New Protocol for the MR Imaging of Pituitary Adenomas. Multiphase, Dynamic and Volumetric Imaging on MAGNETOM Skyra

The Importance of StarVIBE and CAIPIRINHA Sequences

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Introduction

The detection of pituitary microadenomas can be a diagnostic challenge even with MRI. Higher spatial resolution enabled by higher field strengths (3T) has been reported to improve the detection of small adenomas, especially those known to be most difficult to detect, for example, the adrenocorticotropic hormone (ACTH) and growth hormone (GH) producing pituitary adenomas. Stobo et al. reported a sensitivity improvement from 54% to 85% when going from 1.5T to 3T [1]. Dynamic contrast-enhanced (DCE) MRI has also been shown to improve diagnostic performance [2, 3].

Some pituitary microadenomas can be detected without contrast media injection, seen as T2 hyperintensities in the coronal plane. However, many microadenomas are depicted in MRI only after injection of gadolinium due to different pharmacokinetics of contrast enhancement as compared to a healthy pituitary. Microadenomas typically show a delayed peak of enhancement which is often less intense compared to the normal anterior pituitary (90 to 120 ms vs 60 to 80 ms). This makes them appear relatively hypointense in the series of scans performed a few seconds after the injection of gadolinium chelate (see Figure 1 for mean curves of relative enhancement of normal anterior pituitary and microadenomas).

However, not all pituitary microadenomas have the same pharmacokinetics of enhancement. Not all of them are vascularized by the hypophyseal portal system with a delay of interstitial diffusion of contrast medium compared to a normal pituitary gland. Some of them are partially or totally vascularized by pituitary arteries and may enhance earlier than the normal anterior pituitary. Others, conversely, have necrotic or hemorrhagic components which are sometimes predominant and enhance later and less intensively.
In the case of a recent hemorrhagic conversion, parametric imaging and subtracted images are useful because these microadenomas might have a T1 hypersignal before the injection and become isointense compared to normal pituitary gland after injection. Some microadenomas could be cystic and difficult to differentiate compared to simple non-tumor cysts of the pars intermedia and Rathke’s pouch. Here, again, dynamic studies are useful because simple cysts have no enhancement and a flat kinetic curve. ACTH microadenomas often have an enhancement kinetics that are closer to that of the anterior pituitary and are, therefore, more difficult to detect than prolactin and GH microadenomas [7].

New sequences, such as FREEZEit StarVIBE and CAIPIRINHA VIBE, enable high-resolution, temporal and spatial, 3D dynamic studies [4, 5, 8]. The 3D acquisitions allow multiplanar reformatting for better detection of very small (even sub-millimeter) lesions while the high temporal resolution imaging provides better sensitivity to detect pharmacokinetic differences.

We have developed a new MRI examination for pituitary microadenomas on our 3T MAGNETOM Skyra scanner which combines high-resolution volumetric as well as a multiphase, dynamic imaging.

This examination starts with a native series of sagittal T1-weighted, coronal T2-weighted and coronal T1-weighted TSE images with thin slices (1.5 to 2 mm). We then inject contrast with a ‘half dose’ (7 cc at a rate of 2 cc/sec) which has been shown to be sufficient for the detection of microadenomas. We then run a dynamic series – CAIPIRINHA VIBE – with 12 slices of 2 mm thickness in 6 repetitions with a total acquisition time of 2 min 30 sec. With this acquisition, we see several stages of enhancement:

a) early stage with arterial opacification blush of post pituitary then of pituitary stalk, then
b) intermediate stage with opacification of the hypophyseal portal venous system, then
c) progressive opacification of anterior pituitary supported by the portal system.

Microadenomas usually enhance later (and often less intensely) than other portions of the anterior pituitary and appear relatively hypointense during this early opacification stage of the anterior pituitary. The dynamic multi-slice protocol provides many different parameters: wash-in, wash-out, time-to-peak (TTP), area under the curve (AUC), etc. These parameters improve the detectability of microadenomas, especially wash-in and AUC. In addition, this dynamic multi-slice series provides other diagnostic elements such as hypothalamic-pituitary pharmacokinetics, mass effect on pituitary stalk, diagnostic with other hypervascular intrasellar process, aneurism, intrasellar artery or vein. Some microadenomas could be hypervascular in the arterial phase and are only visible in a dynamic study [6]. In a CT dynamic study, Bonneville et al. reported that 34% of microadenomas had a partial or complete early opacification before the portal opacification stage, demonstrating a direct arterial vascularization and not only a pituitary portal as mostly observed in anterior pituitary microadenomas. It seems that such hyper-arterialized microadenomas, opacified at early time, are less often observed in MRI, but they could be visualized by these new 3D dynamic protocols with multiparametric imaging.
Prolactin microadenomas of a 57-year-old woman. Dynamic MRI StarVIBE. Opacification stage of the anterior pituitary (5A), the microadenoma is hypointense compared to the normal anterior pituitary, and the contrast is optimal during the phase of 75 seconds after injection of chelate gadolinium. On a second high-resolution volume series CAIPIRINHA with re-injection, the microadenoma is visualized in the 3 space plans, illustrated by this parasagittal reformation.

Hyperprolactinaemia of a 53-year-old man. Pituitary MRI without injection shows an ‘empty’ sella turcica with pituitary residue pressed against the sellar floor (4A). VIBE multiphase dynamic series shows a lateralized lesion in left wing pituitary (4B, C) with a delay of relative opacification on wash-in parametric imaging (4D). On a CAIPIRINHA volumetric series with re-injection, this left side microadenomas with empty sella turcica is visualized in the 3 space plans (4E, F). Detection of microadenomas on empty sella turcica is difficult with 2D TSE pituitary classic protocols. (4G) The comparative analysis of the pharmacokinetic curve of microadenoma opacification (red curve) and of the normal anterior pituitary (green curve) show both the delay and the lowest relative microadenoma opacification. The relative contrast (hypointensity of microadenoma) predominates between 50 and 80 seconds following the injection of contrast medium.

Prolactin microadenomas of a 29-year-old woman. Despite its small size of 1.4 mm diameter, this microadenoma – initially isointense on T1 without injection – is marked out in the dynamic VIBE series. It is relatively hypointense compared to the normal anterior pituitary, and the contrast is optimal during the phase of 75 seconds after injection of chelate gadolinium. On a second high-resolution volume series CAIPIRINHA with re-injection, the microadenoma is visualized in the 3 space plans, illustrated by this parasagittal reformation.

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Prolactin microadenomas of a 57-year-old woman. Dynamic MRI StarVIBE. Opacification stage of the anterior pituitary (5A), the microadenoma is hypointense compared to the rest of the anterior pituitary. Thanks to the 6 stages of this dynamic series, parametric imaging can be visualized, wash-in (5B) and time-to-peak (5C) showing the lesion of the left side portion of the pituitary gland and its relative opacification delay. In a second volume series (5D-F) CAIPIRINHA enables microadenomas reformations in the 3 space plans. The comparative analysis of the pharmacokinetic curve of microadenoma opacification (red curve) and of the normal anterior pituitary (green curve) show both the delay and the lowest initial microadenoma opacification. The relative contrast (hypointensity of microadenoma) predominates between 60 and 90 seconds following the injection of contrast medium (5G).
However, the spatial resolution in these dynamic studies (which favors temporal resolution and series multiplication) is lower than on the conventional series (even with these new fast 3D sequences). We find it clinically useful to continue with one (or several) high-resolution scans, but there is a risk of making these scans at a pharmacokinetic stage when progressive opacification of adenoma meets or even exceeds that of the healthy pituitary, which decreases the detectability of microadenomas.

The new FREEzeit StarVIBE sequence has an advantage over the T1 TSE sequence as it enables a high-resolution submillimetric and isotropic volume acquisition in one acquisition (48 sections of 0.8 mm in 3 min 50 sec in our protocol) together with the ability to perform 3D multiplanar reformats. As dynamic imaging has been performed with a half dose, we inject a further half dose at a lower rate (0.5 cc/sec) for a total injected dose of 15 cc. This biphasic protocol enables us to make a volume acquisition with submillimeter slices while maintaining the best relative pharmacokinetic detectability of adenomas vs healthy anterior pituitary. Thanks to this high spatial resolution volume acquisition, (sub)millimeter microadenomas – relatively hypointense – can be detected and visualized in 3D space. Even in the most difficult diagnostic circumstances, such as microadenomas on empty sella turcica, we are able to better detect microadenomas.

In conclusion, this protocol combines the advantages of dynamic and anatomic studies in high resolution while using a standard gadolinium injection dose and in an exploration time substantially similar to the one of a classic protocol (with 2D TSE series). The combination of images 3D dynamic studies with high spatial and temporal resolution improves the visualization of microadenomas and contributes to better differential diagnostics, which in turn optimizes the diagnostic sensitivity and specificity of MRI for pituitary tumors.
Invasive pituitary macroadenoma which infiltrates widely the right cavernous sinus. The dynamic MRI after injection of gadolinium does not aim at detecting the voluminous adenoma, but at characterizing its kinetics of opacification (similar to the normal pituitary gland) and at detecting the areas of hyperperfusion or necrosis. The main interest is the possibility of multiplanar reconstruction of the adenoma thanks to the 3D acquisition and mostly to carry out an angioMRI analysis of the stretched, infiltrated and irregular carotid artery as the adenoma covers completely the endo-cavernous carotid.

References