



An Introduction to ECG Gating for Cardiac MRI

Part 3: K-space Segmentation in cardiac MRI

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Keywords: ECG, gating, triggering, k-space segmentation

Introduction

When acquiring cine images we break the cardiac cycle up into cardiac phases to depict a dynamic loop of the beating heart. However, there is not enough time within one heartbeat to acquire all the data required to reconstruct high resolution images for each of these cardiac phases. To overcome this challenge a technique called segmentation is used, where the k-space for each cardiac phase is divided into segments, with each segment being filled over multiple heartbeats (Fig 1). There are also techniques that can fill all of the k-space required within one heartbeat, ie. real-time or single-shot techniques, however this is achieved at the cost of reduced spatial and temporal resolution.

Main Body

There are a few parameters and terms that it is important to understand in relation to k-space segmentation.

Cardiac Phases

The number of images or frames the cardiac cycle is split into for the cine sequence, typically between 20-30. For retrospectively gated cine sequences this can be more accurately thought of as “acquired phases”, ie what the scanner actually acquires, and “calculated phases” what is reconstructed by the scanner after interpolation of the data. Generally, calculated phases are used so that there is a consistent number of cardiac phases for all the cine imaging performed during the exam rather than varying due to changes in the patient’s heart rate or the acquisition matrix.

Temporal Resolution

This is time between successive cardiac phases. It is recommended that this is kept $\leq 45\text{ms}$ to reduce cardiac blurring (Fig 2). The temporal resolution is controlled by the number of view-per-segment selected.

Views-per-segment

Views-per-segment (VPS), or “Segments” on the Siemens platform, refers to the number of k-space lines acquired for each cardiac phase per heartbeat. This parameter is intimately related to the temporal resolution (Fig 2) and breath-hold duration when acquiring a cine sequence. If you increase the VPS it will acquire more k-space lines each cardiac phase, which will take longer and therefore reduce the temporal resolution.



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Conversely, reducing the VPS will improve the temporal resolution but increase the breath-hold duration.

Matrix size

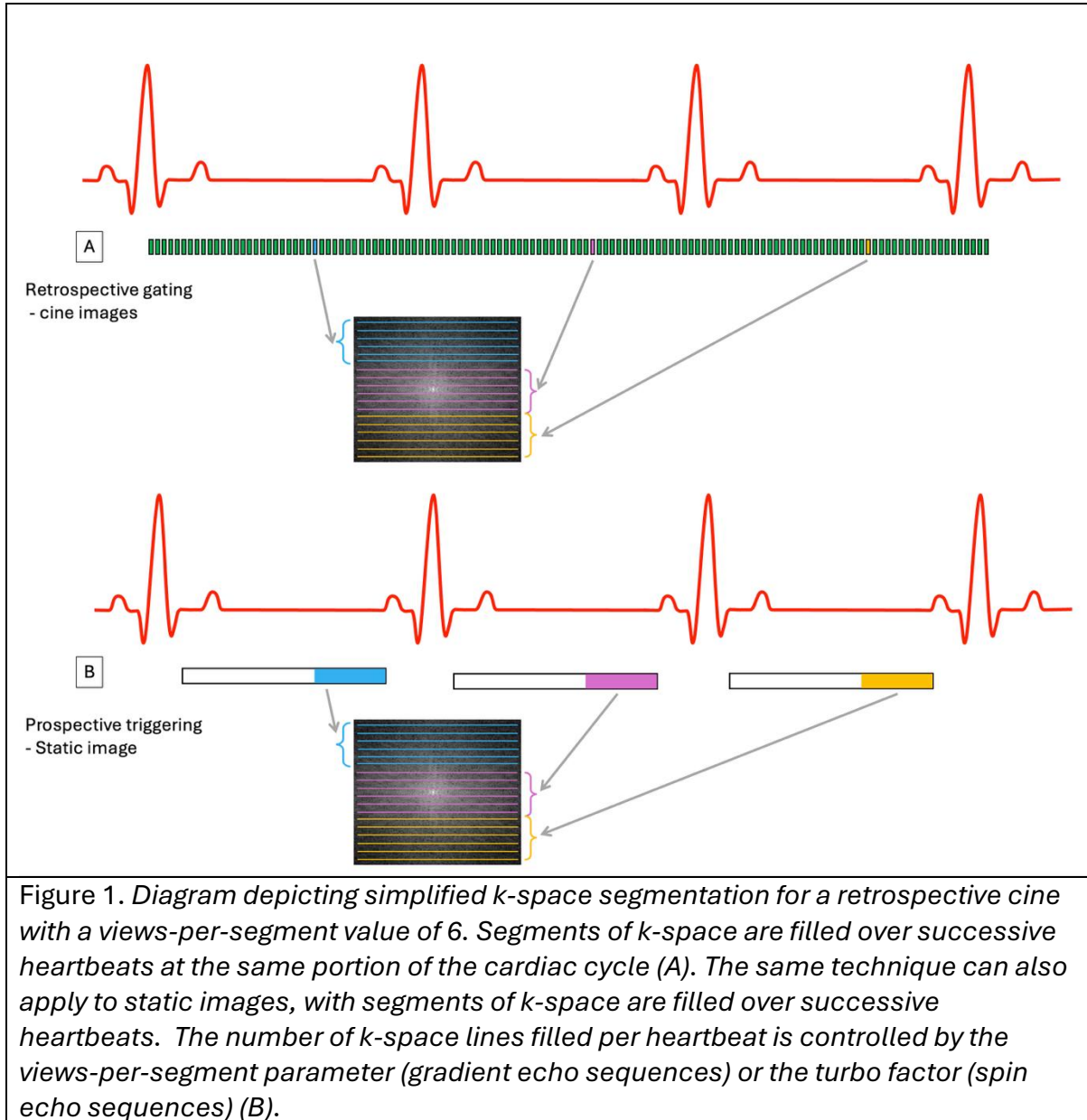
Increasing the spatial resolution of the sequence means more k-space lines need to be acquired for every cardiac phase. If the VPS remain the same then it will take more heartbeats to acquire all the data, and thus there will be a longer breath-hold for the patient.

Heart rate

Once the VPS have been set, the scanner then calculates how many heartbeats are required until all the of the k-space for each cardiac phase is filled. So if a patient has a low heart rate (bradycardia) each heartbeat will take longer and the breath-hold will be longer. The opposite is also true, for a patient with a high heart rate (tachycardia) it will take less time for the same number of heartbeats and the breath-hold will be shorter.

Conclusion

k-space segmentation synchronised with the patient's ECG allows us to achieve high resolution cine and static images within one breath-hold. Understanding the relationship between the views-per-segment, temporal resolution and acquisition duration is important for achieving high quality diagnostic images whilst maintaining a reasonable breath-hold duration for the patient.



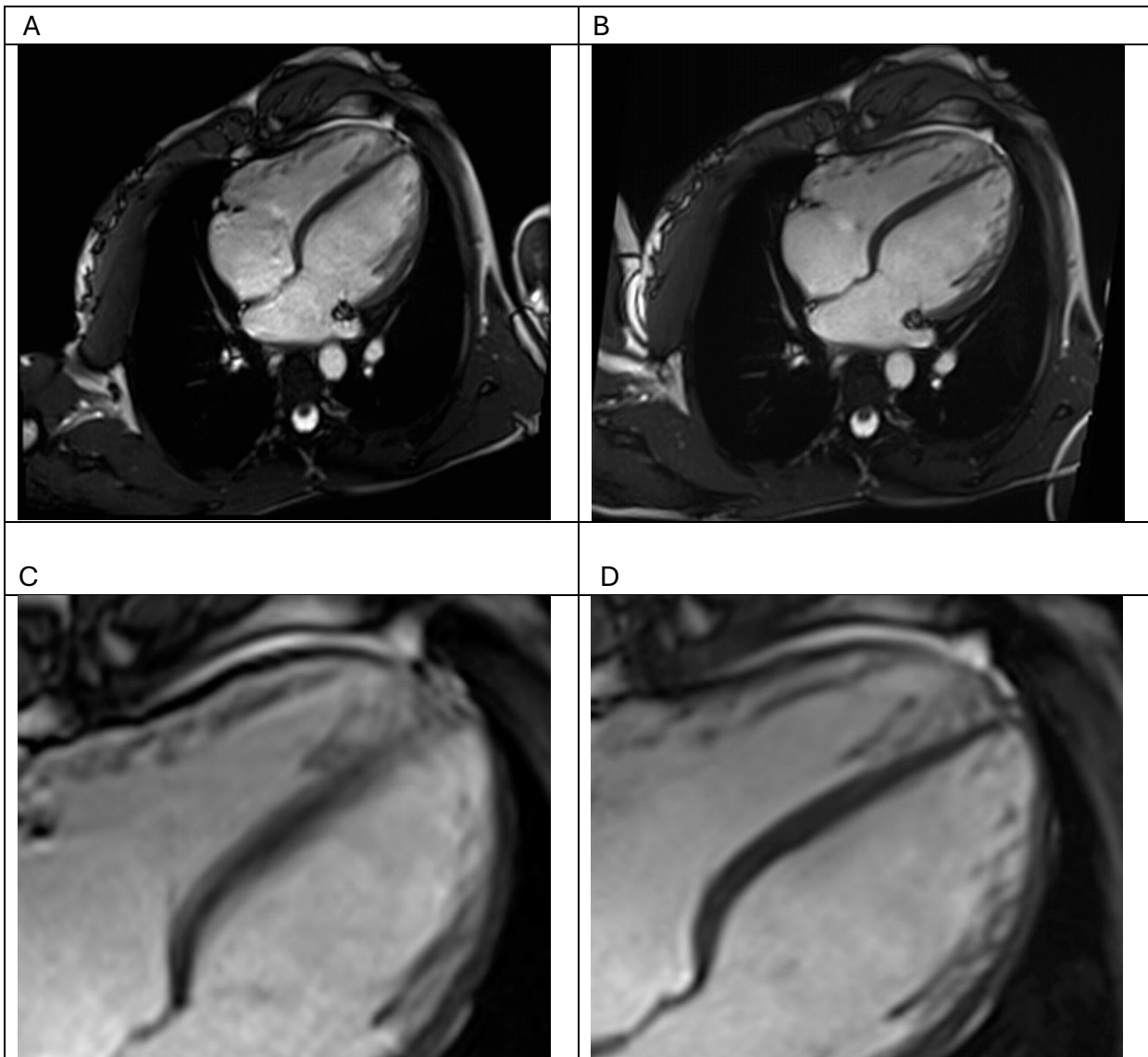


Figure 2. Retrospectively gated cine with poor temporal resolution caused by having too many views-per-segment (A), a zoomed up still from this same series shows the temporal blurring in the septum and trabeculation (C). The same sequence then repeated after reducing the views-per-segment and thus improving the temporal resolution (B), a zoomed up still from this series shows a marked improvement in image sharpness (D).



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Further Resources

EACVI Cardiovascular Magnetic Resonance - Physics for Clinicians Pocket Guide
David Broadbent, Ananth Kidambi, John Biglands

<https://www.escardio.org/static-file/Escardio/Subspecialty/EACVI/CMR%20Physics%20Pocket%20Guide%20iBook%20v1.0.pdf>



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