Syllabus Sessions: Cardiovascular Tissue Characterization (June 3rd 2015)

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Highlights:

- The latest & the greatest of 3D black-blood MRI
- Routine clinical applications of vessel wall MRI
- Potential of black-blood MRI for tumor and thrombus imaging

What is the Clinical Value of Vessel Wall Characterization?

Target Audience:

Radiologists and physicists who are keen to learn about the clinical usefulness of vessel wall characterization in general and black-blood MRI in particular

Objectives:

- To understand the current sequences for vessel wall characterization
- To learn about typical clinical applications of vessel wall MRI
- To get accommodated with emerging applications of black blood MRI of the vessel wall and beyond

Purpose:

Fat suppressed 2-dimensional T1w black-blood (BB) sequences are commonly used to diagnose arterial dissections and vasculitic changes in various vascular beds. However, conventional 2D-BB sequences are time consuming and thus provide a limited coverage of the arteries of interest. In addition it is challenging to combine the required black blood saturation pre-pulse with a navigator, which makes it difficult to apply them for thoracic or abdominal imaging. More recently new isotropic 3D black-blood T1w-TSE sequence with variable flip angles (e.g. 3D-T1-BB-VISTA) for various anatomical regions have been implemented and have been evaluated in patients with CNS vasculitis, large vessel vasculitis, atherosclerotic disease and in tumor patients[1,2,3]. These sequences can be combined with a navigator and with Peripheral Pulse Unit triggering and are thus able to yield excellent image quality in all body regions. The purpose of this talk is to provide an overview of existing and emerging applications of these new 3D-bb techniques and to show their strengths and possible weaknesses.

Methods / Results:

We implemented a 3D-BB sequence at our hospital in July 2013 and have successfully used it in all body regions, including CNS, neck, thorax, abdomen and extremities. We examined all vascular beds, including the aorta, the supra-aortic vessels and even small and medium-sized intra- and extra-cranial vessels. So far we have used these sequences in more than 1000 clinical examinations. Overall, this 3D-BB sequence provides an excellent flow suppression by variable-flip-angle refocusing pulses which allows the visualization of vessel wall thickening and vessel wall contrast enhancement of large, medium-sized and small arteries with good to excellent image quality. In addition 3D reconstructions of the vessels can be obtained which are extremely useful in differentiating the eccentric vessel wall thickening of atherosclerotic disease from concentric wall thickening in vasculitis. Scan times varies depending on the vascular bed and ranges from 3 – 6 minutes.

Advantages for tumour imaging

In a first study on the imaging of intracranial tumours Kammer et al was able to show that 3D-T1-BB-VISTA visualises a significantly higher number of masses compared to conventional 3D MP-RAGE sequences. In addition, diagnostic confidence was also improved which might be explained by a higher CNR Tumor/Parenchyma of brain tumors / metastases in 3D-T1-BB-VISTA compared to the conventional "white-blood" MP-RAGE sequence. Image quality of T1-VISTA was rated excellent in 73.0 % and good in 27.0 % of the exams and none of the exams had to be excluded due to insufficient image quality, suggesting that this sequence is robust and can be used in a routine clinical setting. Interestingly, metastasis, which were only detected by T1-VISTA were significantly smaller than metastasis detected in both sequences and this is of clinical relevance as the earlier we can detect metastases or lesions the better we can treat them. A further effect of the new sequence: With conventionally used gradient sequences blood and lesions appear bright. The black-blood sequence shows masses/lesions brightly but not the blood, which is shown as dark, which makes it easier to detect lesions as there is less distraction from bright blood vessels. In addition meningeal contrast enhancement can be much easier identified on T1w-VISTA compared to conventional T1w-3D-MPRAGE sequences.

Advantages for imaging of large vessel vasculitis

Large vessel vasculitis is a comparatively rare disease with often unspecific clinical symptoms, and its early detection poses a particular challenge for all clinicians. Vasculitides

are primarily based on inflammatory changes in the vascular walls. Diagnosis is made more difficult by the fact that any luminal changes detected are usually unspecific and they can also manifest as a result of other types of diseases. The validity of conventional imaging procedures is therefore often limited. The gold standard for the imaging of large vessel vasculitis so far has been PET-CT. However, black-blood Technology allows us to directly visualise the vascular wall. This makes it possible to detect - at an early stage and with the help of contrast media - thickening and contrast enhancement of the walls, which can be evidence of atherosclerosis or inflammation of the vascular walls. We can therefore use 3D-T1-BB sequences for the direct imaging of inflammatory changes of the intracranial but also the extra-cranial arteries. A pilot study of 17 patients with suspected large thoracic vessel vasculitis and 17 controls resulted in good to excellent image quality in 30 out of 34 exams (88.2%). 37 out of 92 (40.2%) arterial segments in patients with suspected vasculitis showed contrast enhancement and 38 out of 92 (41.3%) concentric wall thickening. Contrast enhancement was strongly correlated with concentric wall thickening (Spearman´s R=0.894; P<0.001). Both findings were found in 15 distinct patients with clinically confirmed vasculitis. Only one out of 97 (1.0%) arterial segments of the control group showed concentric wall thickening and contrast enhancement. Although FDG-PET/CT is currently the accepted gold standard for the diagnosis of large vessel vasculitis black-blood MRI offers several advantages over FDG-PET/CT: (1) absence of ionizing radiation, which might be particularly useful in young patients with Takayasu arteritis or in all patients which have to undergo frequent follow-up exams to monitor anti-inflammatory therapy; (2) simultaneous assessment of contrast enhancement and vessel wall thickening and (3) better differentiation between atherosclerotic disease and vasculitis. In addition, BB-MRI can be easily combined with a contrast-enhanced MR-angiography, which allows simultaneous assessment of the lumen and the vessel wall.

Advantages for imaging of CNS vasculitis

Vasculitis of the central nervous system is a rare disease. Its incidence is largely unknown; its diagnosis is challenging. The diagnostic gold standard is histopathological evidence of vessel wall inflammation. However, a biopsy is an invasive procedure, might have severe side effects and may reveal false negative findings, especially in patients with predominant or isolated proximal artery involvement. BB-MRI is the only imaging method that can directly visualize contrast enhancement of the intra-cranial arteries and initial reports have suggested that this method is helpful in establishing the diagnosis of the disease[4]. In addition it has been

suggested in case series that this method can be used to monitor the inflammatory activity of the disease[5]. Image examples will be shown that 3D whole-brain black-blood T1w-TSE sequence with variable flip angles is able to visualize the intracranial arteries and can also visualize extra-cranial involvement, e.g. of the ophthalmic, vertebral and occipital arteries in less than 5 minutes can time.

Emerging applications of black-blood imaging

A recent pilot study[3] in 13 patients with known or suspected deep vein thrombosis (DVT) has shown that 3D black-blood MRI can be used to diagnose DVT with good to excellent agreement compared to contrast enhanced MRI techniques and sonography. It might be useful when contrast media is prohibited and in patients with suspected thrombosis of the iliac veins, which can be hard to detect with sonography. In addition it could potentially be used to determine the age of a thrombus, depending on its signal intensities on T1, T2 and post contrast T1-weighted images. Currently ongoing studies will have to determine whether this technique will be useful to differentiate between old and recurrent thrombi, which might allow improvement of the diagnostic work-up of recurrent DVT.

Conclusion:

We have successfully implemented a pre- and post-contrast isotropic 3D-T1-BB-VISTA sequence in many of our routine clinical protocols for various body regions and find the sequence extremely helpful for diagnosing and monitoring tumor patients, patients with vasculitis and patients with atherosclerotic disease. Future studies will have to determine whether black-blood MR has the potential to replace PET/CT for diagnosing large vessel vasculitis and whether this sequence is able to replace other contrast-enhanced T1w sequences for tumor imaging, such as T1w 3D-MPRAGE or 2D-TSE imaging.

References

1. Saam T, Maurus S, Kammer N, Treitl, KM, Kooijman H, Reiser MF, Coppenrath E. 3D-black-blood 3T-MRI for the diagnosis of thoracal large vessel vasculitis: a feasibility study“. RSNA 2014 Annual Meeting, 30th Nov. - 05th Dec. 2014, Chicago, ID# 14013882
2. Kammer NN, Coppenrath E, Kooijman H, Reiser MF, Saam T. Whole brain 3D-black-blood 3 T-MRI for the diagnosis of CNS vasculitis: a feasibility study. European Congress of Radiology, Vienna, Austria. ECR 2014, B-0378
3. Treitl KM, Treitl M, Kooijman-Kurfuerst H, Kammer NN, Coppenrath C, Suderland E, Czihal M, Hoffmann U, Reiser MF, Saam T. Three-dimensional black-blood T1-weighted turbo spin-echo techniques for the diagnosis of deep vein thrombosis in comparison to contrast-enhanced MR imaging: a pilot study. Investigative Radiology. In Press.
4. Pfefferkorn T, Linn J, Habs M, et al. Black blood MRI in suspected large artery primary angiitis of the central nervous system. J Neuroimaging 2013;23:379-83.
5. Saam T, Habs M, Pollatos O, et al. High-resolution black-blood contrast-enhanced T1 weighted images for the diagnosis and follow-up of intracranial arteritis. Br J Radiol 2010;83:e182-4.