International Journal of Surgery Open 21 (2019) 7–11

Contents lists available at ScienceDirect

International Journal of Surgery Open

journal homepage: www.elsevier.com/locate/ijso

Research Paper

Carbon-track localisation as an adjunct to wire-guided excision of impalpable breast lesions: A retrospective cohort study

Q. Tran [a,*], R. Mizumoto [b], M.C. Tran [c], M. Reintals [d], V. Gounder [a]

[a] Department of General Surgery, Caboolture Hospital, Caboolture, Australia
[b] School of Medicine, University of Queensland, St Lucia, QLD, Australia
[c] Diamantina Institute of Research, University of Queensland, Brisbane, QLD, Australia
[d] Director of Breast Imaging for I-Med, QLD, Australia

ARTICLE INFO

Article history:
Received 7 February 2019
Received in revised form
14 September 2019
Accepted 24 September 2019
Available online 28 September 2019

Keywords:
Breast
Impalpable lesions
Cancer
Localisation
Carbon
Wire

ABSTRACT

Background: Wire-guided localisation (WGL) is the most widely used approach to excise impalpable breast lesions in breast conserving surgery (BCS). There are several disadvantages to this technique. There are a variety of methods available, each with its own imperfections, therefore a superior approach is much desired. Here we report the efficacy of carbon-track localisation (CL) as an adjunct to hookwire in terms of margins, complications and operating time.
Methods: A consecutive series of patients with impalpable breast lesions undergoing either CL combined with WGL or just WGL alone from 2016 to 2017 were evaluated in this retrospective cohort study. Of 57 patients, 27 CLs with WGL and 30 WGLs alone were performed.
Results: All breast lesions were successfully localised pre-operatively and excised in both groups. Involved margins for invasive or *in-situ* disease were found in 14% in the CL group and 24% in the WGL group ($p = 0.70$). Close margins of <1 mm were found in 29% of the CL group and 48% in the WGL group ($p = 0.34$). The median operating time were 26 min and 37 min for the CL and WGL groups respectively ($p = 0.002$). Complications were noted to be 7.4% with CL and 16.7% with WGL ($p = 0.43$).
Conclusion: Carbon-track as an adjunct to hookwire localisation can be easily adopted and has a short learning curve with improved surgical outcomes. Although requiring further validation from larger studies to demonstrate statistical significance, the outcomes reported here are promising.
© 2019 The Authors. Published by Elsevier Ltd on behalf of Surgical Associates Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Breast cancer is the most common cancer affecting women [1]. It has the highest rate of cancer-related mortality worldwide and is the second leading cause of death in Australian and European women [2,3]. With improvement in mammography (MMG) and more widespread use, cancers are being detected earlier. Breast conserving surgery (BCS), in combination with adjuvant therapies, is the treatment of choice for early breast cancers [4]. Over one third of excised lesions are clinically occult and the most widely used technique to excise these impalpable lesions is wire-guided localisation (WGL) [5]. There are several drawbacks to this method, hence a variety of other approaches have been studied including: carbon marking, biopsy clips, methylene blue, frozen section analysis, ultrasound skin marking, intra-operative ultrasound, cryo-probe assisted, haematoma-directed ultrasound, radio-guided and radioactive-seed localisation. However, every technique has unique drawbacks, and the evidence validating their use are limited. Authors such as Corsi et al. [4] have suggested a combination of two or more techniques may improve outcomes.

Hookwire localisation (HW/GWL) was first described in 1979 by several authors [6,7]. A hookwire is inserted into a non-palpable lesion under ultrasound (USS) or stereotactic guidance pre-operatively and assist the surgeon intra-operatively to excise the lesion. Although this method is widely adopted by up to 80% of surgeons according to Van Esser et al. [8], it has a significantly high re-excision rate. Bourke et al. reported a re-operation rate of 30% in an Australian institution and can be up to 68% in some studies [9,10]. Rose et al. reported close margins <1 mm in 29.2% of HW

* Corresponding author. Caboolture Hospital, McKean Street, Caboolture, QLD, 4510, Australia.
E-mail address: quoc.tran@uqconnect.edu.au (Q. Tran).

https://doi.org/10.1016/j.ijso.2019.09.004
2405-8572/© 2019 The Authors. Published by Elsevier Ltd on behalf of Surgical Associates Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

procedures. Elsewhere, adequate margins have been reported to be 70.8–87.4% [4].

Carbon localisation, first described by Svane in 1983, is an alternative method which is superior to HW logistically and more advantageous in terms of pre-operative localisation [11]. The inert carbon suspension is optimally injected into or adjacent to the lesion and a carbon track is created on withdrawing the needle leaving a small tattoo at the skin to be excised at surgery. Although it is being used in some parts of the world, very few studies have compared it directly with HW in isolation or as a combined approach.

In this retrospective series, a combination of carbon-track with hookwire (Cook's Kopans hookwire) as adjuncts are used to localise non-palpable breast lesions for excision and results are compared against hookwires alone. The primary outcomes are surgical margins and re-excision rates. Other important variables including pre-operative localisation success rates, operating time, post-operative complications and length of hospital stay are reported.

2. Methods

A consecutive series of patients with impalpable breast lesions requiring wire-guided BCS between 2016 and 2017 in a district hospital were evaluated. Pre-operative demographics, clinical and radiographic data were collected. Operating time, concurrent sentinel lymph node biopsy (SLNB), histology, re-operation, complications and length of hospital stay were analysed. At our institution, scout nurses entered the operating time into an electronic database (ORMIS) which commenced from patient preparation and ended when the final dressing was applied.

Pre-operative localisation was performed on a total of 57 patients, of which, 27 consecutive patients underwent both HW and carbon-track for the same lesion. Radiological localisation was performed by a breast radiologist trained in carbon placement under stereotactic control or ultrasound guidance at a nearby radiology service on the day of surgery. After the skin was prepared and anaesthetised, an 18-gauge needle was used to inject 0.2–0.4 mls of sterile 4% carbon suspension (Charcotrace) into or adjacent to the lesion. A track of carbon was generated by continuous infusion on withdrawal and a small tattoo was created at the skin. A Cook's Kopans hookwire was inserted along the same track and its position was checked with two mammographic views. These images were given to the surgeon along with a diagram of the CL and HW demonstrating their length, depth, angles of insertion and endpoints to aid surgical excision. Patients requiring SLNB also had lymphoscintigraphy mapping the day prior using 10 MBq of technetium^{99m} colloid.

At surgery, 2 ml of patent blue V dye was injected subdermally into the peri-areolar followed with 5 min of massage for patients requiring concurrent SLNB. An appropriate skin incision was performed to incorporate the small tattoo and the carbon track was traced down to the tumour. Both the tumour and the carbon track were excised along with the backup hookwire. For patients with HW alone, the wire was used to guide dissection down to the tumour for excision. Sentinel lymph node biopsy (SLNB) followed using surgical gamma probe.

During this study, the surgeon primarily used the carbon track to localise the impalpable lesion. The HW was only used if the carbon track was non-contiguous or could not reliably be traced, of which there were not any cases reported in this series.

The specimen was sent for radiological confirmation of hookwire non-exposure and adequacy of excision was communicated to the surgeon. Pathology results were then reviewed at the fortnightly multidisciplinary meeting to determine the course of further management. Clinical charts were reviewed for complications for two years after surgery.

This retrospective, single-centred cohort study follows the STROCSS guideline and registered in accordance with the declaration of Helsinki (UIN 4640) [12].

3. Results

A total of 57 consecutive participants underwent breast conserving surgery requiring pre-operative localisation. Twenty-seven patients underwent carbon-track localisation in combination with HW. Patient's and lesion's characteristics of each groups are summarised in Table 1. The average age was 63.5 and 63.9 years old for CL and HW groups respectively ($p = 0.90$). SLNB was performed concurrently in 48% of the CL group and 53% in the HW group ($p = 0.79$). Benign pathologies included fibrocystic disease, intraductal papilloma, atypical ductal hyperplasia, radial scar and benign calcification. Malignant disease was found in 78% of the CL group and 70% in the HW group ($p = 0.78$). The average size of the invasive component was 10.6 mm for the CL cohort and 11.9 mm for the HW cohort ($p = 0.55$). The average whole lesion size was 21.8 mm and 19 mm for the CL and HW groups respectively ($p = 0.59$).

Histological and radiological predictors of margin status are compared in Table 2 and are not dissimilar between the two groups. Primary outcome of re-operation rates for both invasive and *in-situ* disease were 29% and 38% for the CL and HW groups respectively ($p = 0.74$) (Table 3). Involved margins were noted in 14% in the CL group and 24% in the HW group (p = 0.7). Close margins of <1 mm were recorded in 29% and 47% for the case and control group respectively ($p = 0.34$). There were improvements across all three variables but none with statistical significance.

Secondary outcomes, demonstrated in Table 4, of successful pre-operative localisation and successful excision rates were both approaching 100% and there was no statistical difference. The median operating time for the CL group was 26 min versus 37 min for the HW group with statistical significance ($p = 0.002$). Two patients in the CL group and two in the HW group required

Table 1
Participant's and lesion characteristics.

	CL	HW	Total	P
Participant (n)	27	30	57	
Average age (years, (SD))	63.5 (11)	63.9 (12)	63.7 (11)	0.90[a]
Concurrent SLNB (n, (%))	13 (48.1)	16 (53.3)	29 (51)	0.79
Histopathology (n)				
Benign	6	8	14	
LCIS	0	1	1	
Malignant (n, (%))	21 (78)	21 (70)	42 (74)	1.0
IDC	2	4	6	
ILC	2	2	2	
Mucinous Ca	1	0	1	
Papillary Ca	1	2	3	
DCIS	5	3	8	
IDC and DCIS	10	10	20	

[a] p-values derived from Student's t-test.

Table 2
Comparison of most common features associated with positive margins [19].

Predictors of Margin Status		CL	HW	Total	P
Presence of DCIS (n, (%))		15 (56)	13 (43)	28 (49)	0.43
Multifocal Disease (n, (%))		1 (4)	3 (10)	4 (7)	0.61
Tumour Size	Invasive (mm)	10.54	11.89	11.2	0.55
	Whole Lesion (mm)	21.8	18.96	20.3	0.59
Lobular Histology (n, (%))		2 (7)	2 (6.6)	4 (7)	1
Microcalcification on MMG (n, (%))		9 (33)	8 (27)	17 (30)	0.77
High Grade (n, (%))		6 (22)	2 (7)	8 (14)	0.13

Table 3
Primary outcomes for invasive and *in-situ* breast lesions.

	CL	HW	Total	*P*
Re-operation (n, (%))	6 (29)	8 (38)	14 (33)	0.74
Involved Margins (n, (%))	3 (14)	5 (24)	8 (19)	0.7
Close margins (<1 mm) (n, (%))	6 (29)	10 (47)	16 (38)	0.34

haematoma evacuation or USS-guided aspiration of infected seroma. Three further patients from the HW group were admitted for wound cellulitis requiring antibiotics. There was no serious life-threatening complications or death in both groups (that is, none in Clavien-Dindo class IV/V).

Continuous variables were described using mean (standard deviation) and tested between groups using Student's t-test if approximately normally distributed or otherwise described using medians (interquartile range) and tested using Wilcoxon signed-rank sum test. Categorical variables were described using frequencies and percentages, and differences between groups were tested using Fisher's exact test. Analyses were performed using the Stata statistical software package (Version 15).

4. Discussion

The collective goal of BCS for a non-palpable breast cancer is accurate pre-operative localisation that facilitates an oncological excision of the tumour with adequate margins but maintain a cosmetically acceptable result with one operation. Practices not adherent to this goal may lead to suboptimal outcomes including delays to adjuvant therapies, increasing the rates of complication, leading to poorer cosmesis, reducing the cost effectiveness of healthcare and placing a greater psychological burden on patients.

An important factor that determines outcome is the adequacy of surgical margins which can be quite variable between institutions [13]. The Society of Surgical Oncology and American Society for Radiation Oncology (SSO-ASTRO) and the American Society of Clinical Oncology (ASCO) recommended a “no ink on tumour” for invasive cancer in 2014 and 2 mm margins for ductal carcinoma *in-situ* in 2016 [14,15]. The Association of Breast Surgery (ABS) in 2015 recommended a 1 mm margin for both invasive and *in-situ* disease [16]. At our institution we use the ABS guideline in assessing re-excision requirements.

Currently, there are a variety of different localisation techniques, but due to a lack of quality clinical trials a recent *Cochrane Review* was only able to draw conclusions about radio-guided occult lesion localisation (ROLL) and radioactive iodine (^{125}I) seed localisation (RSL), which were comparable to WGL [3]. However, in addition to clinical factors, issues of cost, availability of radiopharmaceuticals and nuclear medicine department, licensing regulation and staff training need to be considered, making WGL the more widely preferred technique.

Table 4
Secondary outcomes.

	CL	HW	Total	*P*
Pre-operative localisation rates (%)	100	100	100	1
Wide-local excision (WLE) success rate (%)	100	100	100	1
SLNB success rate (%)	100	97	98	0.49
Complications rate (%)	2 (7.4)	5 (16.7)	7 (12)	0.43
Median operating time of WLE (mins (range))	26 (22–37)	37 (30–50)	33 (26–41)	0.002[a]
Length of stay (LOS) (days)	0 (0–1)	1 (0–1)	1 (0–1)	0.28[b]

[a] p-values derived from Student's t-test.
[b] Wilcoxon rank-sum test or Fisher's exact test.

Wire-guided localisation technique has several drawbacks. The most common limiting factor of HW placement and reliability in positioning relates to the mammographic density of the breast. Namely a fatty breast typically results in movement of the HW after placement as the hook cannot anchor, whereas a dense breast typically results in difficulty placing the HW correctly into the lesion as the wire deviates from its course through the fibrous parenchyma or simply will penetrate the tumour. Similarly, high grade or necrotic lesions and large breasts may also lead to wire retraction making inaccurate localisation. Pre-operatively, mammographic lesions that are only visible on one view is technically difficult to place a HW compared to CL stereotaxis [5]. Wire dislodgment, migration, pneumothoraces, vasovagal episodes and wire transection with retained foreign bodies can occur [9]. Strict compliance from patients during travel is necessary to maintain position if the HW is placed at a separate radiology service and as it is usually inserted on the day of surgery, theatre scheduling can be challenging.

Intra-operatively, HW allows tactile feedback with gentle palpation which aids excision. The thick segment of the wire (Kopan) can be used as a landmark to start dissecting around the tumour. The thick segment of the wire can also be correlated to the mammogram check views as a localisation guide for accurate excision of the tumour (Fig. 1).

Carbon-track has several advantages over HW. The inert suspension does not migrate or diffuse into the tissue and can be inserted days or weeks prior to surgery allowing greater flexibility for theatre coordination. It cannot be dislodged or accidently removed. It can be placed concurrently at the time of percutaneous needle biopsy with little added time and save the patient from undergoing an additional HW at a later date [5]. It is well tolerated and more comfortable for patients [17]. Cost analysis was more favourable for CL versus HW according to Rose et al. [5]. Pathologically, it can assist with lesion localisation without interference to histological interpretation (Fig. 2) [18]. Others have reported carbon can interfere with slicing and therefore should only be injected as far as the edge of the lesion [5]. Precipitation of carbon suspension can cause obstruction of needle tip and the carbon can cause foreign body granulomas mimicking malignancy [19]. Granulomas were not observed in 219 cases when the carbon was excised within 14 days of insertion in one series [5].

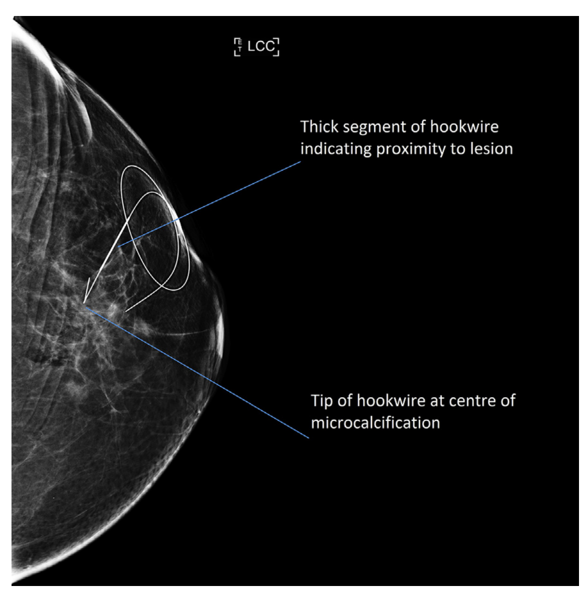

Fig. 1. A left craniocaudal mammographic check view demonstrating the relationship between a hookwire and impalpable breast lesion.

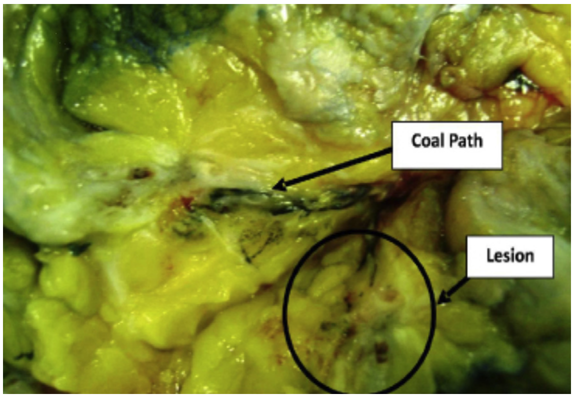

Fig. 2. Macroscopic view of paralesional carbon track.

Intra-operatively, carbon-track can be difficult to trace in the presence of significant bleeding or diathermy artefacts. Patent blue dye may affect track visibility in the upper-outer quadrant when concurrent SLNB are required. In selected cases, carbon-track is difficult to trace if lesions are deep and close to the chest wall especially in large breasts. When there is a cavity haematoma, either due to anticoagulation effect after biopsy or re-localisation for missed lesions for examples, HW is still preferable [5].

In our study, the groups were very similar in terms of factors that are known to be predictors of positive margins (Table 2) [20]. Accounting for these factors, the primary outcomes of re-excision rates, involved or close margins of <1 mm were all improved with carbon-track, but were not of statistical significance. Two patients had close margins but did not undergo re-excision in the HW group. One was due to favourable pathology and the other was due to health reasons. The secondary outcome "operating time" was statistically significant with a reduction of over 10 mins per procedure in favour of CL. Complications were also lower with the group having both HW and carbon-track after 24 months of follow-up, though this was not statistically significant.

A disadvantage of this study is the potential confounding nature of the presence of a HW during the surgical dissection of the carbon track. The surgeons involved in the study were trained in the specific dissection of the carbon track, however HW presence may introduce bias towards surgical localisation of HW in instances where the wire traverse the same tunnel as the carbon. On the other hand, the learning curve associated with this new technique could also translate to less effective carbon track excisions in the early phase and may be reflected in our results. As a combined method, the results are favourable without statistical significance. Additional to the limitations inherent to retrospective observational studies, such as being unblinded and non-randomised, a few important factors need to be considered for this study. Firstly, tissue weight as a surrogate marker for precision and cosmetic results were not assessed and many specimens were therefore not weighted. Patient satisfaction was not evaluated and if surveyed this would have had significant recall bias. For completeness at service delivery level, cost analysis should be performed for the combined procedure. Although our results did not show statistical significance for primary outcomes, CL did not demonstrate inferiority to traditional HW approach. A larger study population is needed for confirmation.

5. Conclusion

Carbon-track localisation has the potential to be an effective alternative to hookwire localisation, and our results show non-inferiority to HW alone. As a combined technique with hookwire, the results were very promising in terms of margins and reduction in operating time. In cases where both the pre-operative and intra-operative factors are favourable, CL could be considered due to better logistics, costs and patient comfort. However, due to a lack of statistical significance and the low volume of literature research available, larger studies are needed to validate our findings before any recommendation could be made for this approach.

Ethical approval

Ethical Approval was obtained from Caboolture Hospital and Departmental Head to commence the study in 2016.

Funding

None.

Author contribution

Quoc (Ryan) Tran contributed to data collection, data analysis, study design and writing. Ryo Mizumoto contributed to data acquisition, revising critically for important intellectual content. My Co Tran contributed to data collection, article drafting and revising it critically for important intellectual content. Michelle Reintals contributed to the conception and design of the study, revising critically for important critical content and final approval. Vinay Gounder contributed to the interpretation of data analysis, revising for important intellectual content and final approval of the study.

Conflict of interest statement

None.

Guarantor

Quoc (Ryan) Tran.

Research Registration Number

researchregistry4640.

Acknowledgment

We would like to thank Dr Karen Hay from QIMR Berghofer Medical Research Institute, Royal Brisbane Hospital, QLD Australia for help with data analysis. A special thanks to Dr M Reintals for sharing her experience with CL.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijso.2019.09.004.

References

[1] Torre LA, Islami F, Siegel RL, Ward EM, Jemal A. Global cancer in women: burden and trends. Cancer Epidemiol Biomark Prev 2017;26(4):444–57.
[2] Australian Institute of Health and Welfare. BreastScreen Australia monitoring report 2018. Canberra, Australia: AIHW; 2018. 2018. Contract No.: 112.
[3] Chan B, Wiseberg-Firtell J, Jois R, Jensen K, Audisio R. Localization techniques for guided surgical excision of non-palpable breast lesions. Cochrane Database Syst Rev 2015;(12).
[4] Corsi F, Sorrentino L, Bossi D, Sartani A, Foschi D. Preoperative localization and surgical margins in conservative breast surgery. Int J Surg Oncol 2013;2013:9.
[5] Rose A, Collins J, Neerhut P, Bishop C, GB M. Carbon localisation of impalpable breast lesions. Breast 2003;(12):264–9.

[6] Homer MJ. Percutaneous localization of breast lesions: experiences with the Frank breast biopsy guide. J Can Assoc Radiol 1979;132:101–5.
[7] Jensen SR, Luttenegger TJ. Wire localisation of nonpalpable breast lesions. Radiology 1979;132:484–5.
[8] Van Esser S, Hobbelink M, Van der Ploeg I, Mali W, Van Diest P, Borel Rinkes Iea. Radio guided occult lesion localization (ROLL) for non-palpable invasive breast cancer. J Surg Oncol 2008;98(7):526–9.
[9] Bourke A, Taylor D, Westcott E, Hobb M, Saunders C. Iodine-125 seeds to guide removal of impalpable breast lesions: radio-guided occult lesion localization – a pilot study. ANZ J Surg 2017;87:E178–82.
[10] Ballal H, Taylor D, Bourke A, Latham B, Saunders C. Predictors of re-excision in wire-guided wide local excision for earlybreast cancer: a Western Australian multi-centre experience. ANZ J Surg 2015;85(7–8):540–5.
[11] Svane G. A stereotaxic technique for preoperative marking of nonpalpable breast lesions. Acta Radiol Diagn 1983;24:145–51.
[12] Agha R, Borrelli M, Vella-Baldacchino M, Thavayogan R, Orgill D, For the STROCSS Group. The STROCSS statement: strengthening the reporting of cohort studies in surgery. Int J Surg 2017;(46):198–202.
[13] Tang S, Kaptanis S, Haddow J, Mondani G, Elsberger B, Tasoulis M, et al. Current margin practice and effect on re-excision rates following the publication of the SSO-ASTRO consensus and ABS consensus guidelines: a national prospective study of 2858 women undergoing breast-conserving therapy in the UK and Ireland. Eur J Cancer 2017;84:315e24.
[14] Moran M, Schnitt S, Giuliano Aea. 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. J Clin Oncol 2014;32:1507–15.
[15] Morrow M, Van Zee K, Solin LJ, Houssami N, Chavez-MacGregor M, Harris JR. ea. Society of Surgical Oncology-American Society for Radiation Oncology-American Society of Clinical Oncology consensus guideline on margins for breastconserving surgery with whole-breast irradiation in ductal carcinoma in situ. Pract Radiat Oncol 2016;6:287e95.
[16] Association of breast surgery ABS consensus margin width in breast conservation surgery 2015. 2015. www.associationofbreastsurgery.org.uk. [Accessed 19 December 2018].
[17] Moss H, Barter J, Nayagam M, Lawrence D, Pittam M. The use of carbon suspension as an adjunct to wire localisation of impalpable breast lesions. Clin Radiol 2002;57:937–44.
[18] Cavalcanti T, Malafaia O, Nassif P, Skare T, Ogata D, Miguel MT, et al. Nonpalpable breast lesions marked with coal suspension: evaluation of anatomopathological aspects, viability of interpretation and inflammatory response. Rev Col Bras Cir 2012;39(6):469–75.
[19] Ruiz-Delgado ML, L`opez-Ruiz J, S`aiz-L`opez A. Abnormal mammography and sonography associated with foreign-body giant-cell reaction after stereotactic vacuum assisted breast biopsy with carbon marking. Acta Radiol 2008;49(10):1112–8.
[20] Lovrics P, Cornacchi S, Farrokhyar F, Garnett A, Chen V, Slobodan F, et al. The relationship between surgical factors and margin status after breast-conservation surgery for early stage breast cancer. Am J Surg 2009;197(6):740–6.