# Contrast-enhanced Spectral Mammography: Technique, Indications, and Clinical Applications

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**Rationale and Objectives:** Contrast-enhanced spectral mammography (CESM) combines the benefits of full field digital mammography with the concept of tumor angiogenesis. Technique and practical applications of CESM are discussed.

**Materials and Methods:** An overview of the technique is followed by a demonstration of practical applications of CESM in our practice.

**Results:** We have successfully implemented CESM into our practice as a screening, diagnostic, staging, and treatment response tool.

**Conclusion:** It is important to understand the technique of CESM and how to incorporate it into practice.

**Key Words:** CESM; contrast-enhanced spectral mammography; breast cancer; screening; diagnosis.



## INTRODUCTION

Contrast-enhanced spectral mammography (CESM) is a relatively new tool in breast imaging armamentarium, which combines the benefits of full field digital mammography (FFDM) with intravenous contrast utilization. FFDM alone is a two-dimensional modality in which summation of overlapping tissues accounts for false-negative and false-positive findings, resulting in increased recall rates and limited sensitivity of the examination, especially in the setting of heterogeneously dense or extremely dense breast tissue. CESM advantageously uses the concept of angiogenesis in tumors by allowing contrast agents to highlight the areas of blood vessel proliferation relative to the surrounding normal breast tissue (1–6). This technique received FDA clearance in 2011. At our institution, CESM has been in clinical use since November 2012 and since its implementation we have performed 2303 studies to date, with 228 biopsy-proven cancers. CESM serves as a valuable tool in high-risk screening, further evaluation of extremely dense breast tissue, diagnostic assessment of suspicious lesions, breast cancer staging, surgical planning, and assessment of treatment response. We use CESM in our practice almost daily as part of the diagnostic workup. CESM can help characterize and guide management particularly when there are multiple suspicious findings on initial screening mammogram. The study is performed immediately before image-guided biopsy to adequately and simultaneously stage both breasts, identify multifocal or multicentric disease, and help characterize and localize the most suspicious areas of enhancement on ultrasound to increase biopsy yield. In the event there is no ultrasound correlate, stereotactic biopsy can be used to target a corresponding finding on the low-energy (LE) images, although this has only been used in a handful of patients. Lastly, if this is not possible, a patient can undergo magnetic resonance imaging (MRI) and have subsequent magnetic resonance-guided biopsy, which targets an abnormal area with excellent correlation between CESM and MRI enhancing abnormalities. This article will illustrate CESM technique (Senge et al., presented at the 2015 63rd annual meeting of the Association of University Radiologists) followed by the practical applications of this modality in daily practice.

## MATERIALS AND METHODS

An overview of CESM technique is followed by a demonstration of CESM applications in our practice.

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## CESM Technique and Practical Applications

*Before the Study*

Institutional guidelines are enforced using protocols and precautions previously established for patients receiving iodinated contrast material (Table 1).

*CESM Technique*

*Image acquisition.*—At the time of the study, a trained technologist obtains peripheral intravenous access in the antecubital fossa preferably with a 22-gauge needle. A dose of 1.5 mL/kg of iodinated contrast material (Isovue 370 at our institution, Bracco Diagnostics, Princeton, NJ) is administered intravenously by a power injector at a rate of 2 mL/s. A 20-mL saline bolus is administered both before and following contrast injection to achieve a tight bolus administration and optimal delivery of contrast to tissues, improving image quality. The connecting tubing is detached from the patient's IV while the catheter remains in place until the end of the examination. Images are acquired following a 2-minute delay, with image acquisition completed within 10 minutes following contrast injection. During this time, the patient is monitored for a rare event of adverse reaction to the iodinated contrast material. An emergency response kit is available in the room.

Images are obtained with FFDM equipment that has undergone software modifications with GE Senographe Essential Full Field Digital System (Mammography X-ray Equipment, Buc, France) (3,4). Image acquisition includes tandem full-field exposures obtained at high and low energies using standard CC and MLO projections of each breast. The CC projection on the suspected side is imaged first in an attempt to capture early arterial enhancement and minimize false-negative results from early washout. Subsequently, the contralateral breast is imaged in CC and then MLO projections. The MLO projection of the suspected breast is obtained last to allow assessment of enhancement kinetics between the early CC and delayed MLO views, which may provide additional information regarding likelihood of malignancy. LE mammograms are performed at the same peak kilovoltage (kVp) and with the same filtration as FFDM, 26–30 kVp (1–6). High-energy acquisition is performed with a copper filter (1,3) and at a higher kVp of 45–49, optimized to the K edge of iodinated contrast material (1–6). Subtraction images (SIs) are produced by the cancellation of background breast tissue and are available for immediate review. Only the LE and SI are sent to picture archiving and communication system for review.

*After image acquisition.*—LE and software-derived SI are immediately reviewed by a radiologist for the presence of abnormal contrast enhancement (Fig 1). At this point, additional images such as spot compression, true lateral, or exaggerated views can be obtained if warranted and must be obtained within the 10-minute time frame. In the setting of microcalcifications, full field magnification projections are obtained in non-CESM mode following completion of CESM portion of the study. The results of the study are immediately reviewed with the patient. Ultrasound assessment may follow, targeting the area(s) of abnormal enhancement.

*Practical Applications of CESM at Our Institution*

*Indications.*—At our institution CESM has a variety of applications (Table 2).

*High-risk screening with CESM.*—We have used CESM as a high-risk screening tool in patients with one of the following

**TABLE 1. Institutional Guidelines to Follow Before Performing CESM**

| Institutional Guidelines | Requirements Before Obtaining a CESM Study |
|---|---|
| | Laboratory value for calculated creatinine clearance within 4 weeks for high-risk patients (age > 60, history of diabetes, hypertension, prior renal transplantation, etc.) is required. |
| | History of any allergies, particularly to iodinated contrast, is reviewed before scheduling. |
| | Medical preparation with Benadryl and steroid premedication regimen as advocated by the ACR Manual on Contrast Media is prescribed for a history of minor contrast reaction. |
| | Patients are told not to eat or drink 4 hours before the examination, as a general precaution. |

CESM, contrast-enhanced spectral mammography.

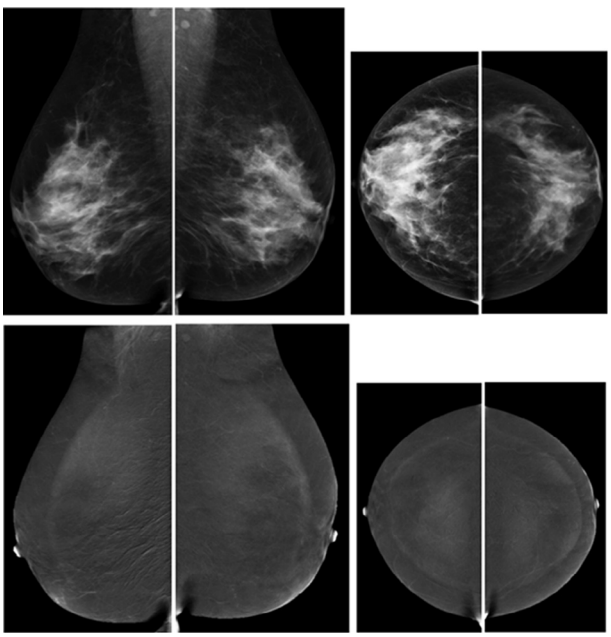

**Figure 1.** A 45-year-old woman at high risk for breast cancer development presented for annual screening mammogram. LE (*top row*) and SI (*bottom row*) MLO and CC images of both breasts are provided. LE images show heterogeneously dense breast parenchyma, which may obscure small masses. No abnormal areas of enhancement are seen in either breast on SI. CC, craniocaudal; LE, low energy; MLO, mediolateral oblique; SI, subtraction image.