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Image Quality Improvement of Composed MR Images by Applying a Modified Homomorphic Filter

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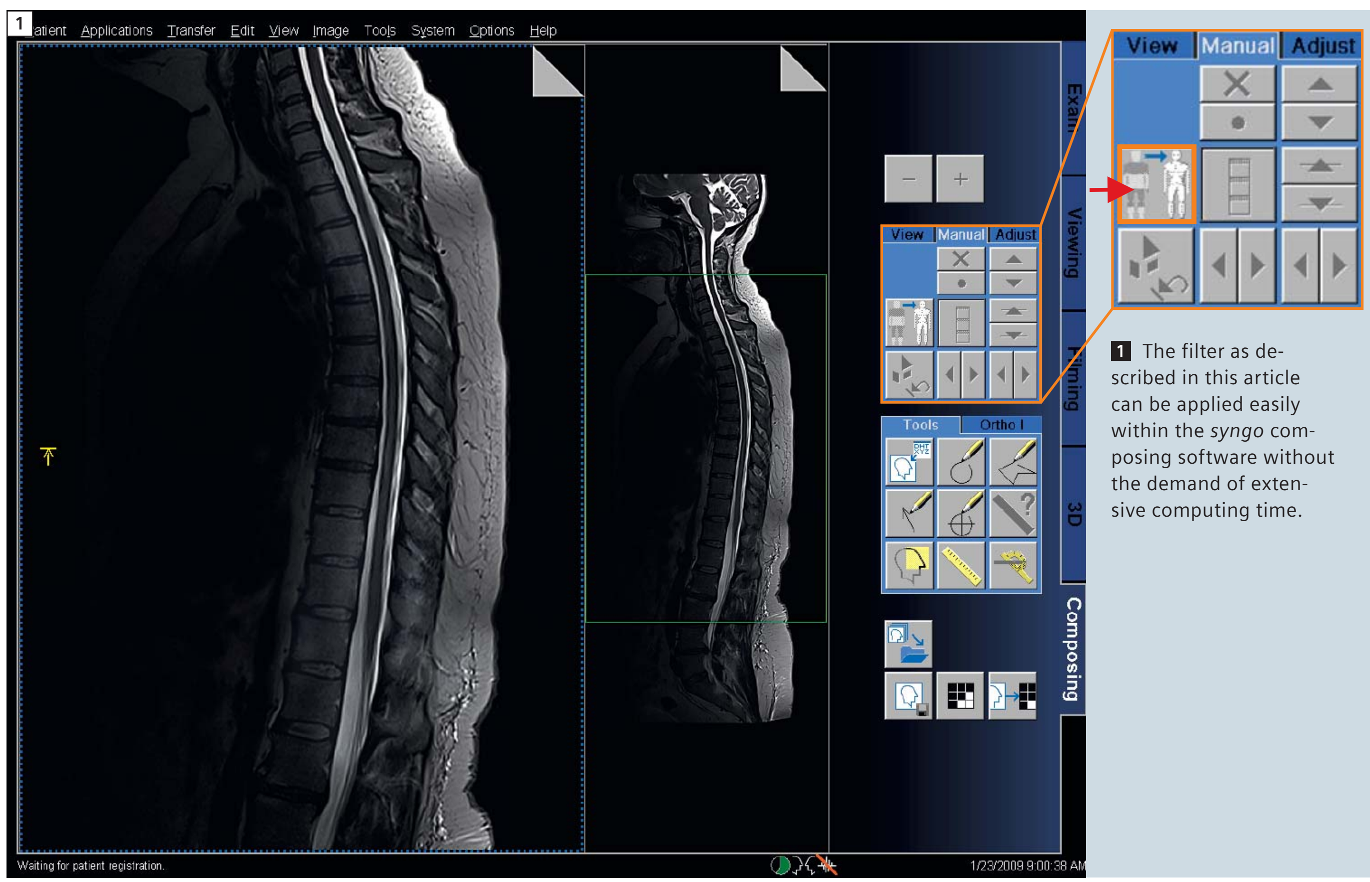
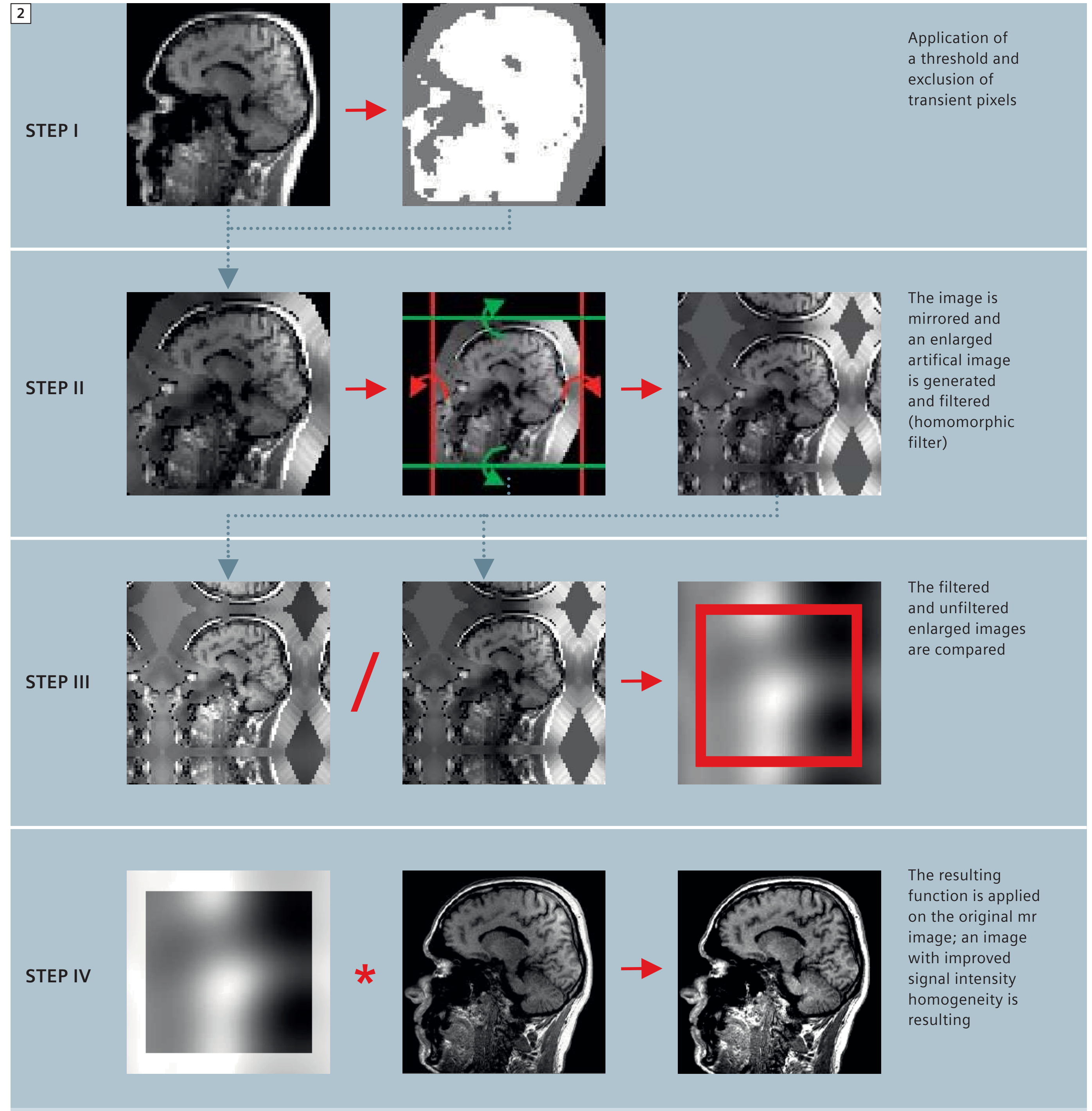
With the development of MR machines that offer the capability to examine large regions of the body without patient and/or coil repositioning [1], MRI can now be used for imaging systemic aspects of diseases e.g. in oncology [1-6]. But documentation of complex pathologies requires a fast and easy assessment of all findings. For this purpose, image-composing techniques may be helpful [1]. To acquire information from large body regions, large fields-of-view (FOV) and multi-channel coils have to be applied [1, 5, 6]. Unfortunately, images with large FOV are often characterized by inhomogeneous illumination. At 1.5T this is caused mainly by local variations of coil sensitivities. This problem can be pronounced at higher field strength by dielectric resonances, causing local B_1 inhomogeneities [7]. Consequently, manual adjustments have to be performed including for small areas of interest, negating the potential advantage of large FOV images for fast and easy access to pathologic findings. This problem will be aggravated regarding composed images.
Therefore, a simple applicable and robust post-processing approach is required to improve signal homogeneity for composing large FOV MR images in clinical routine.



1 The filter as described in this article can be applied easily within the *syngo* composing software without the demand of extensive computing time.



2 Overview of the basic steps of the filter.

The modified homomorphic filter in the *syngo* composing software (Fig. 1) was initially developed to reduce artifacts caused by dielectric resonances [8]. The purpose of the filter is to remove signal inhomogeneities introduced into the image by various phenomena, at 1.5T this is mainly caused by sensitivity variations of the RF-coils.
The method is based on the homomorphic filter as described in reference [9]. Homomorphic filters assume that the acquired image is a multiplication of the ideal homogenous image and the inhomogeneity. Therefore, inhomogeneity can be suppressed by a notch filter (removes low frequency components) applied to the spectrum of the logarithm of the image. In comparison to a standard homomorphic filter, the developed filter includes algorithms to exclude

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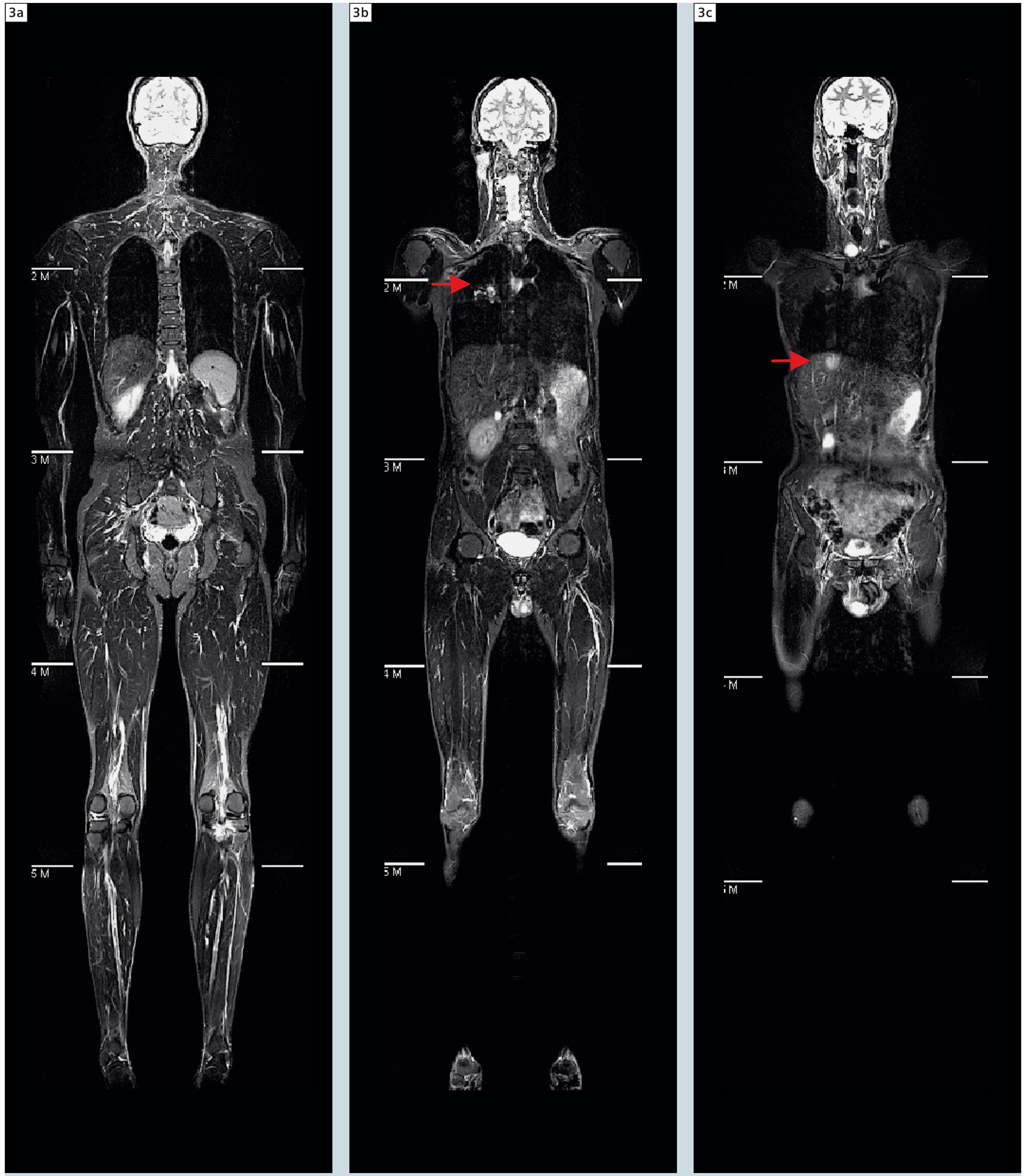
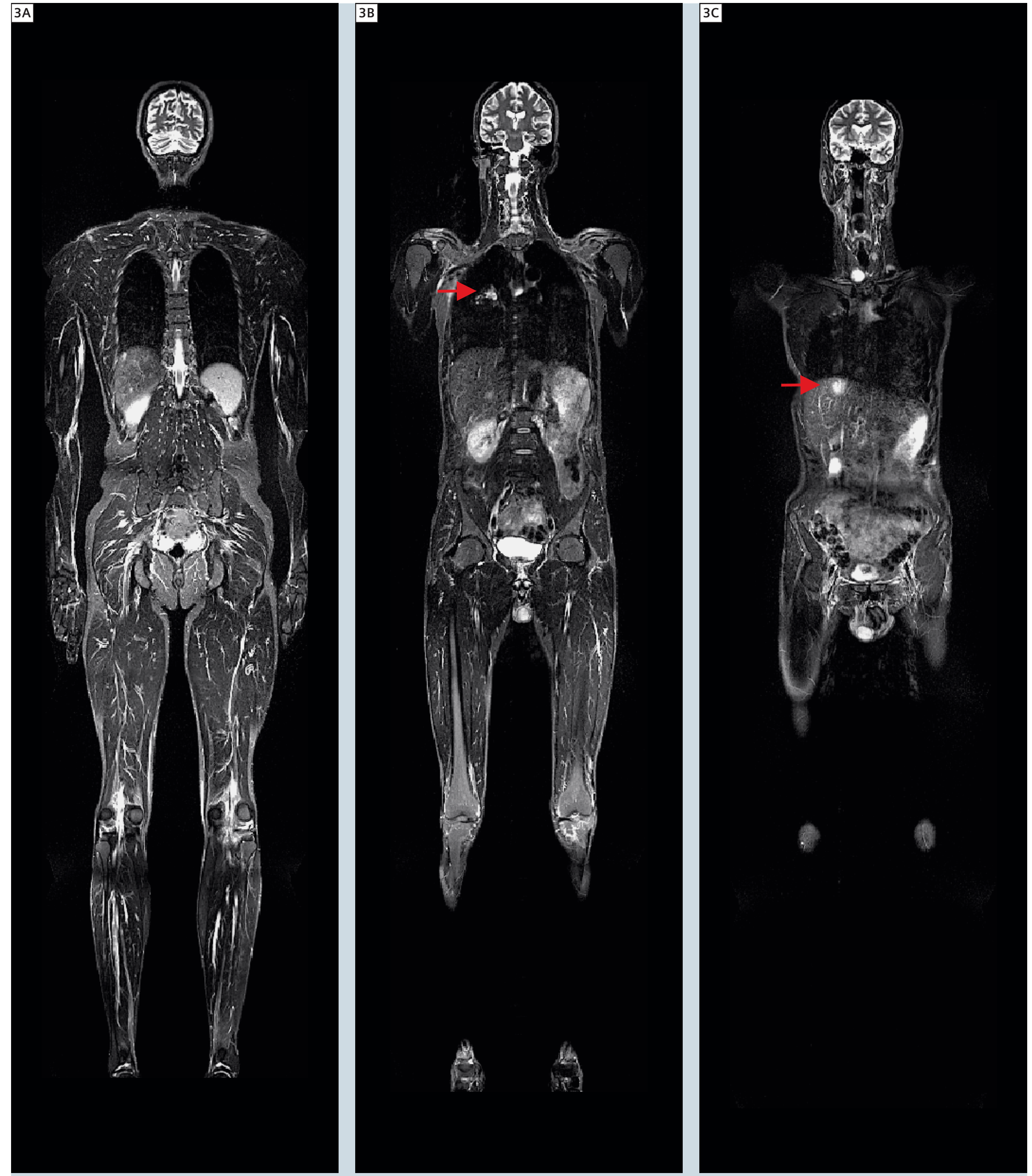


3 This case demonstrates the improved signal uniformity in whole-body MRI, when the homomorphic filter is applied. Original composed T2-weighted STIR images are given in figures **3a**, **b** and **c**; filtered images are given in figures **3 (A)**, **(B)** and **(C)**. While signal uniformity is clearly improved by the homomorphic filter especially for the brain, the metastases (marked by arrows) of the kidney cell cancer are well delineated without loss of contrast to their surrounding tissues. (Note: all images have the same window levels for contrast and brightness.)



3 Filtered images are given in figures **3 (A)**, **(B)** and **(C)**.
Case courtesy of Heinz-Peter Schlemmer and Matthias Lichy, University of Tuebingen, Department of Diagnostic and Interventional Radiology, Tuebingen, Germany.

influences of areas with very low signal intensity inside the object and in the background. A "cepstrum" (spectrum of the logarithm of the image) is calculated from this prepared image and a notch filter is applied on the cepstrum (Fig. 2). The filter can be applied on all kinds of MR images, and is very valuable on composed images. It includes different steps. Firstly, the image resolution is reduced. One effect is that the effective signal-to-noise ratio (SNR) is increased in this new image and, additionally, computing performance is improved. Secondly, areas with low signal intensity are detected by setting of a threshold; isolated pixels in the background and inside the object are removed, including pixels with possible partial volume effects (via erosion). In the next step the initial signal intensities of the removed pixels are replaced by the mean value of N neighboring volume elements (with N~10–100) (compare step 1, Fig. 2). To minimize problems with extreme signal changes (especially present at the image border), the filter mirrors these parts to the outside. For this purpose, the dimensions of the image are enlarged to avoid problems caused by circular convolutions at the borders, which can cause a leap in the sensitivity. Now the standard homomorphic filter algorithm is applied on this new and artificial image with low resolution (compare step 2, Fig. 2). The ratio of the filtered image and the input artificial image provide the correction function (compare step 3, Fig. 2). Finally, the filter interpolates this correction function from the central part of the artificial, low-resolution image to full resolution (this area is corresponding to the non-mirrored central part of the initial image). After a multiplication with the values of the initial fully resolved image, a corrected image with improved signal uniformity is resulting (compare step 4, Fig. 2).

Further information about the function of the filter can be found in reference [8]. A clinical example of the improvement of the signal homogeneity can be found in figure 3, in which it is also shown that there is no compromise in the detection of suspicious lesions introduced by filtering. Further information about the influence of the filter with special regards to diagnostic safety and clinical value for whole-spine imaging in patients with multiple myeloma can be found in [10].

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References

1 Schlemmer HP, Schafer J, Pfannenberg C, Radny P, Korchidi S, Muller-Horvat C, Nagele T, Tomaschko K, Fenchel M, Claussen CD (2005) Fast whole-body assessment of metastatic disease using a novel magnetic resonance imaging system: initial experiences. Invest Radiol. 40(2):64–71.

2 Ghanem N, Lohrmann C, Engelhardt M, Pache G, Uhl M, Saueressig U, Kotter E, Langer M (2006) Whole-body MRI in the detection of bone marrow infiltration in patients with plasma cell neoplasms in comparison to the radiological skeletal survey. Eur Radiol. 16(5):1005–14.

3 Mentzel HJ, Kentouche K, Sauner D, Fleischmann C, Vogt S, Gottschild D, Zintl F, Kaiser WA (2004). Comparison of whole-body STIR-MRI and 99mTc-methylene-diphosphonate scintigraphy in children with suspected multifocal bone lesions. Eur Radiol. 14(12):2297–302.

4 Iizuka-Mikami M, Nagai K, Yoshida K, Sugihara T, Suetsugu Y, Mikami M, Tamada T, Imai S, Kajihara Y, Fukunaga M (2004). Detection of bone marrow and extramedullary involvement in patients with non-Hodgkin's lymphoma by whole-body MRI: comparison with bone and 67Ga scintigraphies. Eur Radiol. 14(6):1074–81.

5 Lichy MP, Wietek BM, Mugler JP 3rd, Horger W, Menzel MI, Anastasiadis A, Siegmann K, Niemeyer T, Konigsrainer A, Kiefer B, Schick F, Claussen CD, Schlemmer HP (2005). Magnetic resonance imaging of the body trunk using a single-slab, 3-dimensional, T2-weighted turbo-spin-echo sequence with high sampling efficiency (SPACE) for high spatial resolution imaging: initial clinical experiences. Invest Radiol. 40(12):754–60.

6 Rodegerdts EA, Boss A, Riemarzik K, Lichy M, Schick F, Claussen CD, Schlemmer HP (2006) 3D imaging of the whole spine at 3T compared to 1.5T: initial experiences. Acta Radiol. 47(5): 488–93.

7 Van de Moortele PF, Akgun C, Adriany G, Moeller S, Ritter J, Collins CM, Smith MB, Vaughan JT, Ugurbil K (2005). B(1) destructive interferences and spatial phase patterns at 7 T with a head transceiver array coil. Magn Reson Med. 54(6):1503–18.

8 Jellúš V, Kiefer B (2005). New Modification of the Homomorphic Filter for Bias Field Correction. Proc. Intl. Soc. Mag. Reson. Med. 13: 2247

9 Gonzales RC, Woods RE (1992). Digital Image Processing, Reading, Addison-Wesley

10 Lichy MP, Mueller-Horvat C, Jellus V, Horger W, Horger M, Pfannenberg C, Kiefer B, Claussen CD, Schlemmer HP (2008). Image quality improvement of composed whole-spine MR images by applying a modified homomorphic filter – first results in cases of multiple myeloma. Eur Radiol. 18(10):2274–82.