perform as well where there is multifocal disease or for lesions presenting as calcification.[17] Further studies reported that specimen mammographic evaluation took approximately the same time, or slightly longer, as handheld ultrasound.[17]

In our study, aside from the reduced procedure time attributed to ISM (compared to SSM) there were no other differences in the surgical outcomes we examined, including IAE rates and re-intervention rates.[18]

Some studies have found a reduction in re-intervention rates after the introduction of ISM.[19] In our series, the re-intervention rate was non-significantly lower following the introduction of ISM (re-intervention rate 14% for SSM and 9% for ISM), possibly limited by sample size, in agreement with what was reported by Layfield et al.[20] Our re-intervention rates are still within the range reported in recent studies, following the SSO-ASTRO guidelines.[10,21–23]

Our study also focused on IAE rates, which slightly increased in the ISM group as shown in Table 2. We did not anticipate substantial changes in IAE rates and re-intervention rates, since the imaging analysis was performed by the same radiologists on both groups and imaging quality is comparable, even though the two imaging techniques have some execution differences. Specimens examined with SSM are compressed with a plate, trying to simulate the conditions of the mammographic examinations. In ISM, instead, there is no possibility of a controlled specimen

Figure 2. (a, b) Two different example cases of architectural distortions assessed by (a) SSM and (b) ISM, respectively. ISM, intraoperative specimen mammography; SSM, standard specimen mammography.

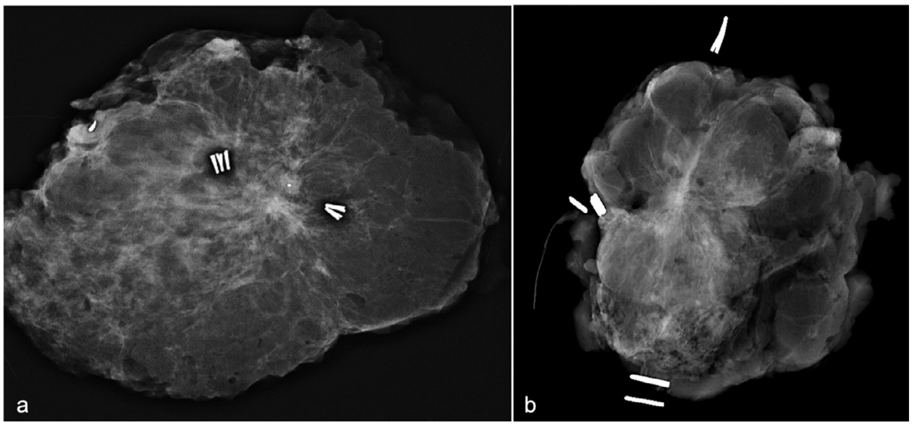
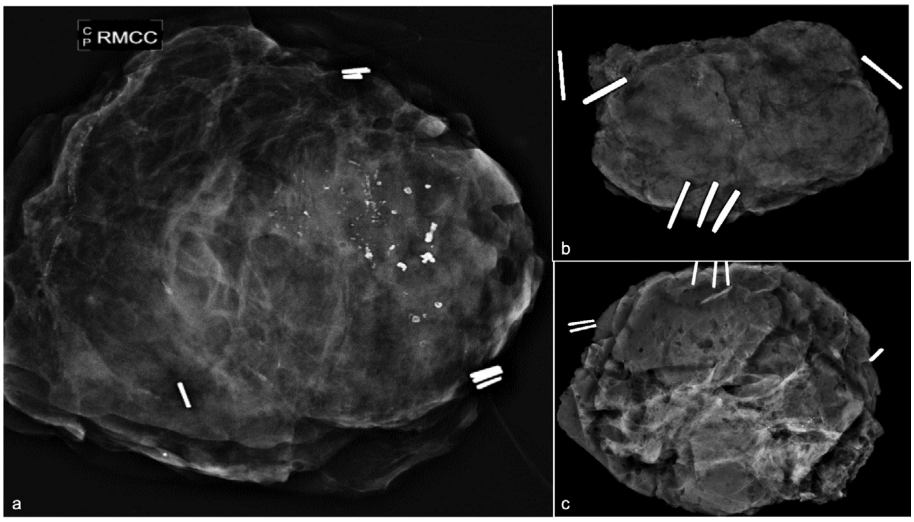


Figure 3. (a, b, c) Three different example cases of microcalcifications assessed by (a) SSM and ISM, both in dense (b) and non-dense tissue (c). ISM, intraoperative specimen mammography; SSM, standard specimen mammography.



compression. We preferred not to compress the specimen or to compress them with tools that could create artefacts. On the contrary, we found it indispensable to perform two projections with both techniques.

We also verified that there were no differences in the correct evaluation of lesions subgrouped on the basis of mammographic features or histological subtypes: these findings strengthen the reliability of ISM also in the assessment of microcalcifications (although this had the limitation of not being able to perform magnification view, which was possible previously when we used SSM).

Even though our study was retrospectively designed, our population was consistent, since it included more than 260 breast cancer patients with generally similar variables across the two groups. The majority of published studies considered less than a hundred patients and only Camp et al[15] and Muttalib et al[14] compared groups of patients with similar characteristics. Furthermore, we evaluated the utility of the two techniques on the three main radiological features depicting cancer without finding any significant differences, suggesting that our comparative results are reliable. In particular, we did not find any significant difference with microcalcifications that can be more challenging to be visualized without a good screen resolution.

The limitations of the study are the retrospective design, and that we did not allow a 'double evaluation' of specimens with both ISM and SSM for direct comparison. Nonetheless, the design allowed us to pragmatically compare BCS operative times between the two groups.

CONCLUSIONS

Our study supports the use of ISM in place of SSM during BCS, as a relatively fast and reliable procedure compared to SSM, allowing a significant reduction in operative times, by streamlining communication around the adequacy of tumor excision between surgeons and radiologists.

ACKNOWLEDGMENT

We thank Dr. Simona Bevilacqua, Dr. Roberto Cianci for their clinical support to this work and Dr. Federica Actis Perinetti for her personal contribution to this study.
We also thank Elisa Castellucchio for her technical support to this study.

CONFLICTS OF INTEREST

All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence their work.

FUNDING

Prof Houssami receives research support via a National Breast Cancer Foundation (NBCF, Australia) Breast Cancer Research Leadership Fellowship.

REFERENCES

1. Siegel R, Naishadham D, Jemal A. Statistics C. *CA Cancer J Clin* 2013; **2013**: 11–30.
2. American Cancer Society (ACS). Global cancer facts and figures, 3rd ed. ACS website. 2015. Available from: https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/global-cancer-facts-and-figures/global-cancer-facts-and-figures-3rd-edition.pdf;[accessed 12 November 2018].
3. Veronesi U, Cascinelli N, Mariani L, Greco M, Saccozzi R, Luini A, et al. Twenty-Year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. *N Engl J*

Med 2002; **347**: 1227–32. doi: https://doi.org/10.1056/NEJMoa020989
4. Blichert-Toft M, Nielsen M, Düring M, Møller S, Rank F, Overgaard M, et al. Long-Term results of breast conserving surgery vs. mastectomy for early stage invasive breast cancer: 20-year follow-up of the Danish randomized DBCG-82TM protocol. *Acta Oncol* 2008; **47**: 672–81. doi: https://doi.org/10.1080/02841860801971439
5. Singletary SE. Surgical margins in patients with early-stage breast cancer treated with breast conservation therapy. *Am J Surg* 2002; **184**: 383–93. doi: https://doi.org/10.1016/S0002-9610(02)01012-7
6. Pinotti JA, Carvalho FM. Intraoperative pathological monitorization of surgical margins: a method to reduce recurrences after conservative treatment for breast cancer. *Eur J Gynaecol Oncol* 2002; **23**: 11–16.
7. Houssami N, Macaskill P, Marinovich ML, Morrow M. The association of surgical margins and local recurrence in women with early-stage invasive breast cancer treated with breast-conserving therapy: a meta-analysis. *Ann Surg Oncol* 2014; **21**: 717–30. doi: https://doi.org/10.1245/s10434-014-3480-5
8. Boughey JC, Hieken TJ, Jakub JW, Degnim AC, Grant CS, Farley DR, et al. Impact of analysis of frozen-section margin on reoperation rates in women undergoing lumpectomy for breast cancer: evaluation of the National surgical quality improvement program data. *Surgery* 2014; **156**: 190–7. doi: https://doi.org/10.1016/j.surg.2014.03.025
9. Olsen MA, Nickel KB, Margenthaler JA, Wallace AE, Mines D, Miller JP, et al. Increased risk of surgical site infection among breast-conserving surgery Re-excisions. *Ann Surg Oncol* 2015; **22**: 2003–9. doi: https://doi.org/10.1245/s10434-014-4200-x
10. Pataky RE, Baliski CR. Reoperation costs in attempted breast-conserving surgery: a decision analysis. *Curr Oncol* 2016; **23**: 314–21. doi: https://doi.org/10.3747/co.23.2989
11. Cabioglu N, Hunt KK, Sahin AA, Kuerer HM, Babiera GV, Singletary SE, et al. Role for intraoperative margin assessment in patients undergoing breast-conserving surgery. *Ann Surg Oncol* 2007; **14**: 1458–71. doi: https://doi.org/10.1245/s10434-006-9236-0
12. American College of Radiology. ACR practice parameter for the imaging management of DCIS and invasive breast carcinoma. 2013. Available from: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/DCIS.pdf [accessed 12 November 2018].
13. Miller CL, Coopey SB, Rafferty E, Gadd M, Smith BL, Specht MC. Comparison of intra-operative specimen mammography to standard specimen mammography for excision of non-palpable breast lesions: a randomized trial. *Breast Cancer Res Treat* 2016; **155**: 513–9. doi: https://doi.org/10.1007/s10549-016-3700-8
14. Muttalib M, Tisdall M, Scawn R, Shousha S, Cummins RS, Sinnett HD. Intra-Operative specimen analysis using faxitron microradiography for excision of mammographically suspicious, non-palpable breast lesions. *Breast* 2004; **13**: 307–15. doi: https://doi.org/10.1016/j.breast.2004.02.005
15. Camp MS, Valero MG, Opara N, Benabou K, Cutone L, Caragacianu D, et al. Intraoperative digital specimen mammography: a significant improvement in operative efficiency. *Am J Surg* 2013; **206**: 526–9. doi: https://doi.org/10.1016/j.amjsurg.2013.01.046
16. Kaufman CS, Bachman BA, Jacobson L, Kaufman LB, Mahon C, Gambrell L. Intraoperative digital specimen mammography: prompt image review speeds surgery. *Am J Surg* 2006; **192**: 513–5. doi: https://doi.org/10.1016/j.amjsurg.2006.06.022
17. Butler-Henderson K, Lee AH, Price RI, Waring K. Intraoperative assessment of margins in breast conserving therapy: a systematic review. *Breast* 2014; **23**: 112–9. doi: https://doi.org/10.1016/j.breast.2014.01.002
18. Kim SHH, Cornacchi SD, Heller B, Farrokhyar F, Babra M, Lovrics PJ. An evaluation of intraoperative digital specimen mammography versus conventional specimen radiography for the excision of nonpalpable breast lesions. *Am J Surg* 2013; **205**: 703–10. doi: https://doi.org/10.1016/j.amjsurg.2012.08.010
19. Ciccarelli G, Di Virgilio MR, Menna S, Garretti L, Ala A, Giani R, et al. Radiography of the surgical specimen in early stage breast lesions: diagnostic reliability in the analysis of the resection margins. *Radiol Med* 2007; **112**: 366–76. doi: https://doi.org/10.1007/s11547-007-0147-3
20. Layfield DM, May DJ, Cutress RI, Richardson C, Agrawal A, Wise M, et al. The effect of introducing an in-theatre intra-operative specimen radiography (IOSR) system on the management of palpable breast cancer within a single unit. *Breast* 2012; **21**: 459–63. doi: https://doi.org/10.1016/j.breast.2011.10.010
21. Heelan Gladden AA, Sams S, Gleisner A, Finlayson C, Kounalakis N, Hosokawa P, et al. Re-excision rates after breast conserving surgery following the 2014 SSO-ASTRO guidelines. *Am J Surg* 2017; **214**: 1104–9. doi: https://doi.org/10.1016/j.amjsurg.2017.08.023
22. Morrow M, Abrahamse P, Hofer TP, Ward KC, Hamilton AS, Kurian AW, et al. Trends in reoperation after initial lumpectomy for breast cancer: addressing overtreatment in surgical management. *JAMA Oncol* 2017; **3**: 1352–7. doi: https://doi.org/10.1001/jamaoncol.2017.0774
23. Moran MS, Schnitt SJ, Giuliano AE, Harris JR, Khan SA, Horton J, et al. Society of surgical Oncology-American Society for radiation oncology consensus guideline on margins for breast-conserving surgery with whole-breast irradiation in stages I and II invasive breast cancer. *Int J Radiat Oncol Biol Phys* 2014; **88**: 553–64. doi: https://doi.org/10.1016/j.ijrobp.2013.11.012