Can heart strain predict death of patients with end-stage kidney disease?

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Introduction

Patients who have severe kidney disease have difficulty removing toxic waste products from the body. The condition is often fatal, with patients frequently suffering and dying from heart disease. We believe the heart disease is due to adaptations in the structure of the heart itself, where two of the four chambers of the heart, the ventricles, enlarge, and heart muscles become less elastic and less powerful (see Figure 1 for a labelled illustration of the heart). This is also thought to affect the electrical activity in the heart, leading to unreliable signalling in the heart and sudden death.

We are specifically interested in how the right ventricle is affected in individuals with kidney disease. This is because patients with kidney disease often require dialysis, where blood is removed from the body, filtered using a machine, then redirected back into the body, exposing the right ventricle to stress and consequential structural changes.

We wanted to use a non-invasive imaging technique, called cardiac magnetic resonance imaging (MRI), to measure these changes in the heart and relate them to the risk of death in patients with end-stage kidney disease. Specifically, we wanted to assess the ability of the heart to stretch and pump blood to the body and find out whether the right ventricle can tell us more about the risk of heart disease in these patients than just looking at the left ventricle alone.

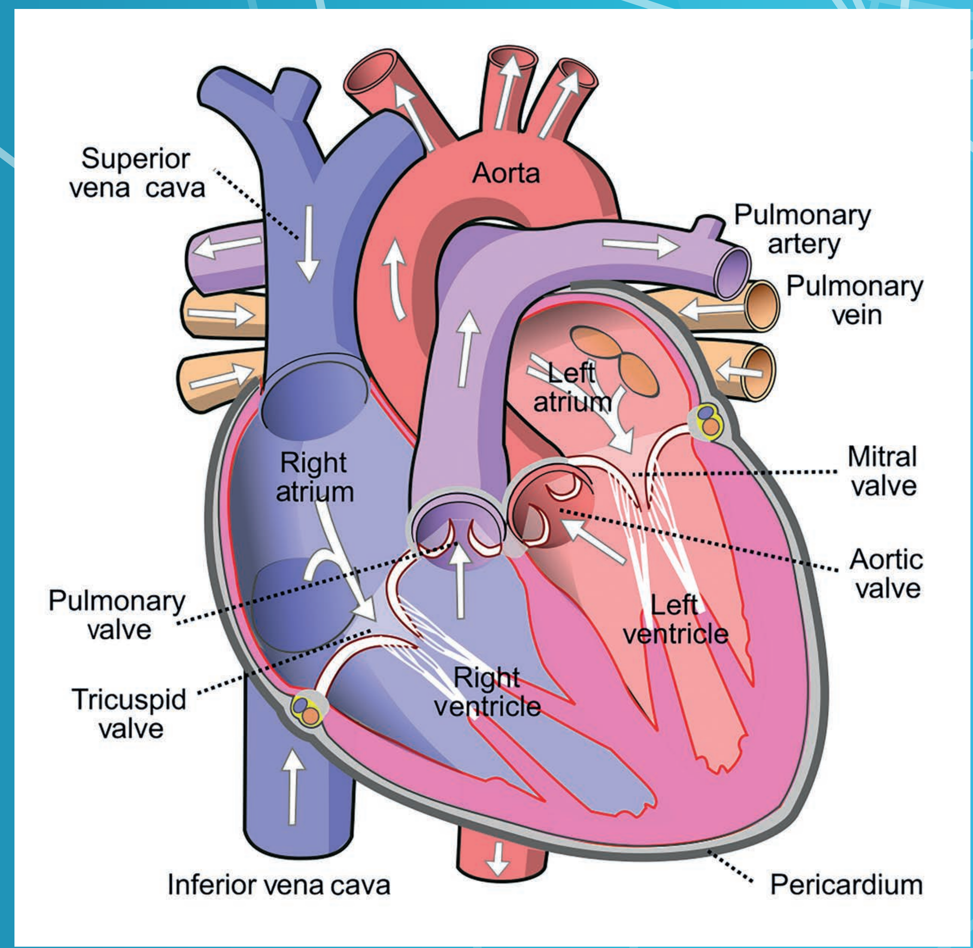

Figure 1 Diagram of the human heart, showing the ventricles (chambers which help pump blood to the body), and the atria (chambers which help fill the ventricles). Credit for image: Author: Wapcaplet from Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Diagram_of_the_human_heart_(cropped).svg#Licensing; Reproduced under GNU Free Documentation License https://commons.wikimedia.org/wiki/Commons:GNU_Free_Documentation_License,_version_1

What did we do?

We analysed MRI images of the heart from 237 patients with end-stage kidney disease. When the heart pumps blood around the body it goes through a cycle of two phases: the chambers contract to pump blood out of the heart (called systole) and then relax, when the heart refills with blood (called diastole). We assessed all 4 chambers of the heart, the atria and ventricles, through one cycle using high tech feature tracking software to measure the size of the chambers and the strain the heart experienced (see Figure 2). These included atrial and ventricular ejection fractions, which is the percentage change of blood in the cavity of the heart between the systole (contraction) and diastole (relaxation) phases.

We used statistical modelling with other patient characteristics that we know have an impact on whether a patient dies (such as age, gender, and existing medical conditions) in combination with our MRI measurements to assess whether we can predict the likelihood of a patient dying.

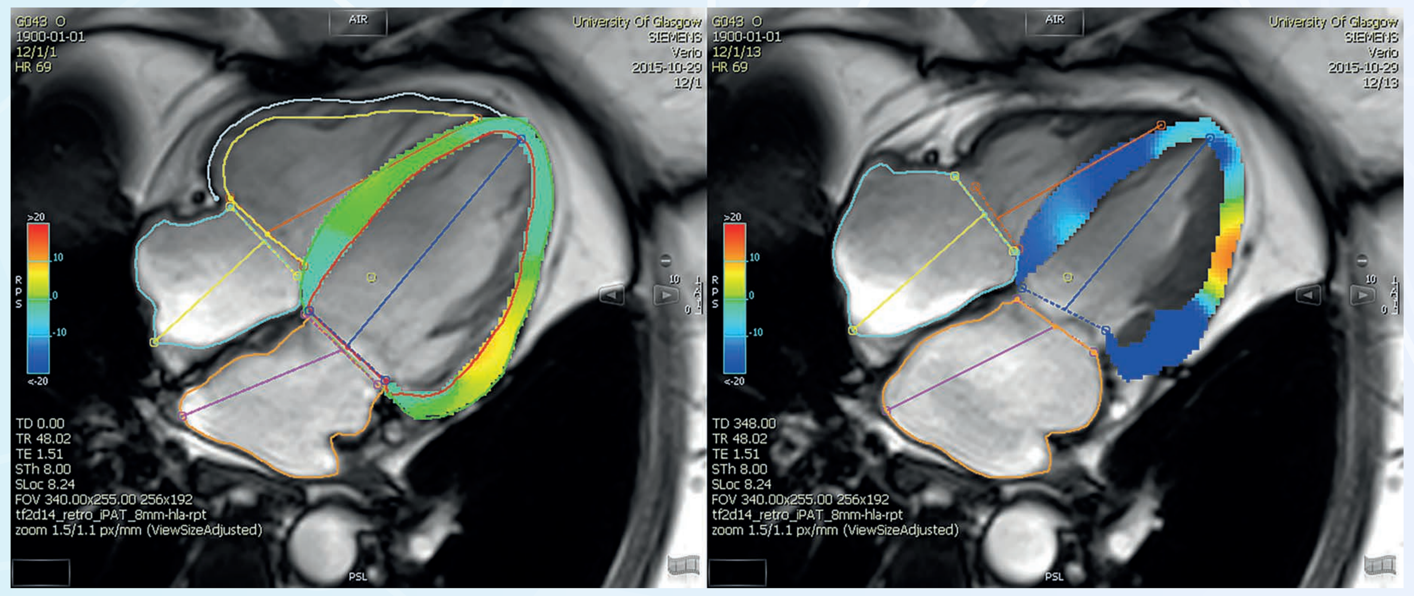

Figure 2 Images of MRI scans showing ventricular strain during diastole (left image) and systole (right image) measured using the feature tracking software. Areas highlighted in blue represent heart muscle that is under the greatest contraction, whereas areas in green and yellow show areas of less contraction (possibly heart muscle that is less healthy).

What did we find?

We found a significant statistical association between the MRI measures of strain with the likelihood of dying in these patients. We developed statistical models which included three variables: age, left atrial ejection fraction (see Figure 3), and left ventricular strain (see Figure 4).

Our measurements from the right ventricle were promising and did demonstrate an association with death, but we found a lot of variability between the measurements taken by different individuals.

Other measures that previous researchers had shown to be associated with death, such as the ventricular mass, and the volume of the chambers during relaxation did not correlate with death in our study after considering the effects of strain.

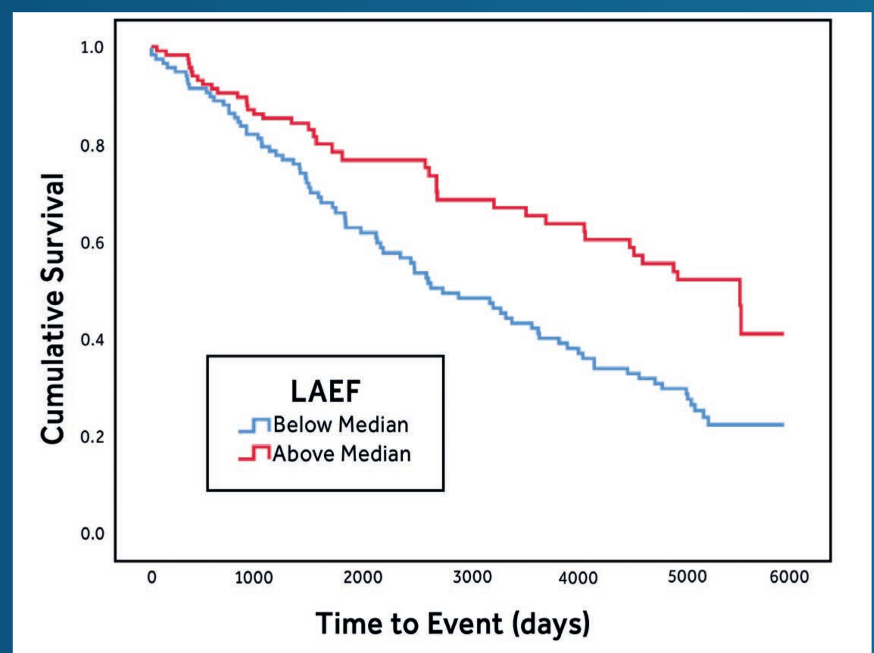

Figure 3 Kaplan-Meier graph which compares left atrial ejection fraction (LAEF) with survival. The red line illustrates the survival of the group with highest 50% LAEF, whereas the blue line represents the worst 50%. At 5000 days, around half of those in the red group were still alive, compared to under 30% for the blue group. The Kaplan-Meier graph is a way used to illustrate events that occur over time. It can be helpful in informing the reader when events are most likely to occur after a certain event.

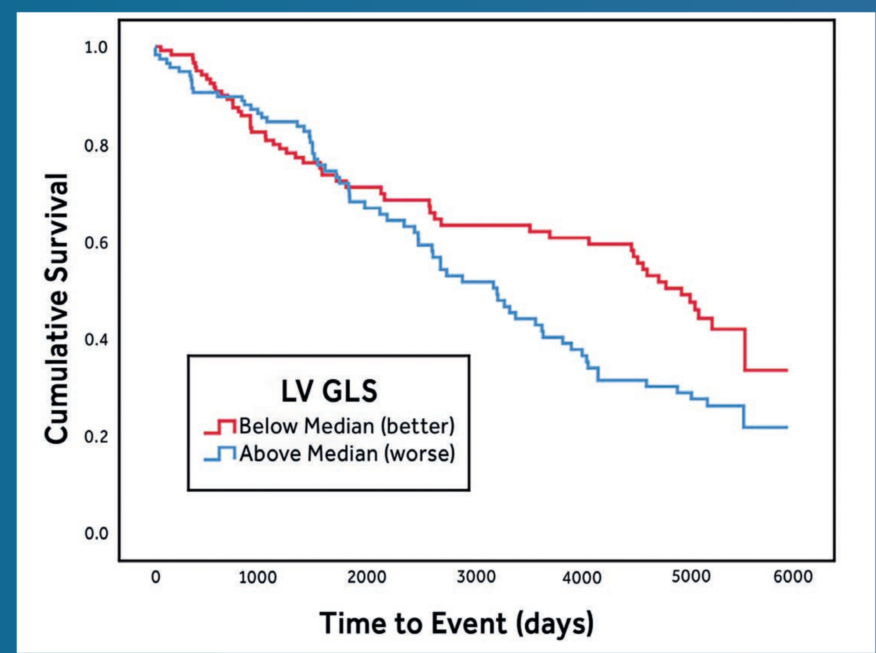

Figure 4 Kaplan-Meier graph which compares left ventricular strain with survival. The values reported here are slightly more confusing as this is reported as a negative number where a lower (more negative) number is better than a higher (less negative) number. Individuals with "better" strain (red) survive longer than those with "worse" strain (blue).

What does this mean?

The measures we took of left atrial ejection fraction and left ventricular strain likely inform us of the condition of the heart. A lower left atrial ejection fraction was associated with worse outcomes. A suggested mechanism for this involves dilation of the atria due to increasing back pressure from the ventricles, which results in a stretching effect, like an inflated balloon. This dilated atrium is then less elastic and provides less pumping force to the ventricles.

As for the ventricles, lower strain is associated with increased likelihood of death. This may be due to changes within micro-vessels in the heart muscle causing ischaemic (shortage of oxygen due to reduced blood flow) changes in combination with increasing stiffening of the muscle – which reduces the ability of the ventricles to stretch and fill in the limited time the heart has during a cycle before contracting.

Who am I?

I am a 4th year medical student at the University of Glasgow and I have recently completed my Intercalated degree in Cardiovascular Studies. I undertook this Medical Research Scotland Vacation Scholarship in June 2019 under the supervision of Dr Alastair Rankin, which allowed me to work with experienced academics at the BHF Cardiovascular Institute and learn MRI analysis from knowledgeable researchers. I am looking to pursue a research career in surgery after completing a PhD.

Luke was supervised during his Vacation Scholarship project, *"Study of right ventricular volumes by feature tracking cardiac magnetic resonance Imaging in patients with chronic kidney disease"*, by Dr Alastair Rankin at the University of Glasgow.