Supplemental Material

Introducing a free-breathing MRI method to assess perioperative myocardial oxygenation and function

TABLE OF CONTENTS

Supplemental Methods

Parameters of Oxygenation-Sensitive (OS) Sequences

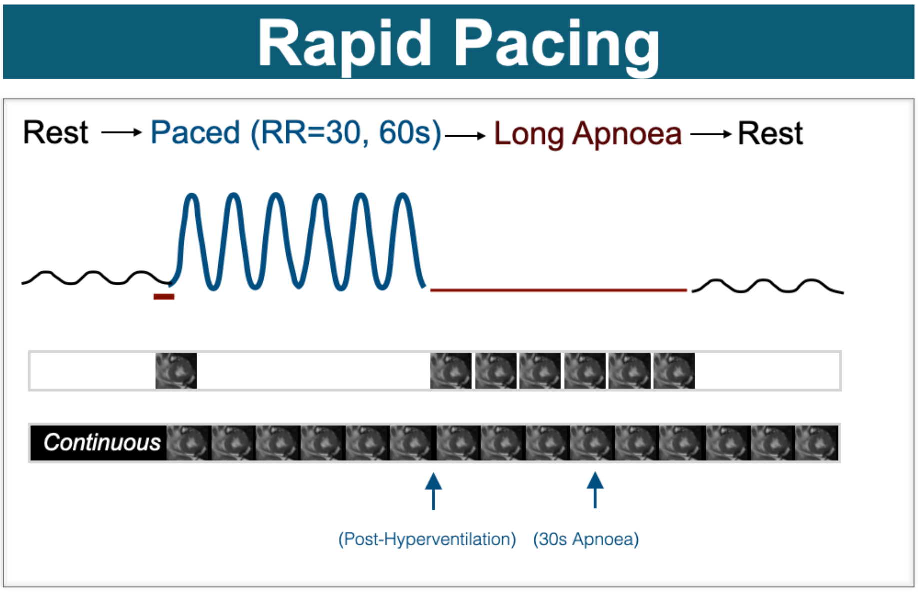
The traditional gold standard breath-hold OS cine ($OS_{bh\text{-}cine}$) was an ECG-triggered balanced steady-state free precession sequence acquired during end-expiratory breath-holds (echo spacing/echo-time 3.4ms/1.70ms, resolution time 40.7ms, flip angle 35°, voxel size 2.0x2.0x10.0mm^3, matrix 192x120, bandwidth 1302Hz/Px).

The free breathing single shot sequence ($OS_{fb\text{-}ss}$) was an ECG-triggered TrueFISP sequence set with a trigger delay of approximately 350-500ms depending on heartrate to target the acquisition window during the diastasis of diastole (echo spacing/echo-time 3.9ms/1.94ms, resolution time 450-475ms, flip angle 52°, voxel size 1.4x1.4x6.0mm^3, bandwidth 592Hz/Px).

The free breathing real-time cine sequence ($OS_{fb\text{-}rtcine}$) was an ECG-triggered TrueFISP set to acquire data continuously triggered at the first R-peak (echo spacing/echo-time 2.8ms/1.24ms, resolution time 49.8, flip angle 45°, voxel size 2.5x2.5x8.0mm^3, bandwidth 1260Hz/Px, acceleration factor GRAPPA 3).

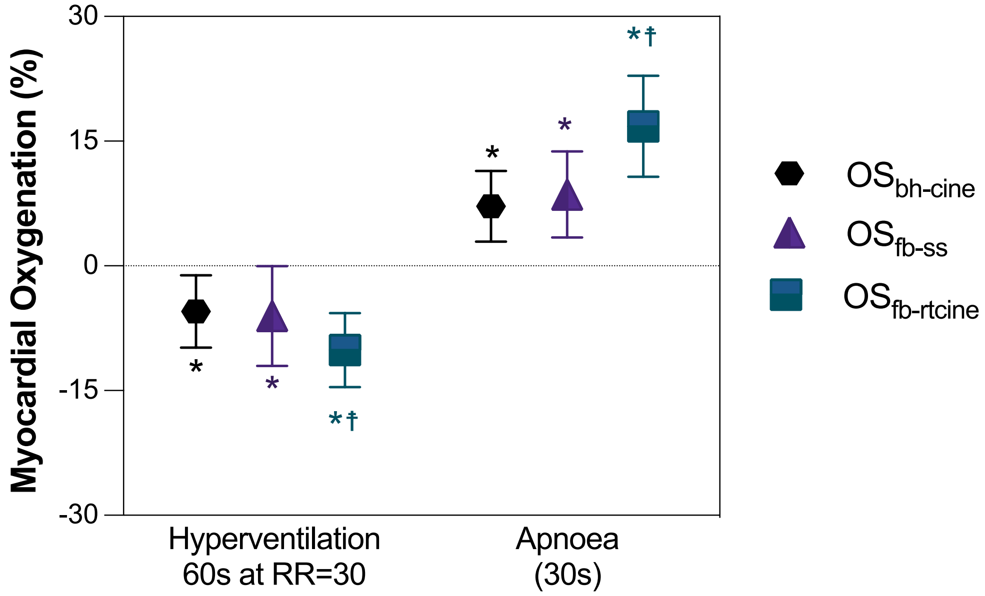
All analysis was performed with cvi[42] (version 5.14, Circle Cardiovascular Imaging, Calgary, Canada).

Supplemental Figure 1: Rapidly Paced Breathing Protocol



This additional breathing manoeuvre was performed for further validation purposes of the free-breathing sequences, as this manoeuvre was used in multiple previous studies. It varies from the anaesthesia induction-like breathing sequence performed in this study by a shorter hyperventilation sequence (60s vs. 150s + 5 deep breaths) at a higher rate (30 vs. 14 breaths per minute). Participants were instructed to follow the breathing patterns depicted in the figure with paced breathing guided by a metronome. Apnoea was performed at end-expiration and held for up to 60s if possible. The traditional gold-standard sequence required acquisition during a breath-hold and could only be obtained during periods of apnoea, while the free-breathing sequences acquired data continuously (black bars). RR= respiration rate.

Supplemental Figure 2: Myocardial Oxygenation Changes from Rapidly Paced Breathing Protocol

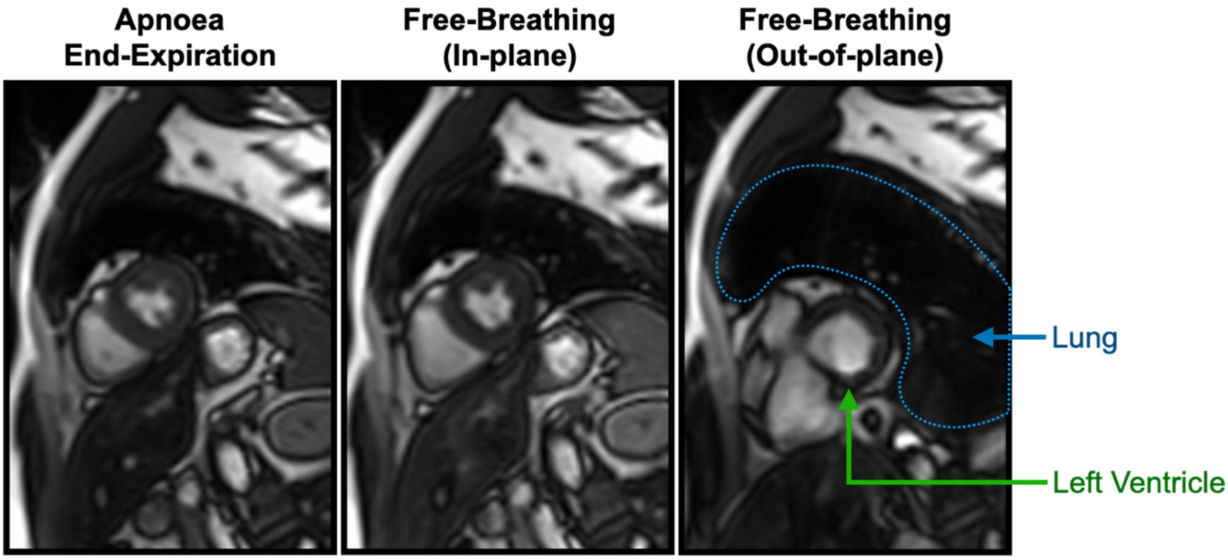


Mean (standard deviation) responses in myocardial oxygenation are shown for all three sequences, the gold-standard breath-hold sequence ($OS_{bh\text{-}cine}$), and the two new free-breathing sequence variants ($OS_{fb\text{-}ss}$ & $OS_{fb\text{-}rtcine}$). With both hyperventilation at a respiration rate of 30, a reduction in myocardial oxygenation was observed, while apnoea from both procedures increased myocardial oxygenation.

*indicates a significant change ($p<0.05$) in myocardial oxygenation for the stage

†indicates a significantly different response ($p<0.05$) in comparison to the gold-standard sequence ($OS_{bh\text{-}cine}$)

Supplemental Figure 3: Image Selection of Free-Breathing Sequences



Frames at end-systole demonstrate the movement of the heart through the fixed imaging plane. During apnoea when there was no chest movement, all images were analysed. For consistency, during the free-breathing period only images when the heart was in a similar plane to apnoea were analysed. For example, in the right panel during a deep inspiration the heart was in a different plane than the first two images, resulting in the outflow tract being in the image rather than the middle of the ventricle. Typically, images were analysed at minimum once per five heartbeats, often resulting in less than 5s between data points.

Supplemental Text: Sample Size Justification

As this was the pilot study to test the sequences, no preliminary data concerning the signal intensity of the free-breathing sequences was available. Thus, sample size was justified to a sample size of 32 based on related healthy control publications rather than calculated. A post-hoc power analysis was calculated for the primary time-point (30s apnoea during the breathing protocol simulating anaesthesia induction). With the free breathing single shot sequence including 29 patients (due to an exclusion of n=3) yielded a post-hoc calculated power (β) >0.99, when accounting for an alpha of 0.05 and a paired mean difference of 8.4±5.6%. A second calculation for the free breathing realtime cine showed a sample size of 12 yielded a post-hoc calculated power (β) of 0.99, when accounting for an alpha of 0.05 and a paired mean difference of 15.7±10.0%.