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Research paper

Intrarenal fat deposition does not interfere with the measurement of single-kidney perfusion in obese swine using multi-detector computed tomography

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ABSTRACT

Background: Altered vascular structure or function in several diseases may impair renal perfusion. Multi-detector computed tomography (MDCT) is a non-invasive tool to assess single-kidney perfusion and function based on dynamic changes in tissue attenuation during contrast media transit. However, changes in basal tissue attenuation might hamper these assessments, despite background subtraction. Evaluation of iodine concentration using the dual-energy (DECT) MDCT mode allows excluding effects of basal values on dynamic changes in tissue attenuation. We tested whether decreased basal kidney attenuation secondary to intrarenal fat deposition in swine obesity interferes with assessment of renal perfusion using MDCT.

Methods: Domestic pigs were fed a standard (lean) or a high-cholesterol/carbohydrate (obese) diet (n = 5 each) for 16 weeks, and both kidneys were then imaged using MDCT/DECT after iodinated contrast injection. DECT images were post-processed to generate iodine and virtual-non-contrast (VNC) datasets, and the MDCT kidney/aorta CT number (following background subtraction) and DECT iodine ratios calculated during the peak vascular phase as surrogates of renal perfusion. Intrarenal fat was subsequently assessed with Oil-Red-O staining.

Results: VNC maps in obese pigs revealed decreased basal cortical attenuation, and histology confirmed increased renal tissue fat deposition. Nevertheless, the kidney/aorta attenuation and iodine ratios remained similar, and unchanged compared to lean pigs.

Conclusions: Despite decreased basal attenuation secondary to renal adiposity, background subtraction allows adequate assessment of kidney perfusion in obese pigs using MDCT. These observations support the feasibility of renal perfusion assessment in obese subjects using MDCT.

1. Introduction

Multi-detector computed-tomography (MDCT) is a reliable and reproducible non-invasive tool for estimation of single-kidney hemodynamics and function.[1] While *para*-aminohippurate and iothalamate clearance methods quantify renal blood flow (RBF) and glomerular filtration rate (GFR), respectively, of total renal mass (both kidneys), MDCT can quantify them in the single-kidney, which is useful in patients with unilateral or asymmetrical disease.[2]

Thirty percent of Americans suffer from obesity[3] and its implications,[4] including intrarenal fat deposition and kidney disease.[5–7] Accurate non-invasive assessments of kidney function in obese individuals is, therefore, potentially useful. Quantification of renal function using CT relies on time-attenuation curves (TAC) depicting renal transit of iodinated contrast agents. However, because the CT attenuation of fat is within a range of highly negative values, substantial fat deposition may decrease the average opacity in renal regions of interest (ROI), resulting in underestimation of parenchymal attenuation.

To avoid such interference, these background values are commonly subtracted to offset baseline values and compute the rise in CT numbers secondary to contrast media transit. However, background subtraction has several limitations, including susceptibility to imaging artifacts like motion that increase variability of CT numbers (Hounsfield Units; HU), insufficient representative background data-points to average, and subjective selection of these points. Whether background subtraction successfully accounts for a fall in renal baseline attenuation due to fat deposition is incompletely understood. We hypothesized that renal fat deposition would not interfere with assessment of single-kidney

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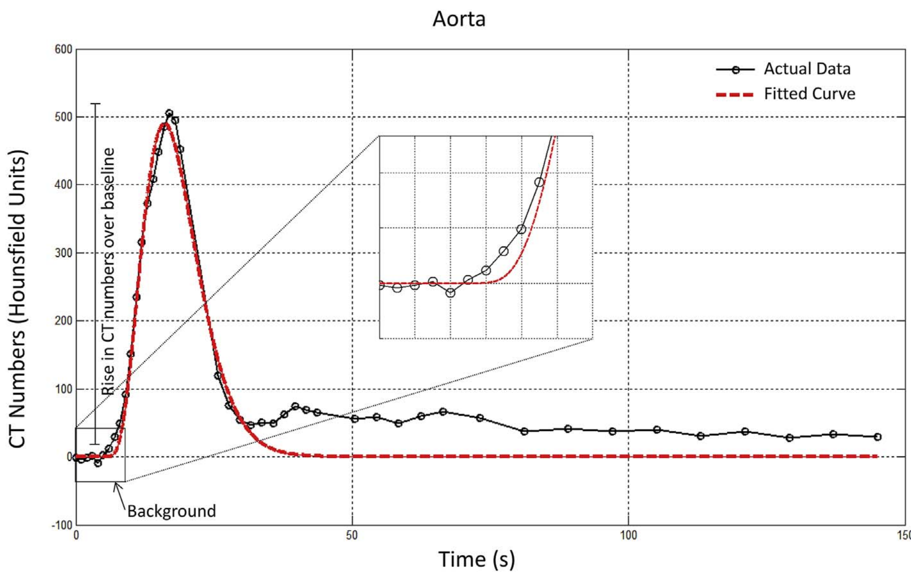

Fig. 1. TAC of aorta showing the background data-points collected, averaged, and zeroed in order to assess a rise in CT number over baseline. Raw data: black; Γ-variate model fitting: red. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Systemic characteristics and renal function at 16 weeks.

Parameter	Lean	Obese
N(kidneys)	5(10)	5(10)
Body weight(Kg)	72.8 ± 10.8	92.1 ± 2.2*
Mean blood pressure(mmHg)	100.4 ± 10.7	126.7 ± 7.8*
Total cholesterol(mg/dL)	83.7 ± 6.8	434.6 ± 79.1*
Total Renal Volume(cc)	137.8 ± 18.6	222.2 ± 20.8*
Cortical Volume(cc)	108.1 ± 17.9	181.2 ± 22.9*
Medullary Volume(cc)	29.6 ± 2.5	41.0 ± 4.2*
Cortical Perfusion(mL/min/cc)	4.0 ± 0.7	4.1 ± 0.5
Medullary Perfusion(mL/min/cc)	2.9 ± 0.9	2.6 ± 1.5
RBF(mL/min)	495.2 ± 50.3	746.9 ± 65.3*
MDCT-GFR(mL/min)	75.8 ± 11.1	144.5 ± 17.0*

*p ≤ .05 vs. Lean. RBF: renal blood flow, GFR: glomerular filtration rate, MDCT: Multi-detector computed-tomography.

perfusion and function using MDCT.

2. Materials and methods

The study was approved by the Institutional Animal Care and Use Committee. Domestic pigs were randomized into two groups (n = 5 each): lean pigs fed a standard chow, and obese pigs a high-cholesterol/carbohydrate diet.[8]

After 16 weeks of diet, MDCT (128-slice SOMATOM Definition Flash, Siemens, Germany) scanning performed to derive standard TAC for renal function with DECT parameters: detector collimation 64 × 0.6 mm, 0 pitch, A and B tubes at 100 kV, 240 mAs and 140 kV (Sn),185 mAs, respectively, and D30f kernel. An iopamidol bolus (0.5 mL/kg/2 s) was injected into a catheter placed in the right atrium after a short delay. Three adjacent 5-mm slices were collected at each of the 140 successive time-points.[1]

DECT images were then acquired to generate iodine and virtual-non-contrast (VNC) datasets from helical scans, using similar

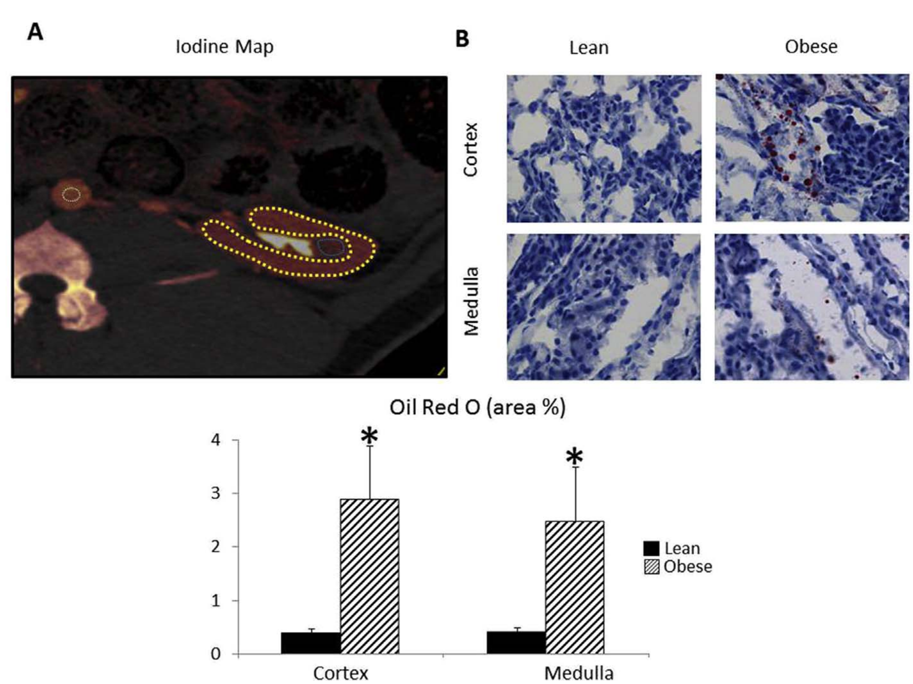

Fig. 2. A: Iodine map depicting ROI in the aorta (white), cortex (yellow), and medulla (blue). B: Oil-Red-O staining indicating deposited fat (red) in obese pig kidneys. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)