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The role of deep-learning T2 PROPELLER, diffusion and perfusion sequences in 3.0T MR evaluation of head-neck tumors

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In evaluating head and neck (HN) cancer, especially in the oral cavity, oropharynx and larynx, obtaining high-resolution images and minimizing motion artifacts is crucial. This is vital for assessing submucosal spread, which is very important for staging and accurate surgical planning. To achieve optimal visualization of tumor-muscle-fat relationships, it is essential to use a 3.0T MR system with T2-weighted sequences. However, motion artifacts may limit the use of 3.0T in these patients. To address this issue, it is generally recommended to acquire a T2-weighted PROPELLER (**P**eriodically **R**otated **O**verlapping **P**arall**EL** **L**ines with **E**nhanced **R**econstruction) sequence in addition to the classic Fast Spin Echo (FSE) T2-weighted sequence. The T2 PROPELLER sequence helps reduce the effects of voluntary and physiological patient motion and magnetic susceptibility artifacts, although at the expense of lower contrast resolution.

At our Institute, we utilize SIGNA™ Premier 3.0T with AIR™ Recon DL, a pioneering deep-learning (DL)-based reconstruction software designed to improve SNR and increase image sharpness. AIR Recon DL is not a post-processing technique, rather it is

SIGNA Premier 3.0T						
	Coronal T2 PROPELLER	Axial T2 PROPELLER	Axial DWI EPI MUSE	Axial 3D FSPGR dynamic	Axial 3D FSPGR post-contrast	3D FSPGR DCE
TR (ms):	5068	8058	5050	4.7	Minimum	4
TE (ms):	150	150	Min full	Min full	Min full	Minimum
FOV (cm):	24 x 24	16 x16	20 x 20	16 x 16	22 x 22	24 x 24
Slice thickness (mm):	3	3	3	1	1	4
Frequency:	384	384	96	272	224	200
Phase:	384	384	102	212	224	200
NEX:	1.5	1.5	2 (b0)	1	1	1
Scan time (min.):	2:43	4:19	4:00	1:40 = Mask + 4 x 20 sec.	2:00	5:25 = 65 x 5 sec.
Options/other:	36 slices; NPW1.8; R=3 (ARC); AIR Recon DL (high)	56 slices; NPW1.8; R=3 (ARC); AIR Recon DL (high)	28 slices; b0, b500 (1 NEX), b1000 (3 NEX); Special	94 slices; R=2 (ASSET); Special; AIR Recon DL (medium)	160 slices; R=1.5 (ARC); Special; AIR Recon DL (medium)	20 slices; R=2.25 (ASSET); AIR Recon DL (low)

Table 1.

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embedded directly in the reconstruction pipeline. The neural network model enhances image quality at the early reconstruction level by removing image noise and ringing artifacts directly from the raw image data, providing consistently good, diagnostic-quality images even for challenging patients and difficult-to-image anatomies. The increase in SNR and image sharpness provided by AIR Recon DL also reduces scan times, which is very important for HN cancer patients.

Our HN acquisition protocol uses a 21-element head and neck coil configuration with a neurovascular adapter (Table 1, 2).

Diffusion-weighted imaging (DWI), based on echo-planar sequences, can be technically challenging due to its high sensitivity to noise and geometric distortion, which are consequences of susceptibility effects that disrupt magnetic field homogeneity. In HN MRI, these distortions are often caused by the numerous air-tissue interfaces linked to the complexity of the anatomical structure and the restorative materials used for dental treatments. Reduced field-of-view (FOV) DWI sequences, such as FOCUS, can improve imaging of the salivary glands and small lesions, reducing anatomical distortions. AIR Recon DL, compatible with FOCUS DWI sequences, can be activated in the reconstruction pipeline to minimize image noise.

An ongoing study at our Institute evaluated the impact of AIR Recon DL on the ADC map used by radiologists for differential diagnosis of lesions. Using a calibrated phantom (Diffusion Phantom, Caliber MRI, Boulder, CO), the study found minimal deviation in ADC values with and without DL application, with the most significant variations observed in higher noise DWI images. The preliminary findings suggested a tendency to a better agreement between nominal

SIGNA Premier 3.0T	Coronal T2 PROPELLER (larynx)	Axial T2 PROPELLER (larynx)	Axial DWI EPI FOCUS (larynx)
TR (ms):	7091	8199	4500
TE (ms):	140	120	Min (52.7-108)
FOV (cm):	18 x 18	14 x 14	14 x 7
Slice thickness (mm):	3	3	3
Frequency:	384	384	100
Phase:	384	384	50
NEX:	1.5	1.5	2 (b0)
Scan time (min.):	2:00	2:28	3:50
Options/other:	24 slices; NPW2.0; R=3 (ARC); AIR Recon DL (high)	25 slices; NPW1.8; R=2 (ARC); AIR Recon DL (high)	23 slices; b0 (2 NEX), b500 (6 NEX), b1000 (10 NEX); AIR Recon DL (low)

Table 2.

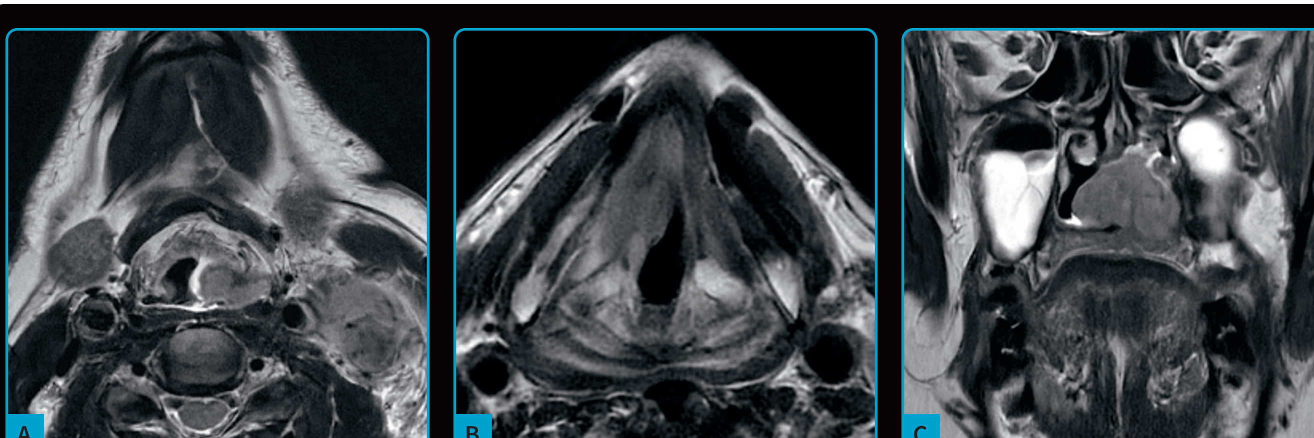

Figure 1. These images demonstrate the value of imaging with T2 PROPELLER using AIR Recon DL in the evaluation of tumors in the (A) left hypopharynx with pathological neck nodes, (B) right larynx on the glottic region and (C) nasal cavity.

and measured values when using AIR Recon DL, suggesting that AIR Recon DL may improve SNR and enhance lesion margin visualization, leading to more accurate region-of-interest delineation (Figure 4).

Clinical and technical description

Advanced MR techniques, such as DWI and dynamic contrast-enhanced (DCE) MR, provide quantitative functional parameters such as tissue cellularity, vascular permeability/perfusion and hypoxia.[1-3] These functional parameters are known to have radiobiological relevance and could potentially guide treatment adaptation based on baseline values and early changes during radiotherapy. DCE-MR was specifically designed to identify tumor vascular heterogeneity and in particular poorly oxygenated sub-volumes of the lesion. DCE-MR is the most frequently used perfusion technique for the HN region. This technique allows for the calculation of semiquantitative and quantitative parameters that have the potential to become a powerful diagnostic and therapeutic oncologic biomarker. It is also used for target delineation, treatment response assessment, and normal tissue injury evaluation.

In an ongoing research protocol at our Institute, we hypothesize that once the hypoxic sub-volumes within the primary tumor site are identified and localized, an intensified Intensity Modulated Radiation Thereapy (IMRT) regimen delivered to these regions will provide superior local control rates than the standard IMRT approach. Based on a pre-treatment DCE-MR study, patients with a hypoxic volume of at least 5 cc at the primary site will be considered eligible and randomized into either the standard or intensified IMRT regimens.

Improvement in perfusion parameters quantification can be achieved by calculating a T1 map at baseline using T1-weighted sequences with multiple flip-angles (FA); our protocol employs FA at 2° – 5° – 7° – 12° – 15° – 25° – 30° with a slice thickness of 4 mm and an acquisition time of 5 seconds per flip angle. DCE-MR is based on a 3D axial FSPGR with a temporal resolution of 5 seconds, a slice thickness of 4 mm, 20 slices per volume, 65 phases total, and an acquisition time of 5:24 minutes. We have used a clustering approach for the perfusion maps to evaluate the hypoperfused tumor sub-volume on the images. Clustering, also defined as habitat imaging techniques, has recently been proposed to assess intra-tumoral heterogeneity.[4] Machine learning algorithms drive this emergent image quantitative analysis to recognize separated tumor components with similar characteristics.[5] These tumor sub-volumes may identify tumor subareas with distinct biological and molecular profiles, suggesting that habit imaging techniques may be central in explaining the different outcomes of patients receiving the same treatment protocol.

Advancements in imaging techniques at 3.0T also allow the acquisition of dedicated MR sequences to obtain a detailed

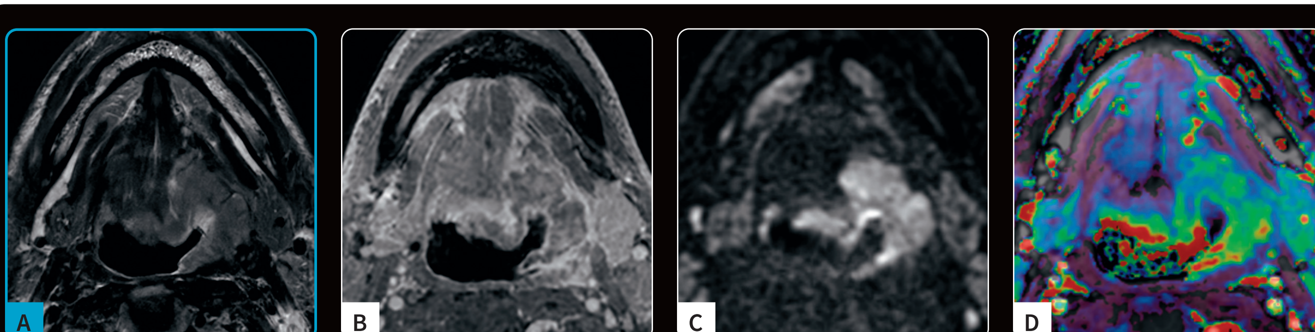

Figure 2. MR images of the base of the tongue in a patient with HPV-positive squamous cell carcinoma (SCC cT4a N0). Post processing was performed on GenIQ. (A) T2-weighted PROPELLER sequences with AIR Recon DL show an infiltration of the extrinsic muscles with the involvement of the lateral and posterior oropharynx wall. (B) T1-weighted FSPGR post-contrast shows the low enhancement of the tumor. (C) MUSE DWI shows a restricted signal intensity. (D) IAUGC (initial area under the gadolinium curve) map derived from DCE-MRI shows a hypovascular lesion.

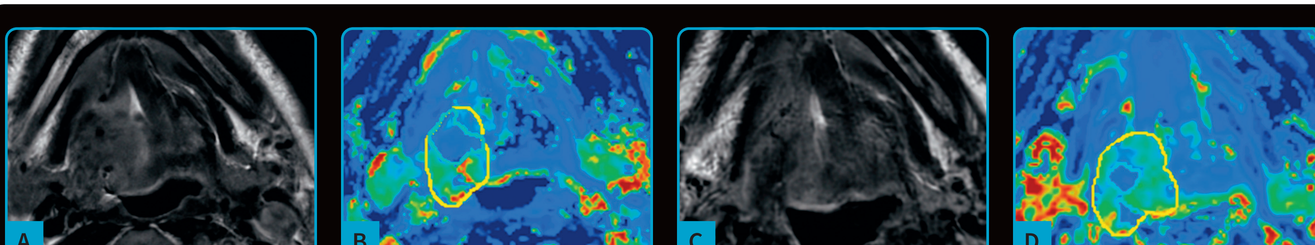

Figure 3. MR T2-weighted PROPELLER with AIR Recon DL before radiotherapy shows (A) a large lesion of the right base of the tongue in a patient with HPV-positive SCC cT4. (B) The K^{trans} map derived from DCE-MRI shows the presence of a hypovascular area into the tumor. (C) T2-weighted PROPELLER with the use of AIR Recon DL after 10 fractions shows a slight reduction in the tumor volume and (D) a more evident decrease of the hypo-oxygenated regions based on the K^{trans} map (- 73.6%), with an increase of the entire tumor vascularization (+ 60.8%). Post processing was performed on GenIQ.

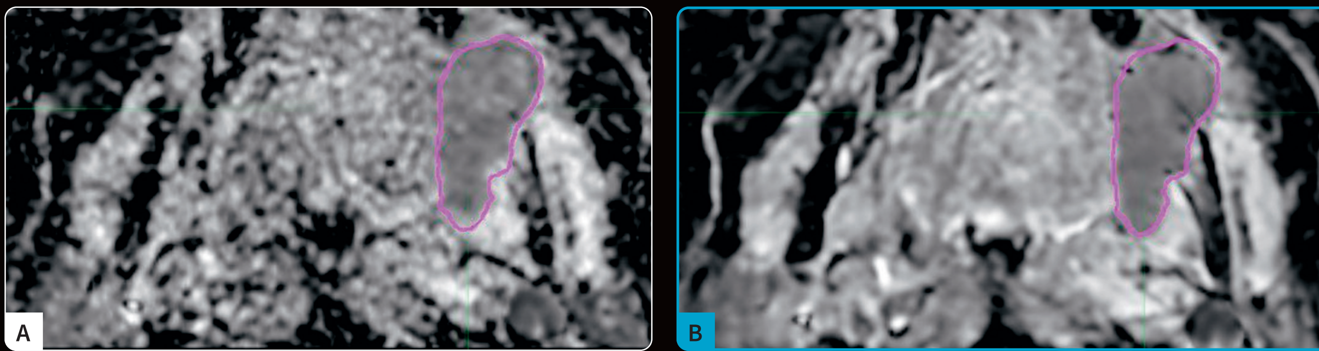

Figure 4. Contour delineation of the largest section of the lesion on the ADC map in diffusion-weighted images obtained with FOCUS and reconstructed (A) without and (B) with AIR Recon DL.

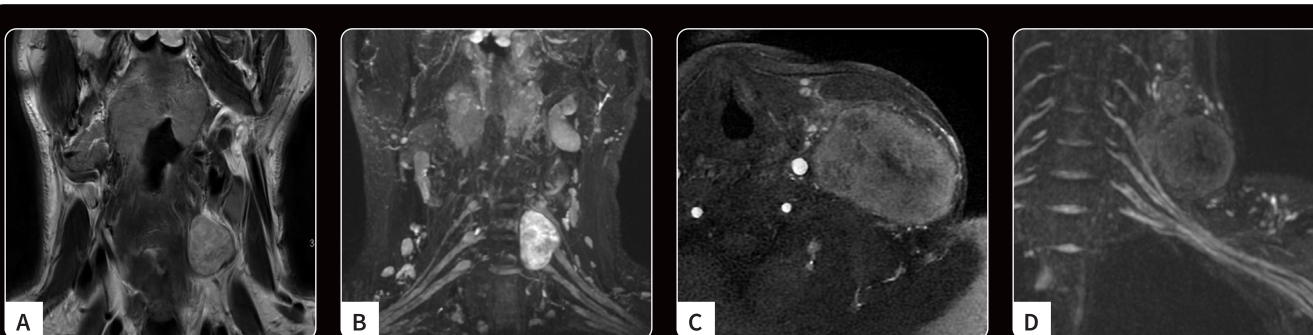

Figure 5. MR Neurography (MRN). (A, B) MRN shows a schwannoma of the brachial plexus. (C, D) MRN shows the relationship between neck nodes and the brachial plexus.

neurography study. Optimizing these sequences is challenging because they need a large FOV, thin slices, high SNR and uniform fat and venous suppression.[6] In oncologic applications, an MR neurography (MRN) study may support the surgeon in planning the surgical intervention, providing detailed information about the nerve location and possible involvement by the disease; it may also help the radiation oncologist to delineate sensible organs at risk, such as the brachial plexus, to reduce unnecessary organ irradiation if in proximity to the target volumes.

What makes it innovative?

PROPELLER sequences are key to imaging anatomies susceptible to motion during MR examinations, particularly in subjects who struggle to remain still, such as those with HN tumors. Now with AIR Recon DL extended to the PROPELLER sequence, we can obtain motion-insensitive images with the same sharpness and diagnostic value as standard FSE, without worrying about repeating scans degraded by motion artifacts.

Perfusion MR allows for the assessment of tumor vascularization and has the potential to enhance the accuracy of MR in both diagnostic and prognostic evaluations; however, its role in HN tumors remains to be defined. Perfusion DCE may be recommended for diagnosis, radiotherapy planning, response assessment after chemo-radiotherapy or induction chemotherapy, and for detecting post-treatment local recurrence during follow-up. For these reasons, we encourage the adoption of a standardized use of perfusion-weighted imaging across research and clinical centers to produce more robust evidence, preferably through multicenter studies, of the clinical value of this challenging yet promising functional MR technique for future applications in HN tumors.

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