DWIBS: Diffusion-weighted whole-body imaging with background body signal suppression

T. Takahara Tokai University Hospital, Isehara City, Kangawa Prefecture, Japan.

▶ *Reprinted from Field Strength [1]*

This article describes a protocol for diffusion-weighted whole-body imaging with background body subtraction (DWIBS) based on free-breathing DWI acquisition with STIR. The protocol has been evaluated in a group of patients with known malignancies in neck, chest or abdomen. The aim of the protocol was to provide an MR-based technique giving results similar to Positron Emission Tomography (PET) for evaluating lesions in the body. The technique is relatively fast, and requires no contrast agent or ionizing radiation.

DWIBS at Tokai University Hospital

▶ **DWIBS is an MR-based technique giving results similar to PET.**

A privately funded institution with 1200 beds, Tokai University Hospital purchased its first MRI scanner more than 15 years ago. Since then four Philips scanners have been installed. Two of them are Intera 1.5T systems with Nova gradients, currently operating at Release 10. The DWIBS exams described in this article are performed on these two systems. DWIBS is an acronym for diffusion weighted whole body imaging with background body signal suppression.

As in many other hospitals, brain and spine exams account for more than half of the 75 patients per day scanned by the four systems, but since the hospital does not have PET, the DWIBS method has become so popular in the various clinical disciplines (internal medicine, orthopedics, oncology and surgery) that it alone attracts 10 patients per day. Since its successful implementation two years ago, some 2000 patients have been scanned.

Another motivator for the DWIBS method is cost. While in Japan a non-contrast MRI scan is reimbursed at $ 300 (USD) and a contrast (Gd-DTPA) enhanced investigation at $ 450, (of which the patient pays one third and the insurance company two thirds) the current cost of a PET scan to the healthcare system and the patient is six times higher.

Like most new MR methods, diffusion-weighted imaging (DWI) was first applied in the brain. In the mid-1990s it became a successful method for assisting in acute stroke diagnosis. Since then, it has been found that the apparent diffusion coefficient (ADC) of tumors is also affected (reduced) due to their larger cell diameter and denser cellularity compared with normal tissues.

A DWIBS protocol based on free-breathing DWI acquisition with STIR has been developed and evaluated in a first group of patients with known malignancies in neck, chest or abdomen.

Whole-body DWI demands high SNR and good fat suppression

The aim of the protocol was to develop an MR-based technique that would give results similar to Positron Emission Tomography (PET) for evaluating lesions in the body. The direction chosen was to evaluate thin-slice DWI and its MIP or MPR reconstructions.

Because DWI is based on the detection of random (Brownian) motion of water over very small distances, the breath-hold scan was initially considered to be the only way to avoid motion artifacts caused by the larger motion of the body's organs over the respiratory cycle. Unfortunately breath-hold scanning has signal-to-noise ratio (SNR) limitations because of its short acquisition

▶ Table 1 Suppression / visualization of tissue with the EPI-STIR combination

Suppressed tissue	Visualized normal tissue	Visualized abnormal tissue
Vessels	Prostate, testes	Tumors
Muscle	Endometrium, ovaries	Abscesses
Fat	Spleen	
Most Organs	Tonsils Lymph nodes Peripheral nerves	

time. This would eliminate the possibility of acquiring thin slices with sufficient SNR for a 3D MIP display; a very useful feature of the PET scanner.

The SENSE parallel imaging method is used to avoid image distortion caused by air in the lungs and intestines. Good fat suppression is also essential, because non-suppressed fat may obscure pathology in a rotating 3D MIP display. Fat suppression by means of SPIR and ProSet is not always robust enough in difficult areas like the neck and shoulders.

The research group at Tokai University Hospital were determined to solve these issues. Tokyo-based Philips clinical scientist Marc Van Cauteren shared their determination [2].

Free-breathing and STIR provide best results
Contrary to popular belief, the group found that free-breathing scanning produces very good image quality (Figures 1, 2). In fact, thanks to the longer scan times permitted by the free-breathing scanning method, multiple signal averages can be used, which yield high signal-to-noise ratios, so that thin slices can easily be obtained. These, in turn, allow good quality MIP reconstructions.

The free breathing acquisition method works so well, because the signal averaging is performed on the reconstructed image and not in k-space. This "averages out" motion artifacts, a phenomenon also observed in conventional body imaging.

In 2D, thick-slice, diffusion-weighted imaging experiments, the SE-EPI combined with the narrow-band SPIR pulse is reasonably successful in generating fat-suppressed images of the central nervous system or even of the body. However to meet the requirement for good fat suppression over the complete field of view associated with a large volume multislice acquisition, the Tokai research group found that STIR combined with a regular EPI sequence is far more effective (Table 1; Figures 3, 4, 5).

Flexibility has always been the hallmark of the Philips scanner. Via the standard user interface, operators can simply build their own protocols by activating parameters that are known to work well in other protocols. No complicated pulse programming software or vendor involvement is necessary to achieve this. Marrying EPI to STIR is just one example.

Another benefit of STIR is the attenuation of the intestinal signal. As intestinal content has a short T1, it is partially suppressed with STIR pulse.

Figure 1. 23 year old man with thymoma. The free-breathing scan (Figure 1a) has much better SNR than the breath-hold scan (Figure 1b) and can be used for high-resolution mPR (Figure 1c).

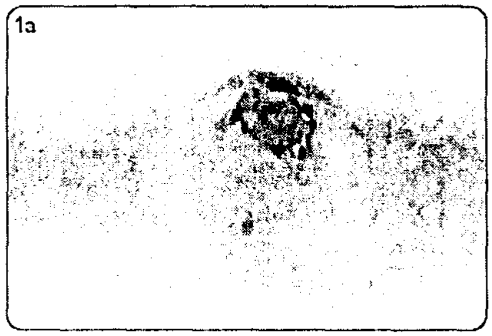


Figure 1a. 8 mm axial image reconstructed from a 4 mm axial free-breathing scan obtained in 7 min.

Figure 1b. 9 mm axial image obtained in a 25 s breath-hold scan.

Figure 1c. 5 mm sagittal image reconstructed from a 4 mm axial free-breathing scan.

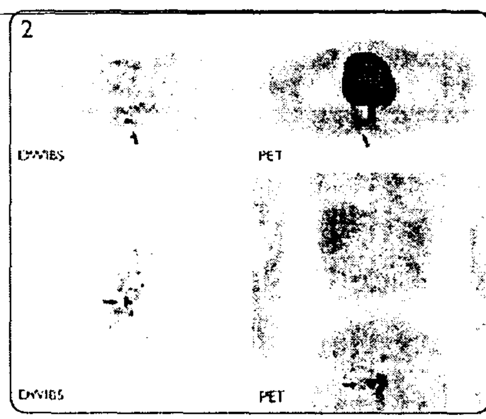


Figure 2. DWIBS has higher resolution than PET in this comparison of a recurrent rectal cancer.

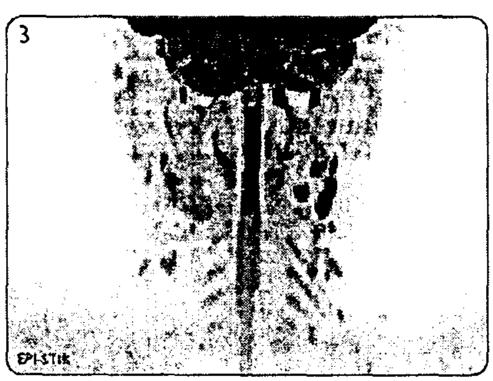


Figure 3. The EPI-STIR sequence clearly shows the swollen lymph nodes around the left sub-mandibular gland (pathology unknown), without interfering fat signal from jaw or clavicle.

Figure 4. 76-year-old woman with advanced breast cancer. Large breast cancer is shown as a low-intensity area. Associated inflammatory process is seen around the tumor and potential axillary lymph node metastasis is well visualized. Note the absence of fat in the shoulder area.

Figure 5. The EPI-STIR sequence is equally effective in suppressing fat in the neck and shoulder area.

Figure 6. DWIBS of patient with malignant lymphoma obtained with the Peripheral Vascular coil. Corresponding coronal MIP image clearly shows swollen lymph nodes in Waldeyer's ring, left-sided neck, supraclavicular, chest, mesenteric and inguinal portions.

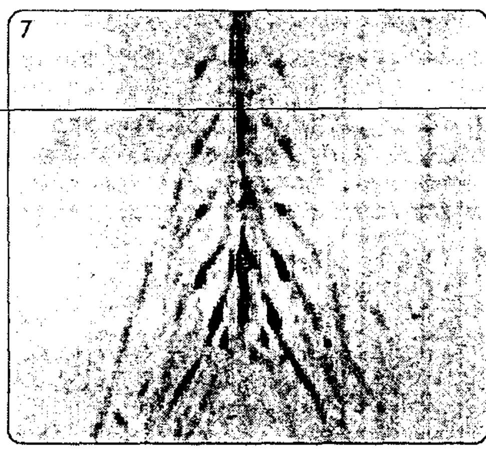
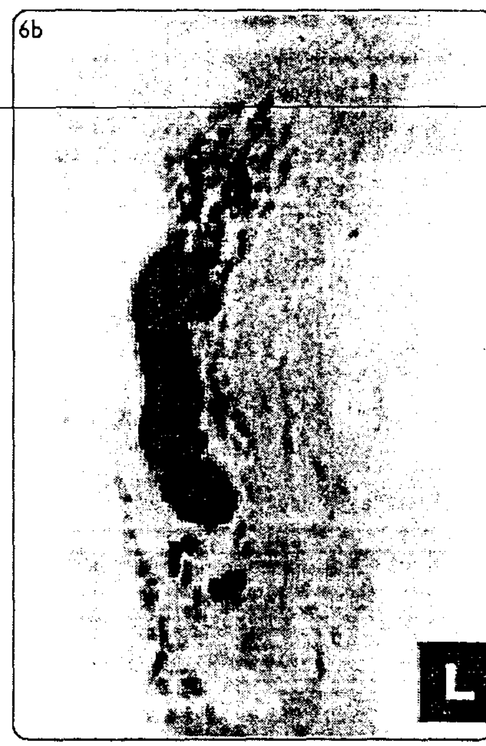


Figure 7. Diffusion-weighted MR neurography of lumbar plexus in a healthy volunteer.



This in turn provides a less obscured image for the detection of intra-abdominal lesions.

The DWIBS protocol

For their experiments, the Tokai group tried two different approaches. One involved the use of a SENSE Body coil, which yields excellent results. To prove the viability of the method, the group also used the 12-channel Peripheral Vascular coil as a whole-body alternative (Figure 6). Partly in order to make the DWIBS images resemble the familiar PET images, the Reverse Video feature is activated in the DWIBS protocol.

The DWIBS sequence requires a total acquisition time of approximately seven minutes.

Since no ionizing radiation is involved as in PET or CT, the DWIBS method can obviously be useful in the frequent follow-up studies associated with chemotherapy. Using a post-processing workstation (e.g. ViewForum), total lesion volume may be automatically be calculated from the images. Although not really associated with the current topic, DWIBS has also been used successfully to aid visualization of peripheral nerve disease (Figure 7).

Conclusion

The development group at Tokai University Hospital firmly believe in the important advantages offered by the new technique. Compared with PET it is less costly, does not involve radiation and does not require the patient to be motionless for 30 minutes. Compared with CT, there is no contrast medium or ionizing radiation. Consequently, they consider the DWIBS method to be an ideal tool for imaging tumors in the body and in the follow-up of patients undergoing chemotherapy ■

Temporal	
TR	> 5000 ms
TE	Shortest (~ 70 ms)
Gradient overplus	Yes
TI	180 ms at 1.5T
SENSE factor	2
Halfscan factor	0.645
EPI factor	47
Spatial	
Slice orientation	Axial
Number of slices	60 to 80
Thickness / gap	4 mm / 0 mm for routine practice (screening) 4 mm / -1 mm to 6 mm / -1 mm for demanding clinical situations
FOV	400 mm
Rectangular FOV	80%
Acquisition matrix	160
Scan percentage	70%
Diffusion	
MPG	All
b	1000 s/mm²
N	10 (Averages)

◄ Table 2. DWIBS protocol for 1.5T

► **Since no radiation is used, DWIBS can be useful for follow-up studies.**

Reference

[1] *Tokai University Develops DWI for Total Body Imaging.* Field Strength 2005; 26: 18-20. http://www.medical.philips.com/main/news/publications/fieldstrength/

2] Takahara T, Imai Y, Yamashita T, Yasuda S, Nasu S, Van Cauteren M. *Diffusion Weighted Whole Body Imaging with Background Body Signal Suppression (DWIBS): Technical Improvement using Free Breathing, STIR and High Resolution 3D Display.* Radiat Med. 2004; 22,4: 275-282. http://www.nv-med.com/rm/pdf/20042204/275.pdf