Automated breast volume scanner (ABVS) as alternative method to conventional ultrasound in pre-operative localization of sonographically visible breast cancer

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Aims and objectives

Breast cancer occurs in millions of people all over the world with an increasing incidence. American Cancer Society recently reported that the incidence of breast cancer is the highest with a mortality the second among all cancers in the developed regions of the world [1].

Ultrasonography (US) and its capability of evaluating breast tissue was first described nearly 60 years ago [2], and has undergone technical advancements, including Color Doppler, Automated Breast Volume Scanner (ABVS), and elastography. Breast US is widely available, painless, well-tolerated, relatively inexpensive, and does not involve ionizing radiation [3]. Nevertheless, the Conventional US (CUS) is an operator-dipendent technique.

ABVS have become a promising method for the detection of breast lesions. This technique, able to produce objective and reproducible images, has several advantages over CUS, among which there are a greater reproducibility, the chance given to lesser trained personnel of gathering standardized views of the entire breast volume, 3D capability through multiplanar reconstruction (MPR), shorter non-real-time review with delayed interpretation, and the potential to get complete documentation [4].

Then, one of the disadvantages of CUS is the evaluation of the breast cancer extent. In particular, the greater difficulty for the surgeons is to detect the presence of widespread intraductal components and their precise locations of such components. Using the 3D volume data obtained by ABVS, tumor extent can be assessed accurately. In addition, especially coronal MPR images can be useful for surgeons because the ABVS is designed to scan patients in the supine surgical position [5].

With improvement in detection of breast cancer at an earlier stage, more breast cancers are being detected at a smaller size. This makes breast conservation surgery a feasible and preferred option for many women to which early-stage breast cancer had been diagnosed. Many women choose to pursue breast conservation surgery because of the improved cosmetic and psychological outcome from breast preservation [6].

The most common technique used to localize the lesion before breast surgery is the wire localization of tumor, either under ultrasound or stereotaxic guidance, has been the most common technique used for preoperative localization. However, wire localization has some disadvantages such as pain and discomfort in some patients, and occasionally carries risks of complications including dislodgement of the wire, intraoperative wire transaction, retention of wire fragments, thermal injury with the use of cautery, hematoma and even syncope [7].
Di Giorgio et al. [8] and Fornage et al. [9] described intraoperative ultrasound localization of nonpalpable breast lesions more than 20 years ago. The sensitivity and specificity of ultrasound reaches 95-100%. Ultrasound can be used to guide surgery in the operating theatre. When applied by a trained operator, it can produce immediate results, allowing the decision to take further shavings with minimal impact on operating times. Furthermore, although ultrasound works well in dense soft tissue with no calcification, it does not perform well where there is multifocal cancer or calcification, which is often present with DCIS [10].

So, ABVS can be considered an alternative valid technique for preoperative localization of sonographically visible breast tumors. Consequently, to obviate the described limitations of CUS and of the other preoperative localization procedures, and thanks to the supine surgical position taken by the women during ABVS scanning procedure, we suggest use of preoperative ABVS in breast cancer localization.

Therefore, the aim of this work is to propose an alternative method to Conventional Ultrasound (CUS) in pre-operative localization of sonographically visible breast cancer, through Automated Breast Volume Scanner (ABVS).
Methods and materials

55 patients, sent by the surgeon for pre-operative localization, performed Automatic Breast Volume Scanner (ABVS) from March 2015 to October 2015.

Examinations were performed by radiologists who had a great experience in breast imaging and at least one year experience with ABVS, using an ACUSON S2000 system (Siemens Medical Solutions, Mountain View, CA) with a large-footprint wide-frequency bandwidth transducer.

All patients were placed in the supine position on an examination table and positioned with the arm above the head (surgical position). For scanning, a common US gel was used for optimal imaging and to avoid contact artifacts. Customized presets were also used to optimize depth, gain, frequency, and view.

Every examination was performed in one projection including the quadrant site of the lesion and the nipple. After volume data acquisition, the axial image series were automatically sent from the Automated Breast Volume Scanner (ABVS) to the workstation and reviewed in multiple orientations in a multiplanar reconstruction (MPR) display.

At the workstation, it was found the depth from the skin surface and the distance between the lesion and x and y Cartesian axes, in a system with axes origin placed on the nipple. The distance in millimeters from the lesion to the x and y axes was reported on a pierced alpha-numeric grid, made of partially flexible polyurethane, which allowed to obtain an alpha-numeric value corresponding to the position of the lesion on the x and y axes.

By means of the grid, whose center positioned on the nipple corresponds to the Cartesian axes origin, we placed with a red pen a marker on the breast skin in correspondence of the alpha-numeric value previously obtained.

A Conventional Ultrasound (CUS) was subsequently performed, a blue skin marker was placed in correspondence of the lesion and the lesion depth from the skin was measured. Both markers had a diameter of 6 mm, corresponding to the holes diameter on the grid.

Consequently, it was evaluated the distance in millimeters between the two markers skin, the mean and standard deviation and the difference in millimeters between the depth of the lesion displayed with ABVS and with CUS, the mean and standard deviation. The total acquisition time per patient was about 10 minutes.
Fig. 1: ACUSON S2000 ABVS Ultrasound System in Catholic University of Sacred Heart, Rome.

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Fig. 2: Through CUS probe, we localized the breast lesion and, in correspondence of that, a blue marker was drawn on the skin.

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Fig. 3: Pierced alpha-numeric grid, made of partially flexible polyurethane, which allowed to obtain the red marker on the skin from coordinates of the lesion extracted from the workstation (alpha-numeric value).

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Fig. 4: The pierced grid allowed to draw a red marker in the hole corresponding to the alpha-numeric value obtained at the workstation. The distance between the two markers, measured from the center of both markers, is of 4 mm.

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In all cases the lesion was displayed both with ABVS and CUS.

The distance between the center of the blue marker (obtained with CUS) and the red one (obtained with ABVS) ranged from 0 to 4 mm. So, the maximum distance on the skin surface between the two markers was 4 mm.

The mean of distance difference on skin surface between the two measurement techniques resulted 2.13 mm.

We also calculated the standard deviation of mean values obtained through CUS and ABVS. Our results revealed a standard deviation value of 1.31.

The distance in mm between lesions and skin surface (depth), calculated with CUS, ranged from 2 to 18 mm. The depth of tumors evaluated with ABVS, instead, ranged from 2 to 20 mm.

The maximum difference in depth, evaluated both with ABVS and CUS, was 3.74 mm.

It was found that the lesions visualized with ABVS were almost always slightly deeper than CUS, except for a few number of cases in which the depth of lesion found with CUS was greater than the depth of ABVS lesions. We found a mean difference of depth between CUS and ABVS of 1.42 mm.

The standard deviation of the mean difference in depth between the two techniques resulted 1.01.
Fig. 5: Conventional US shows in the left breast a lesion with a diameter of 7 mm and a depth of about 12 mm.

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**Fig. 6:** ABVS, axial scan. The axial view is useful to find out the lesion depth from skin surface (13 mm).

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**Fig. 7:** ABVS, coronal scan. The coronal view is useful to measure the distance on Cartesian axes (x: 18.5 mm; y: 10 mm) between nipple and lesion and to obtain the alphanumeric value.

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Conclusion

Approximately 50% of breast cancers in modern surgical practices are non-palpable [11]. Conventional Ultrasound (CUS) is an excellent tool to identify non-palpable breast lesions. An important achievement of breast surgery is to minimize the risk of recurrence and, consequently, an undesirable return to the operating room, as well as an associated decrease in the cosmetic result in the case of breast conservation [12].

Moreover, in patients with breast cancer removed with clear margins at the first excision there is a decreased risk of local recurrence compared with patients who need a re-excision to achieve negative margins [13].

Traditionally, non-palpable lesions have been localized by wire localization, but many failures are reported with this technique and re-excision is needed in until 33% of cases [11].

The lack, in the past, of a preoperative diagnosis of cancer and an accurate localization of lesions is one of the reasons of such a high incidence of breast cancer recurrence in operated women and this is a factor known to be associated with an increased incidence of margin involvement by cancer [14].

Intraoperative ultrasound localization satisfies many requirements for an ideal technique of non-palpable breast tumor localization in which lesions are well visualized by ultrasound. This technique allow also real-time visualization of the margins of resection and, therefore, direct planes of surgery during the excision [7].

Only sonographically visible lesions can be localized with intraoperative ultrasound. So, all lesions visible only by mammography, such as microcalcifications or parenchymal distortions, not associated with sonographic signs, are not candidates for this technique.

Other techniques have been described to localize non-palpable tumors, such as radio-guided technique after peri-lesional injection of Tc-99 (ROLL) [15].

An ideal technique for preoperative localization of small breast lesions should be simple, accurate, cost effective, comfortable for the patient, and carry a minimal risk of procedure related complications. One of the disadvantages of CUS is the evaluation of the breast cancer extent. Automated Breast Volume Scanner (ABVS) is a three-dimensional volume imaging system that is able to acquire data from the entire breast. The system, furthermore, automatically reconstructs whole breast images from the coronal and sagittal views, allowing multiplanar display and true ultrasound tomography of the breast [16]. The tumor extent can be assessed accurately by using the 3D volume data obtained by ABVS. Tozaki et al. reported accuracy of 98% to determinate the correct extension of small tumors when performed in pre-operative time [17]. In addition, coronal
MPR images in particular can be useful for surgeons because the ABVS is designed to scan patients in the supine surgical position [5].

In our experience, the tumor was found by the surgeon during surgery in all cases. The maximum distance between the blue marker on the skin (drawn under CUS guidance) and the red one (obtained thanks to the coordinates of the ABVS) is about 4 mm (mean of 2.13), so the two techniques have allowed a ultrasound localization of lesions substantially comparable. In addition, the maximum difference between the depth achieved by the CUS and the one obtained through ABVS was 3.74 mm (mean of 1.42). The depth of the lesions got through the ABVS was almost in all cases a bit greater than the one obtained by CUS, but so small difference on average can reasonably be defined also when calculating the depth of the injury that is substantially comparable between the two techniques. The time taken by the physicians to run a single scan of the ABVS and to calculate the coordinates of the lesions at the workstation is average 5 minutes (10 minutes if we consider even the time for the localization through CUS technique), so the ABVS preoperative localization is surely very fast and simple to perform. In the future we can imagine the use of the grid by the surgeons after they have received the coordinates of the lesion by radiologists, got through ABVS technique and without the need for marking the skin, so to further reduce the time for the localization of breast lesions.

So, ABVS performed in one projection may be a valid and fast alternative method to conventional ultrasound in pre-operative localization in patients with breast cancer. Further studies with a larger samples are needed to confirm our results and hypothesize a possible use of the alpha-numeric grid by surgeons through the alpha-numeric value obtained with the ABVS.
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