TECHNISCHE MITTEILUNG

MRI-based quantification of renal perfusion in mice: Improving sensitivity and stability in FAIR ASL

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Received 26 August 2016; accepted 6 February 2017

Abstract

Purpose: *The importance of the orientation of the selective inversion slice in relation to the anatomy in flow-sensitive alternating inversion recovery arterial spin labeling (FAIR ASL) kidney perfusion measurements is demonstrated by comparing the standard FAIR scheme to a scheme with an improved slice selective control experiment.*

Methods: *A FAIR ASL method is used. The selective inversion preparation slice is set perpendicular to the measurement slice to decrease the unintended labeling of arterial spins in the control experiment. A T_1^*-based quantification method compensates for the effects of the imperfect inversion on the edge of the selective inversion slice. The quantified perfusion values are compared to the standard experiment with parallel orientation of imaging and selective inversion slice.*

Results: *Perfusion maps acquired with the perpendicular inversion slice orientation show higher sensitivity compared to the parallel orientation. The T_1^*-based quantification method removes artifacts arising from imperfect inversion slice profiles. The stability is improved.*

Conclusion: *Adjusting the labeling technique to the anatomy is of high importance. Improved sensitivity and reproducibility could be demonstrated. The proposed method provides a solution to the problem of FAIR ASL measurements of renal perfusion in coronal view.*

Zusammenfassung

Ziele: *Die Bedeutung der Lage der schicht-selektiven Inversion des Kontrollexperiments in FAIR-ASL Nierenperfusionsmessungen soll demonstriert und ein verbessertes Schema vorgeschlagen werden.*

Methoden: *Es wird eine FAIR-ASL Methode angewandt. Die Inversionsschicht des Kontrollexperiments wird senkrecht auf die Bildgebungsschicht gesetzt und dadurch die ungewollte Markierung von einfließenden Spins reduziert. Eine T_1^*-basierte Quantifizierung wird verwendet, um die Effekte von variabler Inversionsgüte innerhalb der Bildgebungsschicht zu kompensieren. Die quantifizierten Werte werden mit denen des Standardexperiments mit parallel orientierter Inversions- und Bildgebungsschicht verglichen.*

Ergebnisse: *Die mit der neuen Methode gemessenen Perfusionskarten zeigen eine höhere Sensitivität, als die mit der Standard-FAIR-ASL Methode aufgenommenen. Die T_1^*-basierte Quantifizierung eliminiert Artefakte, die durch die reduzierte Inversionsgüte am Rand der selektiven Inversionsschicht auftreten. Die Stabilität der Messung wird erhöht.*

Schlussfolgerung: *Das Anpassen der Experimente an die untersuchte Anatomie ist von großer Bedeutung. Es konnte eine gesteigerte Sensitivität und Reproduzierbarkeit der Messung demonstriert werden. Die vorgeschlagene Methode ist eine mögliche Lösung für das Problem der*

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Keywords: Arterial spin labeling, FAIR ASL, renal, kidney, perfusion, coronal view

FAIR-ASL Nierenperfusionsmessung in koronalen Schnitten.

Schlüsselwörter: Arterielles Spin Labeling, FAIR ASL, Niere, Perfusion, Koronaler Blick

Introduction

Perfusion measurements in kidneys prove to be a valuable tool in preclinical research to assess their function [1], as the filtration is closely linked to the perfusion. There have been several publications on the subject in the recent years [2–6]. Among other methods such as pseudo continuous arterial spin labeling (pCASL) [5,6] a flow sensitive alternating inversion recovery (FAIR) [7] arterial spin labeling (ASL) method was used [2–4]. ASL is well suited for applications in the kidney, as contrast agent based methods can be contraindicated in subjects with renal insufficiency [8]. In FAIR ASL the magnetization is usually prepared using a global inversion which is referred to as the labeling experiment and a slice selective inversion which is referred to as the control experiment. In the standard labeling scheme the selective inversion slice is in the same plane as the imaging slice with a thickness of 1.5–5 times the thickness of the imaging slice. This warrants a high inversion quality throughout the imaging slice. For renal imaging in the coronal view this proves to be problematic, as the selective inversion slice can unintentionally pass through the heart, lungs and vasculature containing a large amount of blood, which may flow into the kidney and mitigate the inflow effect of non-inverted spins on T_1. This reduces the quality of the control experiment and thereby the difference between the global and slice selective experiment, which will ultimately lead to underestimation of perfusion [2,9]. The coronal view is desirable because the long axis of both kidneys can be imaged in a single experiment. In Fig. 1(a) a maximum intensity projection from three adjacent slices with a slice thickness of 0.75 mm is shown. The resulting thickness of 2.25 mm is still below the typical thickness of the selective inversion slice. Nevertheless large parts of the aorta are visible and would therefore be included in the selective inversion slice, deteriorating the quality of the control experiment. The problem is also visualized in Fig. 1(b) where a sagittal FLASH image through a kidney and the heart with the position of the selective inversion slice is shown. Large vessels and parts of the lungs which contain a lot of blood are in the marked area. This problem has been noted in literature before [2,5,9]. In [2] it is mentioned that the inclusion of feeding arteries in the selective inversion sliced leads to perfusion signal loss. In [9] the inversion and imaging slice was positioned so it would not include the aorta in human subjects. However, this poses limits to the imaging slice positioning or slice thickness and can be impossible in small rodents. In [5] a possible solution using pseudo-continuous ASL (pCASL) was demonstrated. However, as FAIR ASL is well established in preclinical research, a solution to the problem for FAIR ASL in coronal view is desirable. This allows the use of existing FAIR ASL protocols. In this work we propose a new solution within the framework of FAIR ASL. By adapting the orientation of the selective inversion slice (see blue area in Fig. 1(a) and (b) right) to minimize the problem of undesired manipulation of inflowing spins by the slice selective inversion the labeling efficiency is improved in comparison to the standard protocol.

Methods

Animal experiments

All experimental procedures were in accordance with institutional guidelines and were approved by local authorities. Mice were placed in prone position. Anesthetization was

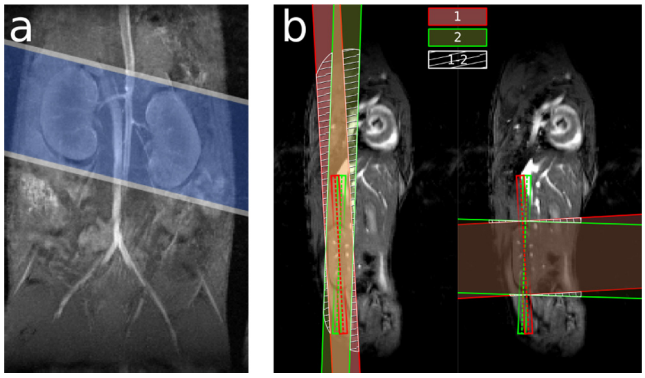

Figure 1. (a) A maximum intensity projection from three slices (thickness 0.75 mm, no gap) that cover a thickness of 2.25 mm. The position and size of the perpendicular inversion slice is marked by the blue bar. Everything visible in this image would be labeled in the slice selective inversion of the standard FAIR experiment. (b) Exemplary image of possible positions of the imaging slices with a 5° tilt (thick red and green lines) and their corresponding selective inversion slices (red and green shading) for the parallel (left) and perpendicular orientation (right). The area marked with the line pattern is only labeled in one of the two slightly titled slices. It is clearly visible that the volume labeled in the perpendicular selective inversion orientation is less than that of the parallel orientation. Also the difference in the amount of labeled inflowing blood, due to a small tilt in the imaging slice, is reduced in the perpendicular orientation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)