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Review

# Mobile gamma cameras in breast cancer care – A review

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**Abstract**

*Background*: Currently, due to progress in detection and to extended screening, surgeons have to deal with increasing numbers of non-palpable lesions in breast cancer. These lesions can be treated by radio-guided surgery in the lumpectomy associated with sentinel lymph node (SLN) procedures. Thanks to advances in detector technology, mini gamma cameras are now available, that can perform real-time lymphoscintigraphy during surgery, or at bedside.
*Aim*: In this article, we review the clinical literature on these dedicated cameras used in breast cancer surgery. The goal is to show how these cameras are used in breast cancer treatment and in SLN biopsy and what kind of benefits they offer.
*Methods*: We conducted our search on MEDLINE and EMBASE databases. We performed a comprehensive review to identify clinical studies or cases using mobile gamma cameras in breast cancer surgery.
*Results*: We collected 14 articles published between January 2000 and March 2012. We analysed the use of the mobile cameras and the obtained results.
*Conclusion*: Mobile gamma cameras seem to be useful imaging tools either used pre-operatively or during surgery. They assist surgeons with accurate localization of SLNs and/or radio-labelled tumours, and in verification that all radioactive nodes have been excised.


*Keywords:* Breast cancer; Hand-held camera; Gamma probe; Radio-guided surgery; Intra-operative; Pre-operative gamma cameras

## Introduction

Breast cancer is the most frequent malignant tumour in women. Around 25%–35% of these cancers are non-palpable at the diagnosis.[1,2] The treatment of these non-palpable lesions is constantly evolving towards less invasive techniques. Actually most of the axillary exploration associated with these lesions is performed through sentinel lymph node biopsy (SLNB). This less invasive technique allows to establish the axillary node status. The other main issue of the conservative treatment is to have the most accurate identification of the non-palpable lesion before and during surgery. The precise localisation of the tumour is the key factor in the quality of surgical care. Excision of cancer must be complete with adequate safety margins while maintaining maximum of the healthy mammary gland nearby (cosmetic outcome). The concept of adequate margins is one of the main factors of local recurrence.[3] Therefore tracking of the tumour in surgery, critically impacts the oncological and cosmetic results. Specific radiotracers are used for radio-guided surgery (SLNB and lumpectomies). For the past ten years, the radioguided occult lesion localisation (ROLL) technique has been applied either by means of radiotracer injection or by intratumoral insertion of radioactive seeds in the non-palpable breast cancers.[4–14] When SLNB is performed at the same time, it is called sentinel node and occult lesion localisation (SNOLL).[9,11,13–32] Currently for all of these breast procedures using radioactivity (SLNB, ROLL, SNOLL) in most cases the medical team is used to perform a pre-operative standard lymphoscintigraphy (LS).[33] It

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predicts the success of the procedure. It establishes a precise mapping of lymphatic drainage (axillary or extra-axillary) of the tumour, determines the number of radioactive SLNs and defines the quality of the isotopic identification of the lesion (location, or skin contamination). These standard lymphoscintigraphies complicate the organization of the procedures and take additional time. Thanks to technological advances, we now have mobile gamma cameras that perform lymphoscintigraphy and can be used at bedside or in the operating room. We have decided to review all the scientific publications regarding these gamma cameras (prototypes or commercial devices) and reporting on clinical cases or trials in breast cancer. We will also describe briefly the different portable cameras, which were used in these trials.

## Material: characteristics and main performances of mobile gamma cameras

The technology used for the different cameras is very heterogeneous. Different concepts have guided the designers of these cameras.

### *Detectors*

One of the most important characteristics is the type of detector. Two different types of detectors are used for this kind of devices: scintillators such as NaI(Tl), CsI(Tl), CsI(Na) and GSO (coupled to photodetectors), or semiconductors such as CZT and CdTe. The main differences between these two types of detectors are higher sensitivity for the scintillators and higher energy resolution for semiconductors.[34] Scintillators are also cheaper than the semiconductors. Most of the cameras presented here are built with scintillators. Indeed with adequate electronics one can improve the energy resolution achieving optimum quality images.

### *Field of view*

Another important feature is the field-of-view (FOV) which is the actual patient region size that can be examined at the same time by the camera. It depends on the type of collimator and on the detector dimensions. In case the camera includes a parallel-hole collimator the field of view matches the sensitive area of the camera. But if the camera is equipped with a pinhole collimator the field-of-view can be larger than the surface of the camera, like in pinhole (camera obscura) photography. When the camera moves away from the radioactive source the field-of-view becomes larger but the fraction of photons that pass through the hole decreases with the inverse of the distance source-hole squared, resulting in a loss of sensitivity and a faded image.[35]

The required size of the FOV impacts the weight of the device and whether it must be attached to an articulated arm or not. Even for a light-weight camera an arm can be necessary (*e.g.* for a pinhole camera) because the duration of acquisition for a good quality image demands the camera to be stable. On the other hand, a rather already heavy camera (*e.g.* 2 kg) with a parallel hole collimator can nevertheless be laid upon the patient and held still without much effort from the operator. Other parameters need to be also taken into account in this discussion. Indeed the duration of acquisition of the image depends on the amount of the radioactivity accumulated in the lesion or the SLN. And this effective radioactivity depends both on the amount of injected activity and on the delay between injection and imaging. Therefore, these two parameters condition the image quality and the necessity for the camera to be held still. From another point of view, a hand-held camera can be positioned very close to the radioactive source resulting in a better localization by the surgeon. It is less cumbersome and can be laid on the operating table, like other surgical tools. In this case, however, it must be lightweight and with a small FOV. One of the drawbacks of a small FOV is that the user has to obtain several images to cover the area of interest. The choice between articulated arm- or hand-held camera options depends on the envisaged applications in radio-guided surgery.

### *Sensitivity*

Sensitivity is the detected gamma count rate per unit of activity. It is measured by putting a radioactive source of a known activity in front of the camera and selecting the energy of the photons coming from the source. It of course depends on the geometry of the collimator (geometrical efficiency) and on the material of detector (detection efficiency). It also depends on the distance from the source to the detector. This distance is mentioned in the Table 1 in cm in the air. In the tissues sensitivity drops rapidly with depth of the radioactive focus due to photons being absorbed or/and scattered in tisssue. As mentioned above sensitivity partly defines the duration of acquisition of an image. But a good quality image is also related to the capacity of the camera to reject diffuse (scattered) photons whose trajectories do not point back to the initial source, and therefore must be discriminated against. This is done by applying proper energy window that preferentially selects the direct gammas coming from the source. Unfortunately, due to statistical effects, fraction of the scattered gammas (which pass through in the human tissues) nevertheless gets selected, resulting in poorly contrasted images. That's why energy resolution plays an important role: the lower (better) it is the more strict the selection in photon energy can be. It is measured by taking the inverted ratio of the average energy of the photopeak (direct photons) and the full-width-at-half-maximum (FWHM) of the photopeak curve.

### *Spatial resolution*

In mammary carcinoma spatial resolution is a less critical parameter as the surgeon inserts the counting non-imaging probe into the wound to get close to the radioactive focus. One can distinguish two kinds of spatial resolution: intrinsic