MAXIMUM INTENSITY PROJECTION IN CONTRAST-ENHANCED MAGNETIC RESONANCE OF THE BREAST: CURRENT APPLICATIONS AND PROSPECTIVES.

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Abstract: Over the last 10 years, breast MR technique has improved due to the introduction of Gadolinium contrast agents and to the advance of hardware and of post-processing: temporal subtraction, time-intensity curves for small regions of interest, maximum intensity projection (MIP) and multiplanar reformatting (MPR).
MIP, the most commonly used processing technique, is a 2D projection image obtained from 3D data by a ray-tracing algorithm which displays only the highest intensiy signals in the examined volume.
In un-enhanced MRI, MIP is indicated for breast implant study. In contrast-enhanced MRI, MIP of subtracted images obtained from dynamic 3D GE T1 weighted coronal sequences using thin slices (<3mm) without gap, produces a similar-angiographic image of enhancing lesions, highlighting their spatial distribution for surgical treatment planning.
In particular, in our experience, asymmetrical vascularization of the breasts, topographical correlation between the nodule and increased vascularization, perilesional or intralesional vessels must be considered important signs that should raise suspicion for cancer according to the neoangiogenesis theory.
Moreover, MIP automatically performed by a software for each subtracted series on the basis of time-intensity evolution for each examined point, provides a colour map, usable for a computer aided diagnosis of cancer in breast MRI.

Introduction.

The advance of breast MRI technique is due to a mixture of factors: the introduction of Gadolinium contrast agents, hardware's improvement i.e. pre-processing (high field strength, dedicated breast coil, imaging protocols) and software's improvement i.e. post-processing imaging: temporal subtraction (postcontrast –precontrast images), intensity- to-time curves for small targeted regions of interest (ROI), maximum intensity projection (MIP) and multiplanar reformatting (MPR) (1).

MIP, the most commonly used processing technique, is a 2D projection image obtained from 3D data by a ray-tracing algorithm which produces an image of white pixels representing the highest intensiy signal in that location within the examined volume. In un-enhanced breast MRI, MIP is used to evaluate the morphology of breast implant in the doubt of implant failure.

In contrast-enhanced MRI, by using temporal subtraction technique, it is possible to evaluate the presence of malignant lesions on the basis of morphology and enhancement pattern. MIP, that produces a similar-angiographic image, gives additional tools to characterize breast MR enhancing lesions. In particular these post-processing reconstructions shows the morphology of enhancing lesions, their spatial distribution useful for surgical treatment planning and a vascular map pointing out vascular asymmetry due to the increased vascularity associated to ipsilateral breast neoplasm.(2).

MRI Indications and Protocol Technique.

In our Institution MR is performed by using a 1,5 T unit (Symphony, Siemens, Erlangen, Germany). The patient is placed in the prone position with both breasts hanging in a dedicated double breast coil immobilized with a special compression device to minimize breast distortion and motion artifact.

Un-enhanced MRI is the method of choice for verifying and excluding implant defects in particular to verify the integrity excluding small implant leaks, to evaluate the presence of a fibrous capsule, implant displacement and silicone migration.

We use standard sagittal fast spin-echo T1 weighted images, fat suppressed sagittal fast spin-echo T1 weighted, water and fat suppressed axial and sagittal fast spin-echo T2 weighted images, water and silicone suppressed T2 weighted images and TIRM (Turbo Inversion Recovery in Magnitude) sequences. Slice thickness used is 4 mm with a slice gap of 0.4 mm. FOV, number of slice partitions and scan time depend on breast volume.

Contrast enhanced MRI is indicated for the study of breast parenchyma in particular for:

-screening in high risk women (familiar or genetic predisposition);

-evaluation of known or suspected breast cancer;

-detection of occult breast cancer in case of axillary nodal metastasis;

-monitoring response to post-surgical primary chemotherapy;

-pre-surgical evaluation of residual disease following neo-adjuvant chemotherapy.

In contrast-enhanced breast MRI we select carefully the patients.

In fertile women MRI is performed between the second and the third week of the menstrual cycle, while in post-menopausal replacement therapy we recommend the suspension 6-8 weeks in advance. In these cases in fact, non-specific, disseminated or even focal enhancement may occur, leading to diagnostic errors.

In addiction to standard T1- and T2- weighted sequences for imaging the breast and axillary region bilaterally, we use a 3D T1 weighted gradient-recalled echo-sequence with a repetition time (TR) of 13 msec or less, thin slices (<3mm) without intersection gap, one excitation, flip angle of 25°, a rectangular field of view of 36 cm or smaller, a matrix of 128x256 mm, acquisition time per repetition of the sequence 90s. After an un-enhanced baseline acquisition, a bolus (0.2 mmol/Kg of body weight) of Gadoteridolo (Prohance, Bracco, Milan, Italy) is injected by using an automatic injector at a rate of 2 ml/sec followed by 20 ml of saline flush. After the un-enhanced acquisition, the same pulse sequences are repeated at 0, 90, 180, 270 and 360 s after bolus injection.

Images analysis and post-processing.

In un-enhanced breast MRI the images are analysed sequentially and post processed with MIP. We evaluate the morphology of implant, margins and the presence of extra-capsular silicone (Fig.1).

In contrast-enhanced breast MRI we usually start evaluating the conventional T1 and T2 weighted sequences and the 3D T1 weighted gradient recalled echo images before and after contrast medium administration. Then we perform image subtraction. The un-enhanced images are subtracted from the contrast enhanced ones acquired 90 s after contrast agents injection. The subtraction technique eliminates the signal of fat, significantly increases vessel-to-background contrast and contrast/noise and eliminates wraparound artifacts and high signal intensity of cysts (Fig.2a,2b). Subtracted images point out enhancing breast lesion, and on the basis of enhancement kinetics and morphologic features together, help to differentiate enhancing lesions suspect for malignancy from benign ones. We usually associate maximum intensity projection of subtracted images. MIP is a bi-dimensional image obtained with a ray-tracing algorithm. The intensity assigned to each pixel of the image represents the highest intensity encountered along any pre-defined direction of parallel rays within the imaging volume. Practically, the software connects the high intensity dots of the blood vessels and enhancing lesions in three dimensions, providing a bi-dimensional similar-angiographic image that can be viewed from any projection. One of the drawbacks is that since light reflection is ignored entirely, depth information is not

displayed and MIP does not give a realistic 3D representation. However this can be circumvented by displaying the images in a CINE mode or in different projections making the projection angle vary. The MIP views generally used to examine 3D MR images of the breast pass through each orthogonal planes, producing sagittal, coronal and axial projections. The axial view presents a MIP through the breast from top to bottom (fig.3a). The sagittal view presents a MIP through the breast from one side to the other (Fig.3b), while the coronal view is from front to back (Fig.3c). Sometimes however some low-intensity structures visible in individual section may be lost in the MIP image. To compensate for such loss of information in these cases it is also possible to limit the projection to a subvolume of interest instead of projecting the whole volume. This solution allows to reduce post-processing time too. MIP projection is a non invasive method to design a vascular map of the breast usable for detecting neoplasms also of small dimensions and/or the increased neo-angiogenetic vascularity associated (Fig.4).

According to Folkmann theory (3) in fact, there is a neoangiogenesis associated to cancer characterized by increased vascular permeability, reduced flow resistence in the tumor vessels, increased microvascular density due to the tumor higher metabolism and angiogenic stimulation of the whole breast with consequently an anarchic structure of microcirculation. Macroscopically, the increased blood need of the tumour causes an hypervascularization of the neoplasm, vascular anarchy with arterial-venous shunts (3).

In particular, in our experience we stress the importance of " MRI minimal findings" for the diagnosis especially in the case of small neoplasms. In these cases the asymmetrical vascularization of the breasts and increased dimension of perilesional and intralesional vessels must be considered suspicious for cancer even if no clear nodular lesion is dectected. Moreover, MIP is useful also in the case of known focal lesion (clinical examination, mammography and ultrasound) as a pre-operative study to define the relationships with the surrounding structures in particular the nipple, the size and number of malignant lesions and for identifying or excluding multifocality, multicentricity and controlateral lesions. These data provide a local staging of the neoplasm with imaging information for the treatment planning that are more familiar to the clinician.

Moreover, MIP (automatically performed by a software for each subtracted series on the basis of signal intensity-to-time evolution for each point examined) may provide a modulating colour brightness map, usable for a computer aided diagnosis of cancer in breast MRI (4).

FIGURES.

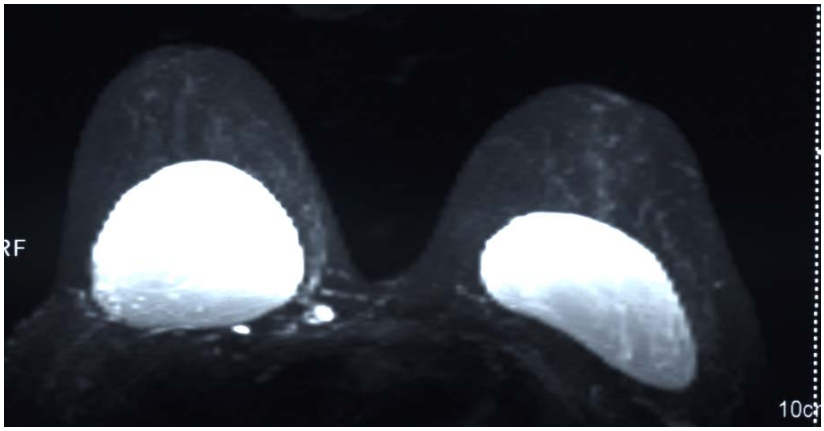

Fig.1: axial MIP shows breast implant leakage with little drops of silicone out of right implant.

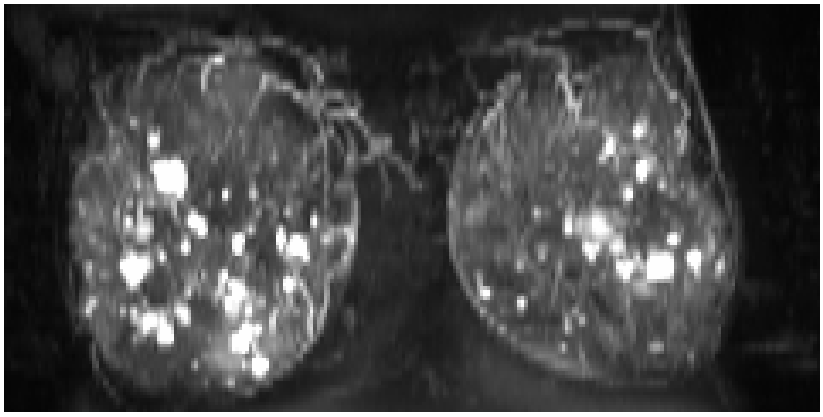

Fig.2a: MIP obtained from 3D T1 weighted sequences shows multiple cysts.

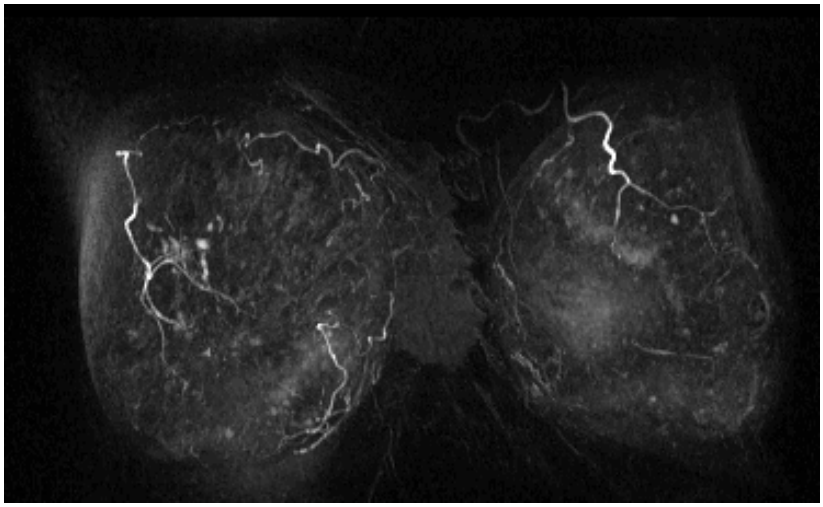

Fig.2b: MIP of subtracted images of the same patient points out a nodular enhancement in the right breast. At histopathology the lesion results DCIS.

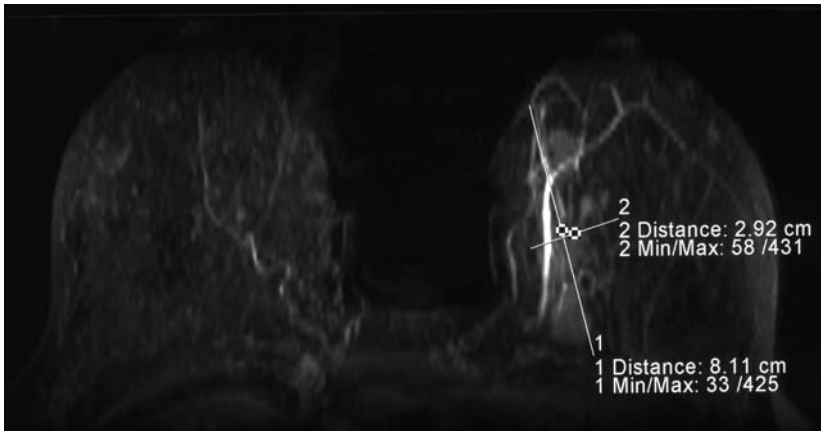

Fig.3a: axial MIP of a locally advanced cancer.

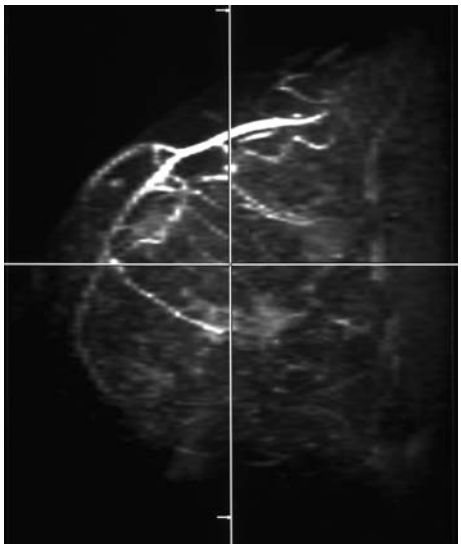

Fig.3b: sagittal MIP of a locally advanced cancer.

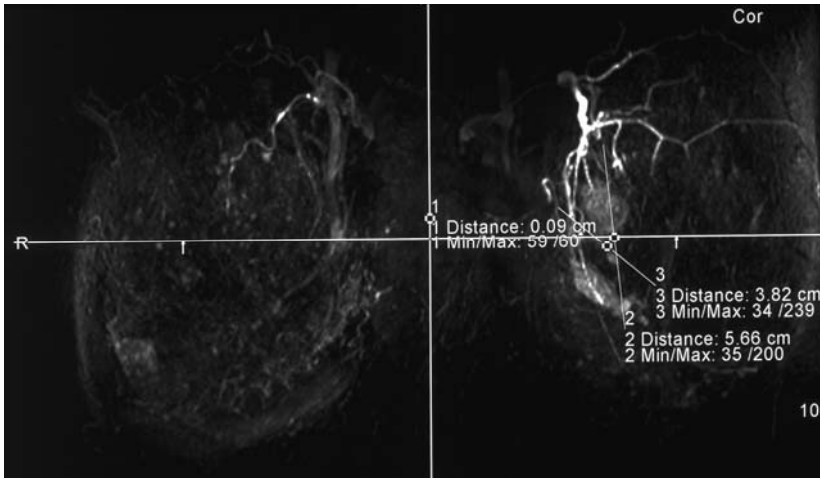

Fig.3c: coronal MIP of a locally advanced cancer.

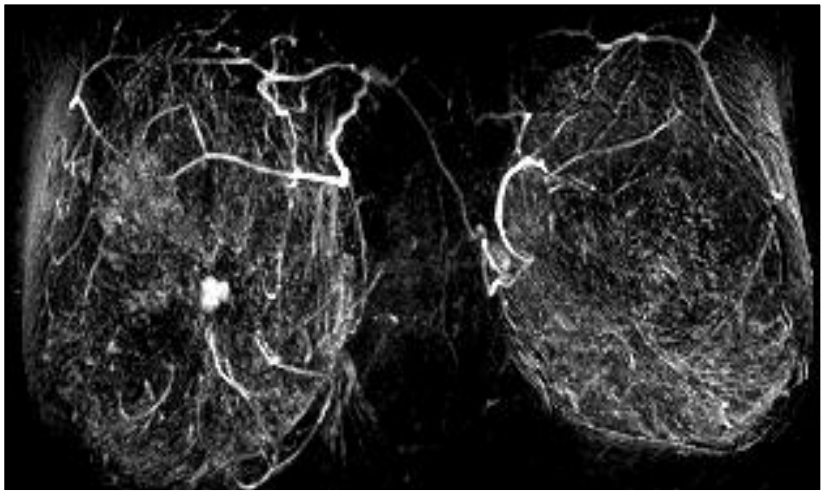

Fig.4: coronal MIP of subtracted images shows a nodular enhancing lesion in the right breast associated with an ipsilateral increased vascularization.

References.

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3) Folkman J et al. 1995. Adv Cancer Res,43, 175-203

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