

## 8 Reproducibility of Kidney Volume Analysis in Renovascular Disease

### 1 Introduction

It is common practice for contrast enhanced MRA to be used for anatomical assessment of renal artery stenosis (RAS) in patients with renovascular disease 1. A functional assessment of renal tissue can also be obtained by using contrast enhanced MR Renography (CE-MRR), where a small bolus of contrast agent is tracked over time as it travels through the renal vasculature and perfuses into the kidney cortex 1.

CE-MRR is a technique by which it is possible to monitor renal cortical perfusion, and hence obtain an understanding of kidney function. Indices of perfusion can be obtained by measuring the magnitude and time course of cortical contrast enhancement through a 3D dynamic post-contrast MR dataset, and such measurements have been shown to correlate with the degree of renal artery stenosis as measured by MRI 1. The objective of this ongoing study is to establish whether renal perfusion measurements from MRI mirrored expected trends associated with previous history of cardiovascular disease, clinical measurements of renal function, and associated cardiovascular risk factors in a cohort of patients with renovascular disease (RVD) 2.

My role in the study was to determine cortical and total volumes for all kidneys and to perform inter- and intra-observer comparisons to determine the accuracy of this approach.

### 2 CE-MRA Data Acquisition

Fifty-five consenting patients with RVD were recruited for MR imaging. CE-MRA was performed for each patient using the methods described in section 6.2.2.4. The second post-contrast (early venous phase) 3D FLASH images were used to generate the cortical and total kidney volumes.

Prior to analysis, each kidney was graded into one of three categories defining the severity of RAS (as viewed on arterial phase source images and MIP data). Thirteen renal arteries were graded as 'minimal' (0-30% stenosis), ten were graded as 'moderate' (31-70% stenosis) and seventeen were graded as 'severe' (71-100% stenosis). The reason for grading the arteries was to also determine whether volume reproducibility was dependent on the severity of RVD.

### 3 Data Analysis

Post-processing was performed using Numaris® 3.5 software (version 3A13E, Siemens Medical, Erlangen, Germany). Cortical and total volumes of each kidney were measured. Patient data was transferred from the local PACS system onto a Virtuoso workstation for post-processing. Each 3D FLASH sequence consisted of 56 individual coronal images. The software algorithm used to determine the volumes was based on signal thresholding. A sliding control on the screen was adjusted up or down to highlight the cortical or total volume on each image. Care was taken to ensure that only relevant parts of the kidney were included and that cysts were excluded from the total volumes. 'Add' and 'Cut' tools were available in the software to enable accurate definition of the volume. Once the correct volume (as determined by the observer) was determined, the software calculated the volume via pixel counting. When all pertinent images in the FLASH sequence were defined in this way, the software summed the defined areas for each slice to give a total value after multiplying by the slice thickness. The software also generated a 3D render of the kidney that was composite of the individual slice volumes as defined by the observer.

4 Data Recording

Data on cortical and total volumes for both kidneys of each patient were recorded and statistically analysed. For each kidney, the left and right cortical and total volumes were noted. In addition, the resulting 3D images depicting the volumes were individually stored in the workstation and a record was kept of the slices used to determine the volumes.

5 Interobserver reproducibility

A cohort of 28 patients was examined for interobserver reproducibility that is each kidney was evaluated independently by two observers. Figure 8-1 below shows the interobserver difference for the right cortical volume for the same patient.

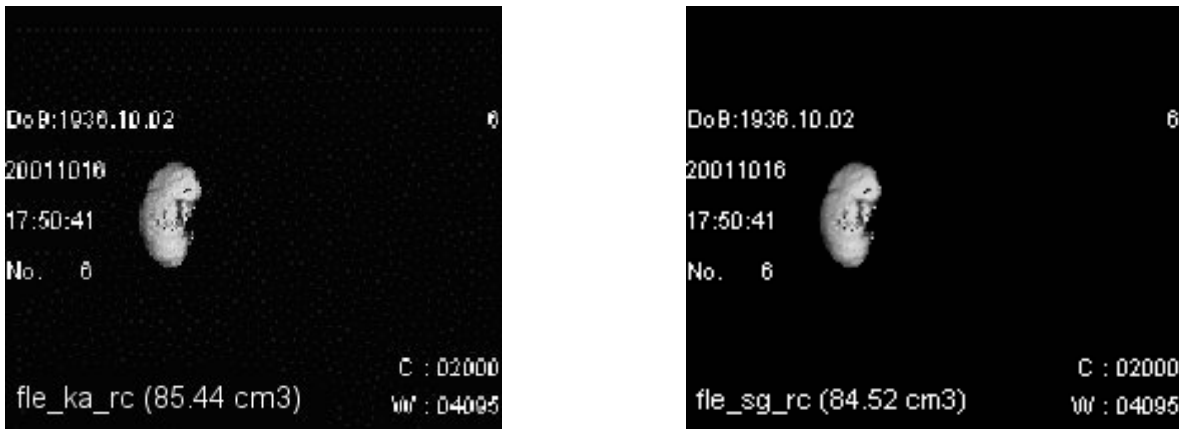


Figure 8- 1: Interobserver reproducibility in right kidney cortical volume measurement. The difference (coefficient of variation – CoV) is 1.09%.

Figure 8-2 below shows the interobserver difference for the right total volumes for the same patient.

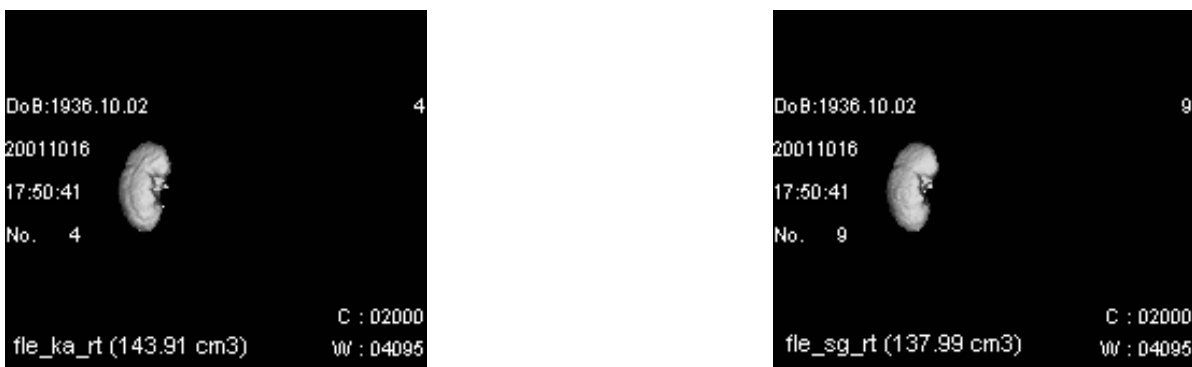


Figure 8- 2: Interobserver reproducibility in right kidney total volume measurement. The CoV is 4.29%.

6 Intraobserver reproducibility

The same cohort of patients were examined for intraobserver reproducibility that is, each kidney was evaluated twice by the same observer. Figures 8-3 below shows the intraobserver difference for the left cortical volumes for the same patient.

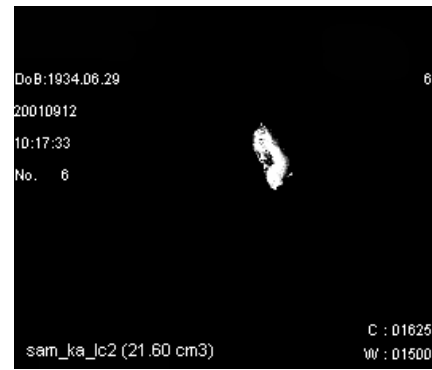
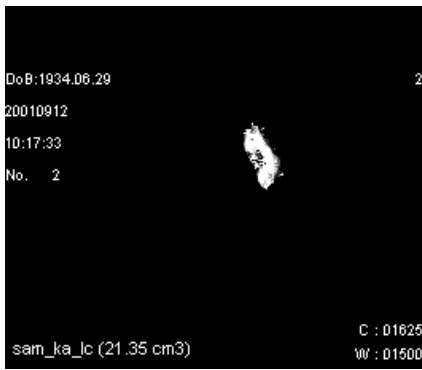


Figure 8- 3: Intraobserver reproducibility in left kidney cortical volume measurement. The CoV is 1.17%.

Figures 8-4 below shows the intraobserver difference for the right total volumes for the same patient.

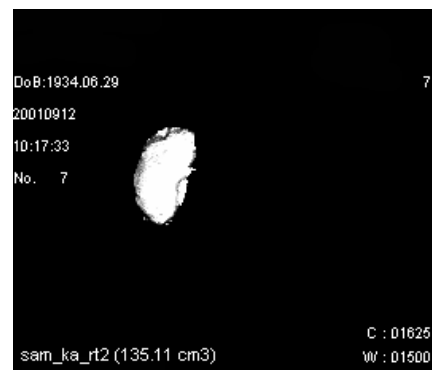
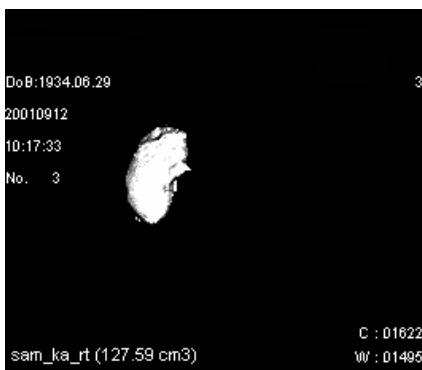


Figure 8- 4: Intraobserver reproducibility in right kidney total volume measurement. The CoV is 5.89%.

7 Summary of Findings

The inter- and intra-observer reproducibility was determined for all kidneys then the data was filtered to show the reproducibility for each grade of RVD. The results are summarised in figure 8-5 below. KACV1 and KACV2 represent the values obtained by myself for the cortical volumes when I analysed the dataset twice. Similarly, KATV1 and KATV2 represent the values obtained by myself for the total volumes. SGCV1 and SGCV2 represent the values obtained by a second observer for the cortical volumes. The results show that there was a close correlation in inter- and intra-observer reproducibility for both group 1 (minimal RVD) and group 2 (moderate RVD) for both cortical and total volumes. This was not the case for group 3 (severe RVD) and in this group the divergence in the inter-observer total volumes was greater than for groups 1 and 2.

	KACV1	KATV1	KACV2	KATV2	SGCV1	SGTV1	
<b>ALL</b>	MEAN	66.72	125.96	65.85	127.71	65.77	127.91
	SD	40.24	54.73	37.53	56.94	35.45	55.85
	SE	5.48	7.45	5.11	7.75	4.82	7.60
<b>Group 1 (Minimal)</b>	MEAN	85.77	132.53	86.97	132.45	87.52	135.66
	SD	31.28	41.57	29.96	41.61	30.07	40.86
	SE	7.37	9.80	7.06	9.81	7.09	9.63
<b>Group 2 (Moderate)</b>	MEAN	85.87	145.33	86.56	146.83	86.31	148.73
	SD	40.18	50.36	36.96	49.41	37.64	53.14
	SE	9.47	11.87	8.71	11.65	8.87	12.52
<b>Group 3 (Severe)</b>	MEAN	49.17	87.21	48.38	86.51	50.77	90.55
	SD	26.97	54.42	27.26	54.53	29.78	53.62
	SE	6.36	12.82	6.42	12.85	7.02	12.64

Figure 8- 5: Inter- and Intra-observer Reproducibility for ALL Patients

8 Findings based on CoV

CoV SUMMARY GRID	Intra Cort	Intra Total	Inter Cort	Inter Total
GP1	3.88	2.33	6.07	2.89
GP2	4.96	2.13	5.62	3.92
GP3	3.72	4.06	6.70	6.10
AV(GP1-3)	4.19	2.84	6.13	4.30

Figure 8- 6: Summary of Inter- and Intraobserver Coefficients of Variation (CoV)

Analysis of patient kidney data in Figure 8-6 above showed that average intra- and interobserver coefficients of variation of 4.19% and 6.13% were obtained for cortical volumes, and 2.84% and 4.30% for total volumes respectively.

In addition it was found that intraobserver CoV was always less than interobserver CoV and the total volume was easier to reproduce than cortical volume. Further analysis showed that the total intraobserver measurement for group 2 was the easiest to measure and that the cortical interobserver measurement for group 3 was the most difficult to measure. Interestingly, the cortical volume appeared to be independent of RAS severity and the total volume became more difficult to measure as RAS severity increased.

9 Findings based on Mean volumes

As shown in Figure 8-7 below, it was found that:

- [1] The 'normal' range (GP1) is  $85.77 \pm 7.37$  cm<sup>3</sup> for mean cortical volumes.
- [2] The 'normal' range (GP1) is  $132.53 \pm 9.80$  cm<sup>3</sup> for mean total volumes.
- [3] Patients in the GP3 cohort had the smallest mean cortical and total volumes.
- [4] Patients in the GP2 cohort had the largest mean cortical and total volumes.
- [5] Both cortical and total mean volumes for all patients were smaller for the left kidney.
- [6] Both cortical and total mean volumes were larger in males.

KIDNEY VOLUMES - SUMMARY GRID				
	Cort Mean	Cort SE	Total Mean	Total SE
ALL	73.60	5.04	121.48	7.42
GP1	85.77	7.37	132.53	9.80
GP2	85.87	9.47	145.33	11.87
GP3	49.17	6.36	87.21	12.83
RIGHT	79.33	7.00	129.21	10.22
LEFT	67.87	7.20	113.48	10.74
MALES	75.45	7.49	125.37	10.83
FEMALES	71.27	6.36	116.79	9.59

Cortical and Total Kidney Volumes versus Severity of RAS

◆ Cortical Kidney Volumes  
 ■ Total Kidney Volumes

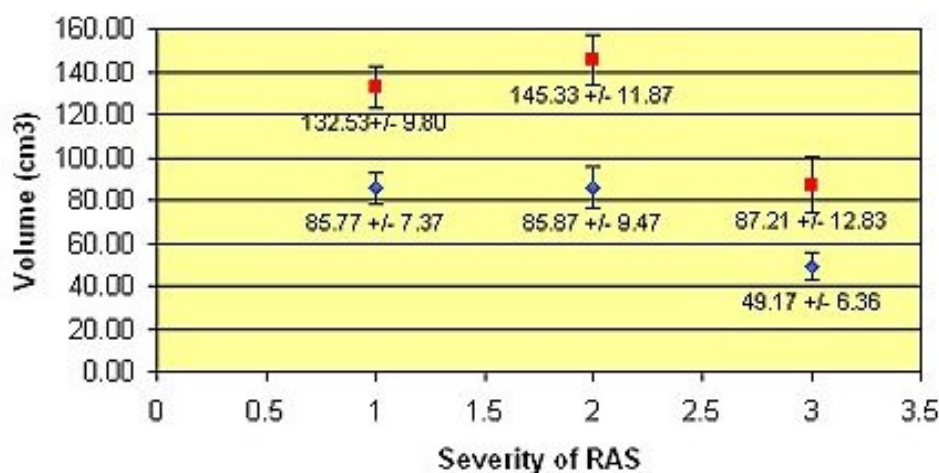


Figure 8- 7: (Top) Summary of Mean Cortical and Total Kidney Volumes. (Bottom) Cortical and Total Kidney Volumes versus Severity of Renal Artery Stenosis

10 Conclusions on Inter- and Intra-observer Reproducibility

Various useful trends were seen in this kidney volume reproducibility experiment. It was found that the mean cortical volume for patients with severe RAS was significantly reduced relative to those with either mild or moderate RAS. Similarly, the mean total kidney volume for patients with severe RAS was also significantly reduced relative to those with mild or moderate RAS. Patients who had one kidney with moderate RAS and an expanded volume

often had a kidney with severe RAS and a reduced volume on the contra lateral side. Regarding reproducibility, it was found that the intraobserver coefficient of variation (CoV) was always less than interobserver CoV. Analysis of patient kidney data showed that the average mean intraobserver coefficient of variation for cortical and total volumes was 3.5% and the average mean interobserver coefficient of variation was 5.2%. While a CoV of < 3% was the desired outcome, the values obtained in this experiment show a high degree of reproducibility.

This study has demonstrated that MRI determined kidney volumes are a valid assessment of true renal volume. It may therefore be more appropriate to use cortical or total kidney MRI volumes as an index of functional renal mass in patients with renovascular disease.

## 11 References

- [1] Gandy S. J., Sudarshan A. P., Sheppard D. G., Allan L. C., McLeay T. B., Houston J. G. Dynamic MRI contrast enhancement of renal cortex: A functional assessment of renovascular disease in patients with renal artery stenosis. *Journal of Magnetic Resonance Imaging* 2003; 18(4): 461-466.
- [2] Gandy S. J., Blackley R., Armoogum K., Sudarshan T., Sheppard D. G., Houston J. G. Assessment of Kidney Length and Volume Using MRI in Patients with Suspected Renovascular Disease. *Nephrology Dialysis Transplantation* 2003; 18(4): 649-650.