APPLICATION OF THE ULTRAFAST SEQUENCE IN THE DYNAMIC CONTRASTOGRAPHIC STUDY IN THE MAGNETIC RESONANCE IMAGING OF THE BREAST: OUR EXPERIENCE

Curatolo Calogero[1], D'Amato Elisa[2], Daricello Marco[1], Caruso Virginia[1], Orlando Alessia Angela Maria[1], Lo Re Giuseppe[2], Galia Massimo[2]

[1] *Dipartimento di Diagnostica per Immagini, A.O Universitaria Policlinico "Paolo Giaccone", Palermo*
[2] *Sezione di Scienze Radiologiche, BIND, Università degli Studi di Palermo*

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ABSTRACT

In the last decade, breast MRI has played a role of primary importance, as a "gold standard" method in the early diagnosis of breast cancer in high-risk women, in assessing the extent of the disease and the response to neoadjuvant chemotherapy. Currently, the 3D GRE Rapid-Acquisition sequence in dynamic acquisition without and with endovenous administration of contrast medium, is fundamental for the breast MRI protocol, as the current diagnostic approaches in Magnetic Resonance are based precisely on this sequence, able to guarantee accurate diagnostic performances detecting pathological mass and non-mass-enhancement. Ultrafast sequences are modern sequences based on the 4D Time-Resolved technique with k-space sampling modalities which allow the evaluation of post-contrast images with very high temporal resolution. The purpose of our work is to illustrate in particular the use of the 4D-THRIVE sequence implemented in our breast MRI study protocol.

INTRODUCTION

Magnetic Resonance, thanks to its multiparametricity, achieves higher sensitivity and greater accuracy than mammography and breast ultrasound. These characteristics have made it, in recent years, the reference method in early diagnosis in high-risk women, in the assessment of loco-regional extension and of the response to neoadjuvant chemotherapy in patients with breast cancer, in the follow-up after surgery, as well as in the study of breast implants.

However, although multiple studies have shown that the multiparametricity of the MRI protocol is excellent, technological evolution continues to expand, presenting further innovations that can further improve the diagnosis and characterization of breast lesions.

Dynamic contrast-enhanced MRI (DCE-MRI) of the breast is well established in clinical practice as it provides high sensitivity for breast cancer detection and represents a guide to describe and classify breast lesions in accordance with BI-RADS criteria. However, it takes a long time, making up about 40% of the total exam duration.

The introduction of Ultrafast sequences allows a desirable balance between high spatial resolution and high temporal resolution, a need that until recently required the research for a compromise between these two objectives, with the possibility of characterizing the lesions in an equally reliable and efficient way.

The aim of our work is to describe the technical characteristics, applications and advantages of modern Ultrafast sequences and in particular of the 4D-THRIVE sequence in the study protocol of Breast MRI.

MATERIALS AND METHODS

In our study we will describe the technical and technological principles of the 4D-THRIVE sequences and the study protocol of Breast MRI performed at our Radiology Unit with 3 T MRI scanner (Philips Ingenia, Philips Healthcare, Eindhoven). Representative images of modern 4D-THRIVE sequences and related post-processing will then be shown. Finally, the main advantages of applying Ultrafast sequences in Breast MRI protocols, emerging from the analysis of the scientific literature, will be discussed.

RESULTS

Ultrafast 4D-THRIVE sequence in Breast MRI: technique and k-space sampling

The Ultrafast 4D-THRIVE sequence is based on a "Time-Resolved" technique, with Key-hole and CENTRA K-Space sampling methods. This method uses a radial sampling scheme, acquiring a limited number of central Ky-Kz profiles (central disc) in a centric elliptical manner.

The central region is acquired in each scan (low frequencies or those defined as most "useful" for the purposes of the image) while the sub-regions acquired less frequently (high frequencies or those defined as "scattered"), are shared according to a view sharing scheme alternating (Fig. 1)

The combination of all the innovative acceleration techniques such as the CENTRA Keyhole method, the Partial Fourier, and the SENSE Parallel Imaging has allowed to obtain a very high temporal resolution (4-8 sec) while maintaining spatial and contrast resolution

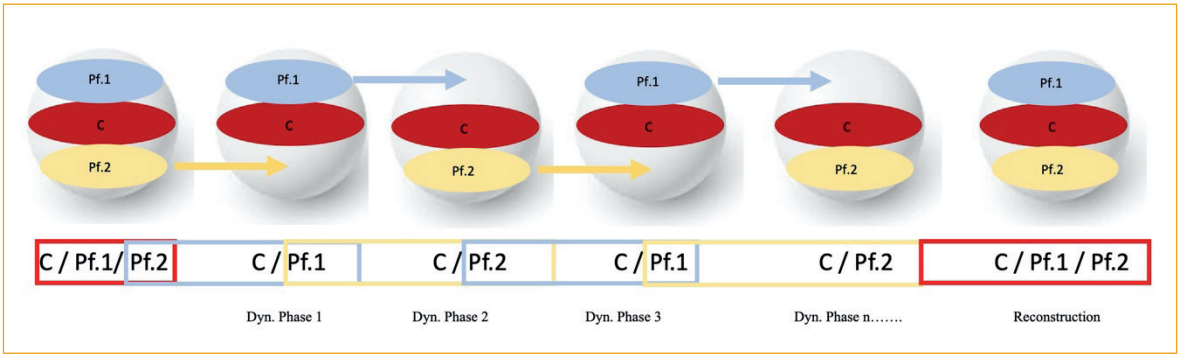

Fig. 1 - *Schematic representation of the centric elliptical technique with alternating view sharing.*

efficient in documenting the presence of neoplastic lesions.

In the field of breast MRI, after a complete k space sampling in the pre-contrastographic phase, multiple Ultrafast phases (10-16) are acquired continuously for about 60-90 seconds with a temporal resolution of 4-8 seconds, starting the acquisition simultaneously with the ev injection of contrast agent, for a total scan time of 102-120 sec.

Breast MRI study protocol with Ultrafast sequences

MRI exams were performed with a very high field MRI scanner, 3T Philips Ingenia (Philips Healthcare, Netherlands Eindhoven) equipped with combined gradients with Amplitude of 45 mT/m and Slew-Rate of 200 T/m/s, using a breast coil dedicated 7-channel phased-array dSTREAM SENSE BREAST Coil. All the patients were studied in prone feet-first position, with the breasts introduced into the two cavities of the coil, with the arms raised above the head, making sure that the hands do not touch each other, in order to avoid closed circuits, then electrical loops. In all exams, the contrast agent used is Gadobutrol (Gadovist-Bayer-Schering Pharma).

The MR scan protocol includes the evaluation of the breast parenchyma by using 3D TSE T2 (Varia-

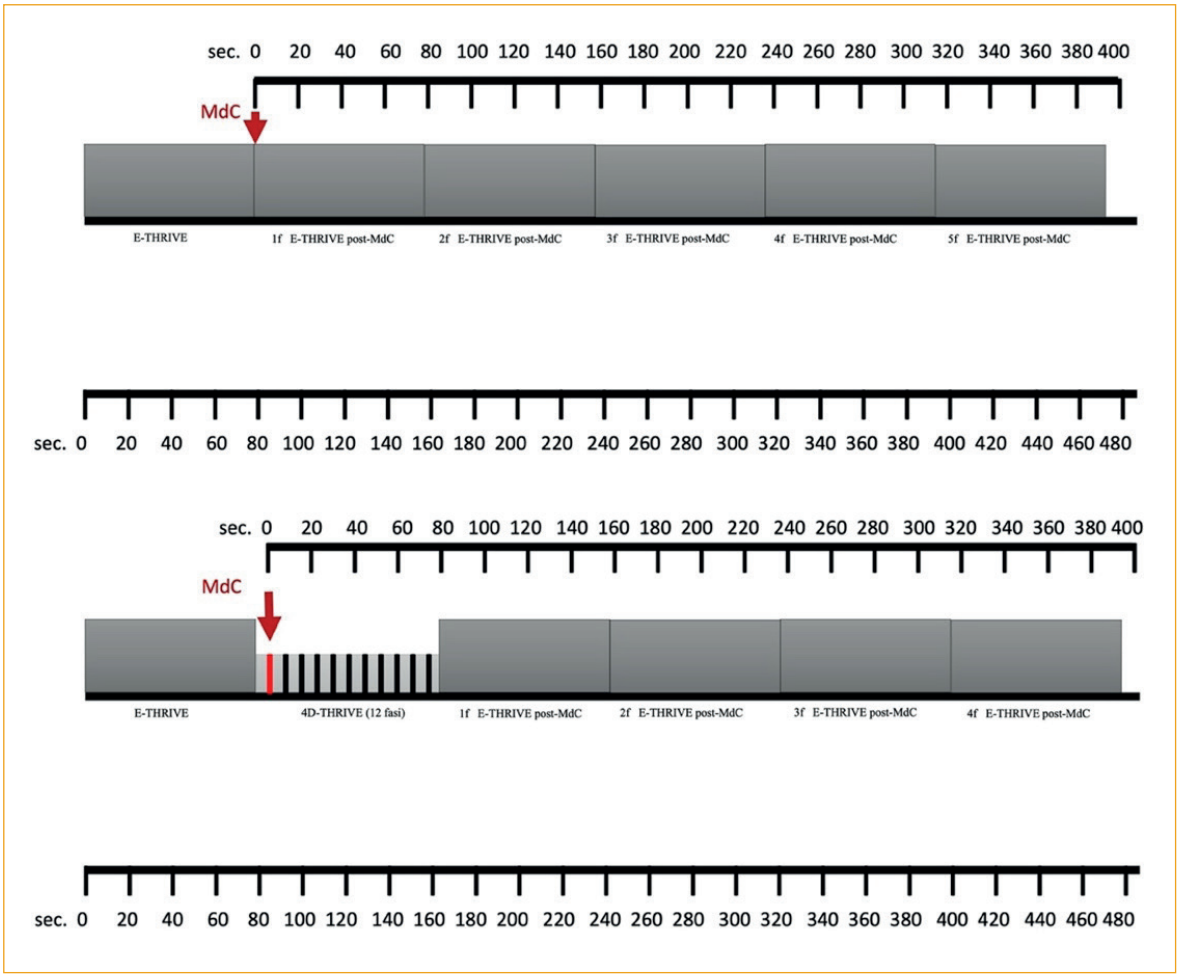

Fig. 2 - *Temporal scheme of the "classic" DCE protocol without the application of the 4D-THRIVE at the top; temporal scheme of the DCE protocol with the acquisition in the first post-contrast phase of the 4D-THRIVE with 12 sub-phases in the first 80 seconds after the ev injection of CM.*

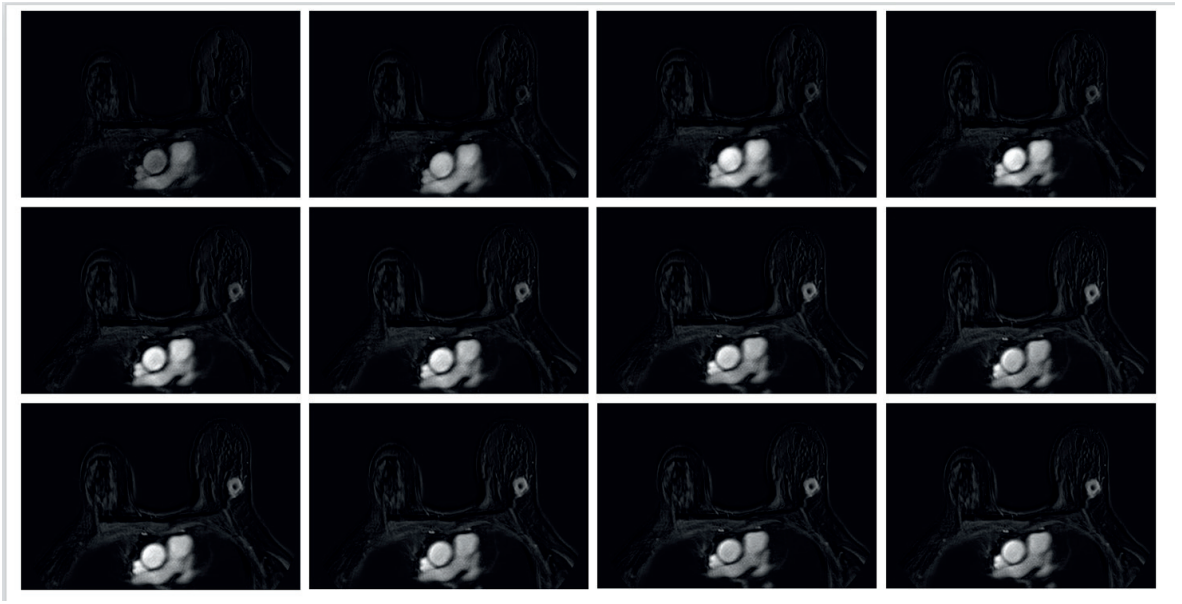

Fig. 3 - *Representation of the 4D-THRIVE sequence of the individual arterial sub-phases (12) 12 sub-phases in the first 80 seconds after the injection of gadolinium i.v. Mass-type enhancement of a heteroplastic lesion at the level of the QSE of the left breast can be noted, with a TTE <5 sec. The central vacuum signal is related to the presence of a clip.*

ble Flip Angle) and STIR (IR-TSE) axial sequences, and subsequently, whereas the conventional protocol consists of a dynamic axial e-THRIVE with SPAIR fat suppression (one phase pre and five phases post-CM bolus injection), in our protocol we have replaced the first two post-CM phases with the Ultrafast 4D-THRIVE sequence consisting of 12 sub-phases each with a temporal resolution of about 5-6 seconds with a coverage overall time of about 80-120 sec. Fig. 2 represented the temporal schemes of the conventional DCE sequence and then of the "hybrid" protocol used in our study.

The parameters of the conventional e-THRIVE are the following: TR 6.7 ms, TE 3.3ms, field of view (FOV), 320 mm pixel 1.10 x 1.10 x 1.50, partitions = 110, FA = 10 °, acceleration factor Sensitivity Encoding (SENSE), P = 2.3 S = 1; SPAIR fat suppression (p = 2), acquisition time, 92 seconds per phase.

The 4D-THRIVE parameters are the following TR 6.7 ms, TE 3.3ms, field of view (FOV), 320 mm pixel 1.10 x 1.10 x 2.50, partitions = 70, FA = 10 °, acceleration factor Sensitivity Encoding (SENSE), P = 3 S = 1; SPAIR fat suppression (p = 2), Keyhole Central size 32%, reference scan 17sec, TFE = 50, acquisition time 5 seconds for each phase (12).

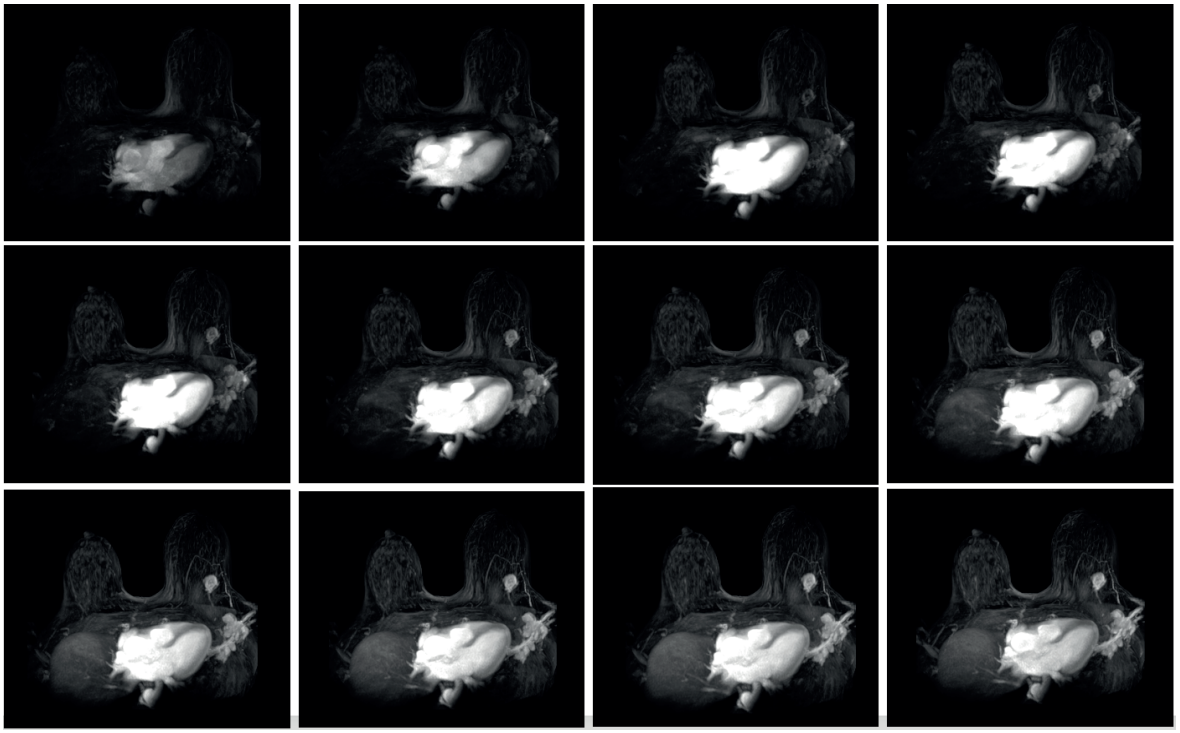

Fig. 4 - *MIP reconstruction from the individual arterial sub-phases (12) of the subtracted 4D-THRIVE, after administration of the i.v. In addition to the heteropalsic lesion, there is a package of metastatic lymph nodes to the ipsilateral axillary cavity.*

Fig. 5 - *Temporal scheme of the dynamic contrast protocol with the use in the first post-contrast phase of the 4D-THRIVE with 12 sub-phases in the first 80 seconds after the iv injection of gadolinium*

Ultrafast images visualization and analysis

The most correct way to evaluate Ultrafast images for lesion characterization is to look at the subtraction images (Fig. 3). New parameters will be evaluated from the Ultrafast kinetic curves:

- "Time To Enhancement (TTE)", ie the time it takes for the lesion to enhance after the enhancement of the descending aorta (<10 s for malignant lesions);
- Maximum Slope (unit: percent relative enhancement per second): high values in malignant lesions.

Finally, the MIPs generated from the subtracted images of the Ultrafast sequences provide a real time assessment of the influx of contrast medium into the lesions, and in the case of malignant tumors a "light bulb effect" is observed, in which we see the cancer enhancing in a dark background (Figure 4).

In the case shown in figures 3 and 4, no additional findings were detected from the evaluation of the e-THRIVE images obtained at the 3rd, 4th and 5th minute post-CM (see Fig. 5).

DISCUSSION AND CONCLUSIONS

Breast MRI thanks to its high diagnostic accuracy in the loco-regional extension balance in patients with breast cancer and in the detection of occult mammary tumors, it allows to optimize the treatment and prevention path.

Through the acquisition of the 4D-THRIVE sequence it is possible to acquire a number of multiple phases ensuring multiple information in real-time. In particular, the Ultrafast 4D-THRIVE sequence allows to obtain not only a high temporal resolution, but also an optimal spatial and contrast resolution and with a complete anatomical coverage of the mammary gland, resulting in an improvement in the detection and characterization of focal breast lesions in various early post-contrast sub-phases, phases in which it is possible to obtain a higher specificity and sensitivity of the examination.

However, the spatial resolution compared to the e-THRIVE applied in the subsequent phases, inevitably turns out to be lower, moderate because it has resolution in plane and thicknesses slightly higher depending on the intensity of the magnetic field and on the number of channels of the coils. However, the detection rate of additional findings significant for diagnosis in the e-THRIVE sequence not highlighted in the 4D-THRIVE sequence, from scientific literature data, is not relevant or extremely low.

Finally, in recent years, the diagnostic utility of these new parameters (TTE and MS) generated by the Ultrafast sequences has been demonstrated in the differentiation between malignant and benign lesions and in improving the positive predictive value. Furthermore, several studies have shown that these parameters have an accuracy greater than or comparable to that of the classic time/intensity curves reported in the BI-RADS. In conclusion, although Ultrafast sequences are used in practice almost exclusively in combination with the conventional dynamic sequence in resulting hybrid Ultrafast-DCE protocols, there are well-founded assumptions for the Ultrafast sequence to completely replace the conventional DCE sequence in breasts MRI study protocols, resulting in a significant shortening of the acquisition time of the examinations and therefore the possibility of increasing the number of examinations per session.

REFERENCES

1. Levine E, Daniel B, Vasanawala S, Hargreaves B, Saranathan M. ‹‹3D Cartesian MRI with compressed sensing and variable view sharing using complementary poisson-disc sampling››. Magn Reson Med. 2017 May;77(5):1774-1785
2. Vanzulli A. e Torricelli P. ‹‹*Manuale di RM per TSRM*››. Milano Poletto Editore Srl, 2013: 195-212.
3. Sardanelli F., Giuseppetti G.M., Canavese G. et al., «Indications for breast magnetic resonance imaging. Consensus document "Attualità in senologia", Florence 2007.» *La Radiologia Medica*, 2008 Vol. 113 Issue 8, 1085-1095
4. Giess CS, Yeh ED, Raza S, Birdwell RL. ‹‹Background parenchymal enhancement at breast MR imaging: normal patterns, diagnostic challenges, and potential for false-positive and false-negative interpretation››. Radiographics. 2014 Jan-Feb;34(1):234-47.
5. Kuhl CK, Jost P, Morakkabati N, Zivanovic O, Schild HH, Gieseke J. ‹‹Contrast-enhanced MR imaging of the breast at 3.0 and 1. 5 T in the same patients: initial experience››. Radiology, 2006 June; 239(3):666–76.
6. Spick C, Szolar DHM, Preidler KW, Reittner P, Rauch K, Brader P, Tillich M, Baltzer PA. ‹‹3 Tesla breast MR imaging as a problem-solving tool: Diagnostic performance and incidental lesions››. PLoS One. 2018 Jan;13(1)
7. Soher BJ, Dale BM, Merkle EM. ‹‹A review of MR physics: 3T versus 1. 5T. Magnetic resonance imaging clinics of North America.›› 2007 Aug;15(3):277–90.
8. Curatolo C, Santoro V, ‹‹Risonanza Magnetica della Mammella con i moderni scanner 3T: principi fisici e vantaggi tecnici rispetto alle apparecchiature 1,5 T››. JAHC- Journal of Advanced Health Care. 2019 Sept. Vol.1 Issue 1