

# $^1\text{H}$ MR Spectroscopy of the Breast\*

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## Introduction

Breast MRI has emerged as a highly sensitive modality for the imaging of breast tumors, although its specificity remains variable, ranging from 30% to 80%. To improve the specificity, detailed assessment of lesion morphology using three-dimensional MR imaging and of kinetic patterns depicted using dynamic protocols may be useful. In addition, new characterizations of tumor cellularity on diffusion-weighted imaging and of tumor metabolism on  $^1\text{H}$  MR spectroscopy can be obtained in routine clinical breast MRI examinations.

In vivo  $^1\text{H}$  MR spectroscopy of the breast, actually molecular information obtained in a non-invasive manner, has demonstrated that Choline (Cho) can be detected in breast cancers, whereas Cho is generally undetectable in normal breast tissue. Increased levels of composite Cho compounds is thought to be an indicator of the activity of breast neoplasms and of the viability of breast cancers. Therefore,

breast MR spectroscopy has shown great promise as a way to differentiate between benign and malignant lesions, and to gauge the effect of chemotherapeutic agents in patients with locally advanced breast cancer.

To date, there has been no large dataset with which to evaluate the clinical usefulness of in vivo breast  $^1\text{H}$  MR spectroscopy. Recent technical improvements in breast MR spectroscopy and in the stability of the obtained spectra, even on 1.5T MR equipment, make it possible to investigate breast MR spectroscopy worldwide. In our hospital more than 200 breast MRI examinations are performed each month, and more than 600 breast MR spectroscopy (MRS) exams have been obtained in six months.

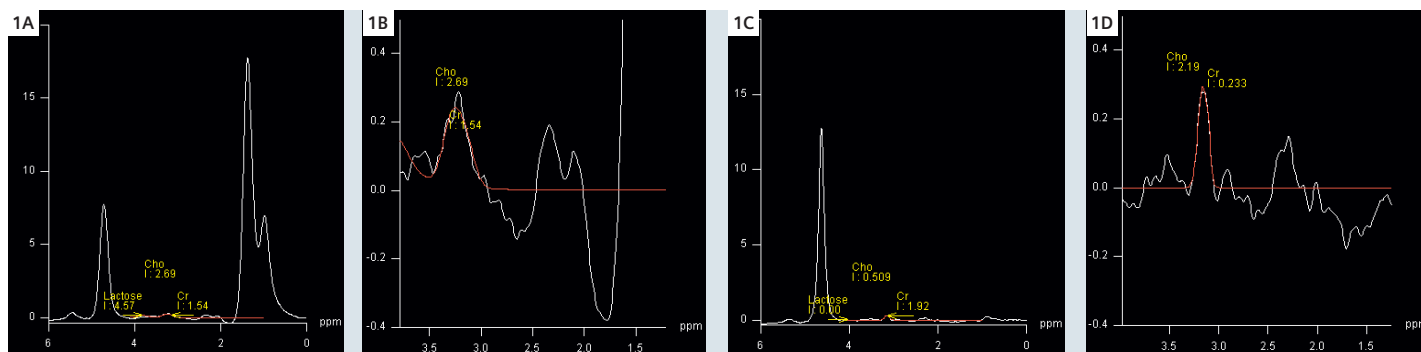
## Sequence description

The breast spectroscopy sequence\*\* is a spin-echo sequence with the following added capabilities: spectral suppression

pulses, up to 8 regional saturation bands for outer volume suppression, physiological triggering, online frequency correction, extended voxel dimension limits, and multi-channel data combination.

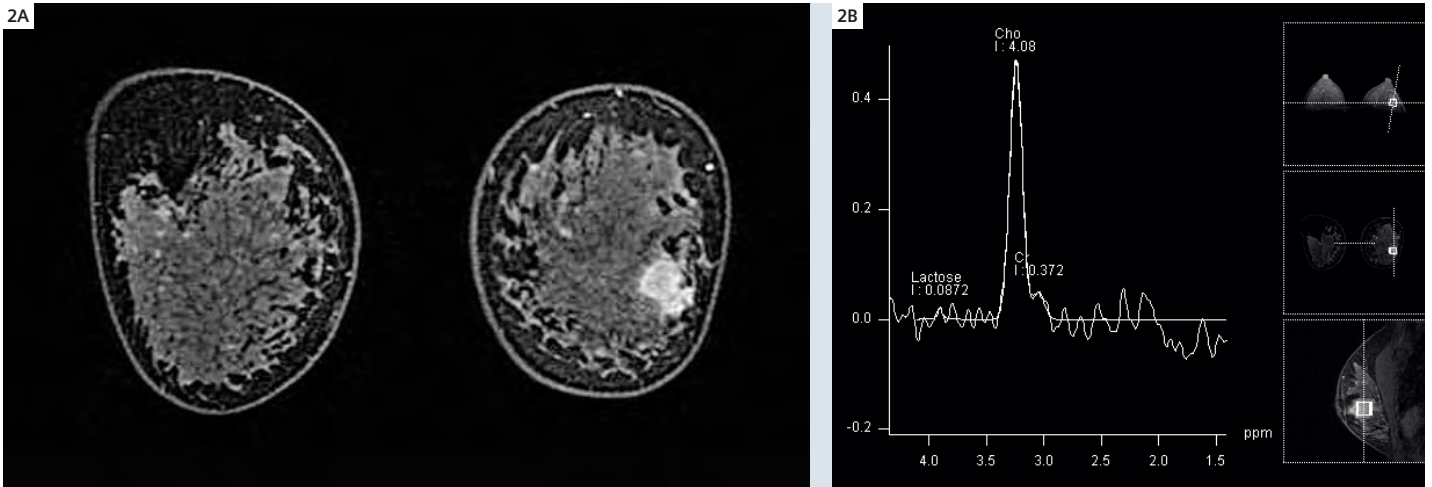
## Spectral suppression

By the spectral suppression method, transverse magnetization is selectively dephased before and after the second spin-echo pulse. The quality of spectral suppression can be visualized by the following simulated frequency response profile of our numerically optimized pulses: Magnetization components of  $M_{xy} = -1$  are dephased; components of  $M_{xy} = 1$  are rephased. This method of spectral suppression has been described as "MEGA" or double "BASING". The parameters shown in Fig. 1 work well for breast spectroscopy where the peaks of interest are between 2.5 and 3.5 ppm. With the centre of the lipid suppression pulse being at 1.3 ppm (4.7–3.4) and the width of the suppres-



**1** MR Spectra of breast cancer without (A and B) and with (C and D) lipid suppression. SVS TE = 270, voxel size 15 x 15 x 15 mm<sup>3</sup>, TA = 7 min. (B) and (D) are displayed spectra from 1.2 to 4.0 ppm of (A) and (C). Choline peak is detected more clearly in (D) than in (B).

\*Some of the concepts and information in this paper are based on research and are not commercially available in the U.S.



**2** High resolution 3D dynamic imaging, showing a breast cancer in the right breast. SVS spectra from a biopsy proven invasive breast cancer acquired on a MAGNETOM Avanto.  $^1\text{H}$  MR spectroscopy proved to be quite sensitive for detecting invasive carcinoma.

sion pulse being 1.55 ppm, signals in the spectral range of 0.5–2.1 ppm are suppressed.

#### Online frequency correction

The sequence includes online frequency correction, implemented within the reconstruction program, and the correction requires a water peak for inline shifting. Therefore, to ensure sufficient water signal, use the water suppression setting “Weak water suppression” and a longer “WET recovery delay,” the delay between the WET schema and the excitation.

#### Post-processing

Filter: Hanning, width 400 ms, Zero filling: 2048, Baseline: polynomial order: 6, Phase correction: manual or auto using choline; Note that a bias is introduced by phasing a single signal. Curve fitting: calculation range: 1.6 ppm: choline.

#### Differential analysis

Regarding the differentiation between benign and malignant breast lesions, we report several promising results. In malignant lesions,  $^1\text{H}$  MR spectroscopy achieved a high overall sensitivity (more than 80%) (Fig. 2). Moreover,  $^1\text{H}$  MR spectroscopy proved to be quite sensitive for detecting invasive carcinoma from sarcoma and ductal carcinoma in situ. In ductal carci-

noma in situ, the limited number of cases until now has been investigated with lower sensitivity, while most benign tumors were negative on  $^1\text{H}$  MR spectroscopy. However, false positive cases were sometimes experienced (Fig. 3). With the ongoing development of MR technology and breast matrix coils, detection of weak Cho peaks in benign lesions is increasing, and the specificity may be decreasing. In the near future, technology to determine the quantity of composite Cho compounds may be needed.

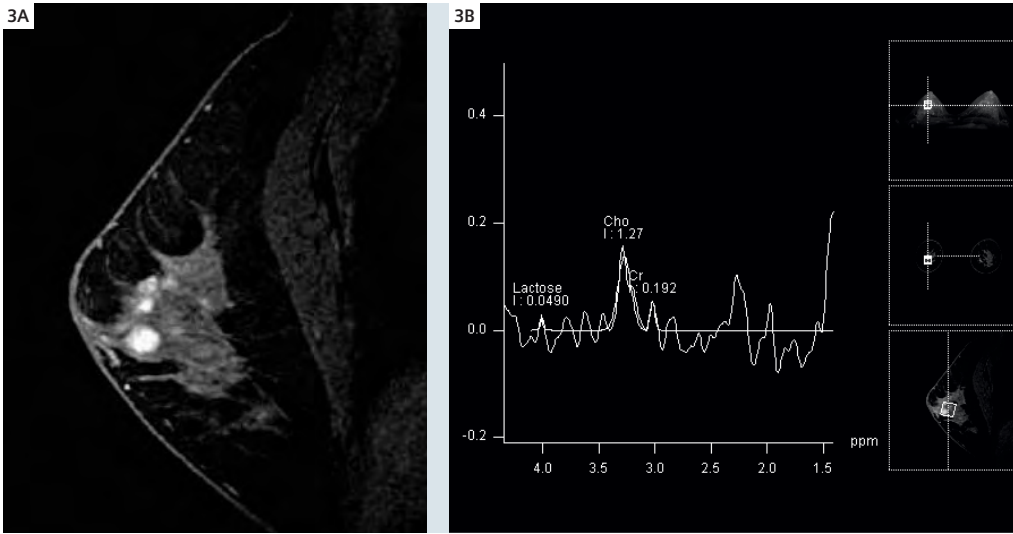
#### Monitoring the therapeutic response

Another potential application of  $^1\text{H}$  MR spectroscopy is in the assessment of the response to neoadjuvant chemotherapy. Contrast-enhancement patterns may lead to misleading findings and false-negative results due to the effects of chemotherapeutic agents. In contrast,  $^1\text{H}$  MR spectroscopy and diffusion-weighted imaging are demonstrating great promise in the evaluation of the direct effects of chemotherapeutic agents. The presence of a Cho peak in breast cancer may reflect the increased cell proliferation, with a decrease in this peak after treatment reflecting decreased viability of the tumor (Fig. 4). In short, metabolic changes observable

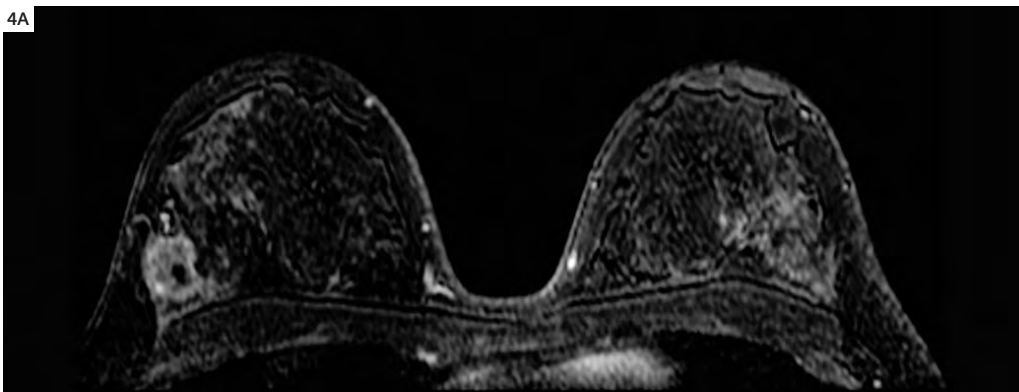
by  $^1\text{H}$  MR spectroscopy are predictive of subsequent clinical response. We believe that early changes in the Cho peak after one or two cycles of neoadjuvant chemotherapy are important information for the decision to continue treatment. Furthermore, the same measurement protocol is required for each follow-up examination. Using the Phoenix functionality of the *syngo* software, the same parameters and voxel size ( $15 \times 15 \times 15 \text{ mm}^3$ ) are ensured for all measurements.

#### Conclusion

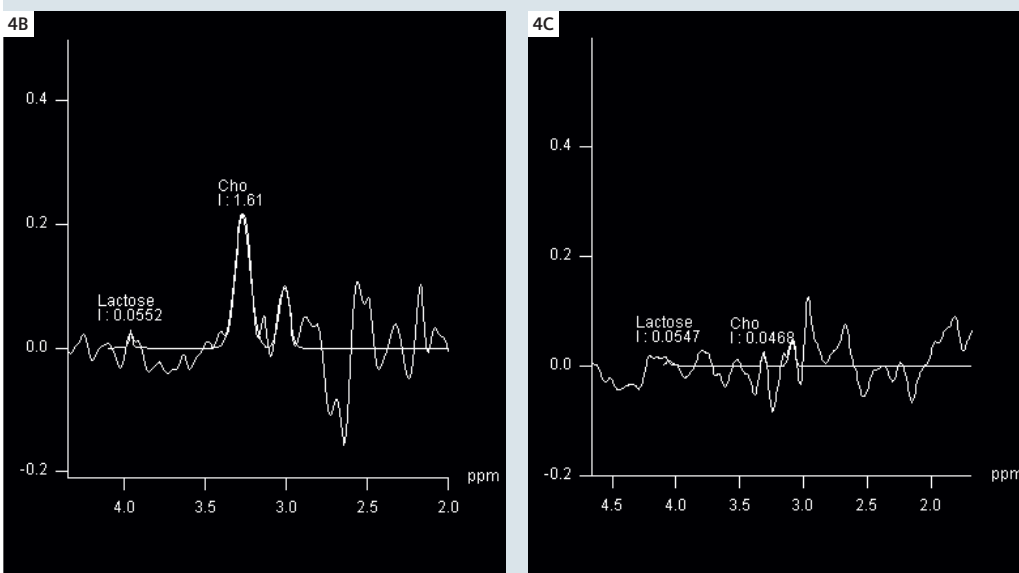
Recent technical improvements in breast MR spectroscopy, including special software to reduce large lipid signals, have made it possible to obtain stable spectra even on 1.5T MR equipment. Clinical investigations using breast MR spectroscopy have just begun; however, the technique has already shown great promise in the MR diagnosis of breast lesions and in the therapeutic decision for patients with breast cancers. With further development and the assessment of Cho quantity in the tumor, breast MR spectroscopy may be helpful in the elucidation of the biology of breast cancer.



**3** SVS spectra showing weak Cho peak from a biopsy proven fibroadenoma. False positive cases occur.



**4** Transverse MPR images of high resolution 3D dynamic imaging, showing a breast cancer in the right breast (A).



SVS Spectra before (B) and after (C) neoadjuvant chemotherapy. Metabolic changes observable by <sup>1</sup>H MR spectroscopy are predictive of subsequent clinical response.

\*\*WIP – Work in progress. This information about this product is preliminary. The product is under development and not commercially available in the U.S., and its future availability cannot be ensured.