

Initial Evaluation of Virtual Histology Ultrasonographic Techniques Applied to a Case of Renal Transplant

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ABSTRACT Ultrasound virtual histology (USVH) techniques have been applied to B-mode images of coronary, carotid, and peripheral arteries and to deep venous thrombosis. We expanded USVH to evaluate the kidney. This case reports USVH applied to a renal transplant. A 29-year-old male with chronic renal insufficiency received his sister's kidney. B-mode images were recorded during (a) routine 1-day posttransplant US examination; and (b) a second follow-up US performed 6 days later once the patient became symptomatic. B-mode brightness of each pixel was classified into 14 ranges. USVH demonstrated high echogenicity of the kidney on day 1; gray scale median, GSM = 60, was elevated when compared with average GSM = 37 for normal, young kidneys. Muscle-like plus fiber-like echoes, $46 + 10 = 56\%$, were higher than expected for a normal young kidney, $34 + 3 = 37\%$ ($p = 0.0071$). GSM increased to 88 on day 7. Normal resistivity indices (RI) on day 1 increased from 0.66–0.70 to 0.81–0.90. Biopsy confirmed kidney rejection. These findings confirmed the concepts that tissue changed before hemodynamics were altered and signs and symptoms developed. Ultrasonographic tissue characterization, particularly of transplanted kidneys, deserves extensive investigation focused on early changes that precede present-day detectable abnormalities.

Introduction

Ultrasonography (US) allows for pixel analysis of B-mode images and estimation of tissue characteristics. Intravascular US has been applied to coronary and carotid arteries in association with angioplasty and/or stent treatment.^{1,2} Transcutaneous US virtual histology (USVH) has been applied to the carotid artery.³

A simplified version using only grey scale median (GSM) analysis has demonstrated that (a) carotid plaque with low GSM has unacceptable risk for embolization and cerebrovascular symptoms during stenting,⁴ (b) peripheral arterial intimal dissection may be directed by plaque GSM,⁵ and (c) acute deep venous thrombosis has low GSM that increases when the thrombus becomes subacute.⁶ USVH, also described as characterization of tissue by ultrasonography (CATUS), has been generalized to include analysis of pixel brightness applied to B-mode images from carotid arteries,⁷ venous and arterial thrombosis,^{8–10} endovascular treated aortic aneurysms,¹¹ lymphedematous legs,¹² normal kidneys,¹³

and, in this particular case, to a transplanted kidney at risk of rejection.

Methods

Patient Characteristics

A 29-year-old male with chronic renal insufficiency received his sister's kidney. Creatinine rose from 4 to 6 and urea from 97 to 135 during the first 6 postoperative days. The patient developed anuria and generalized edema. Biopsy confirmed kidney rejection with tubular-interstitial components.

Ultrasonography

Standard kidney transplant US was performed during routine 1 day post transplant.¹⁴ This examination included evaluation of renal artery and vein anastomoses, kidney size, and resistivity indices (RI). A 2 second follow-up US was performed 6 days later.

B-mode images obtained during the two posttransplant US examinations were submitted to USVH.

US Virtual Histology

Lal's carotid plaque pixel characterization was adapted to kidney analysis (Table 1).³ Pixel brightness

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Table 1

Ultrasound Virtual Histology Applied to B-mode Images of a Transplanted Kidney and Normal Kidneys: Percentage of Pixels by Brightness Intervals

Description	Interval	Percentages			p
		Normal K	TK Day 1	TK Day 7	
Blood	0-4	0.9	0	0.2	>0.34
Blood-fat-like interval	5-7	1.2	0	0.3	>0.27
Fat-like	8-26	25.3	3.7	7.2	<0.001*†
Fat-muscle-like interval	27-40	28.1	17.3	9.1	<0.001†
Hypoechoic muscle-like	41-60	24.6	29.9	15.4	0.014‡
Hyperechoic muscle-like	61-76	9.5	16.3	10.8	>0.15
Hypoechoic muscle-fiber	77-90	4.4	11.3	9.4	>0.069
Hyperechoic muscle-fiber	91-111	3.4	10.6	14.3	<0.05*†
Fiber-like: low level	112-132	1.7	5.1	11.0	0.007†
Fiber-like: mid low level	133-153	0.7	2.6	8.7	0.008†
Fiber-like: mid high level	154-174	0.3	1.4	5.2	0.034†
Fiber-like: high level	175-196	0.1	1.1	4.0	>0.05
Fiber-calcium interval	197-210	0	0.6	2.6	>0.1
Calcium	211-255	0	0	2.3	>0.1
Grey scale median		37	60	88	

TK, transplanted kidney.

Significant differences between *normal and day 1, †normal and day 7, ‡day 1 and day 7.

intervals characterizing blood, fat, and calcium were kept the same. Muscle brightness interval was subdivided into hypoechoic and hyperechoic muscle-like intervals.

Fiber brightness interval was subdivided into four intervals: hypo or low, mid-to-low, mid-to-high and high or hyperechogenic fiber-like intervals. The default

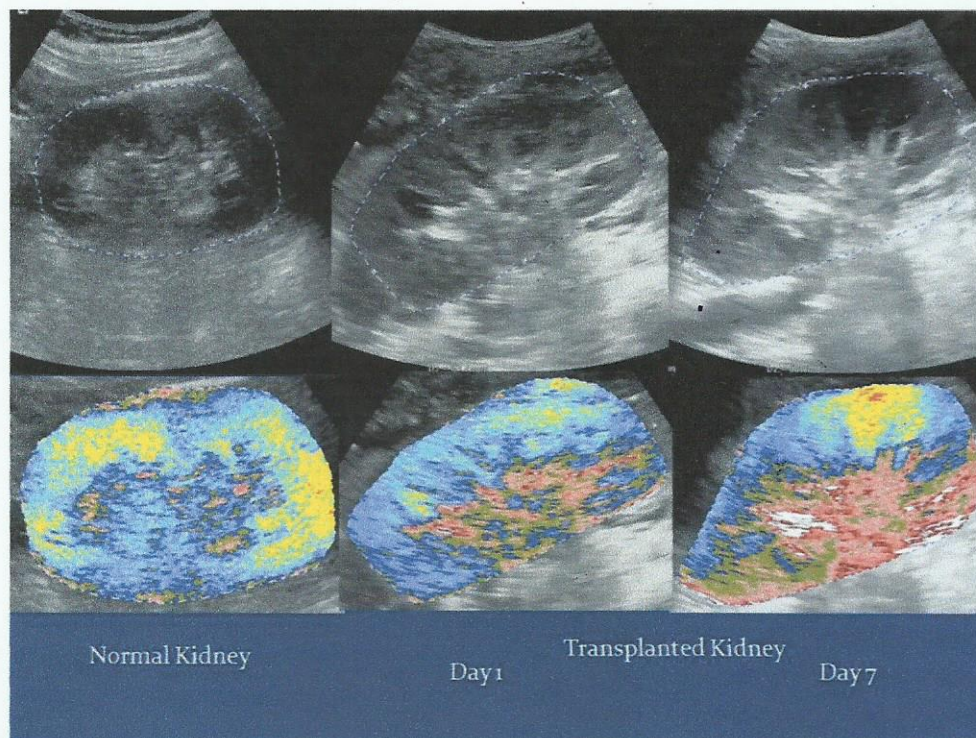


Figure 1

B-mode images and ultrasound virtual histology artificially colorized images of a normal, young kidney and a transplanted kidney evaluated 1 and 7 days post-transplant. Echogenic changes may be related to transplant rejection. Early tissue alterations preceded hemodynamic changes and symptomatology.

brightness interval ranges were redefined for clarity of information into blood-fat, fat-muscle, hypoechogenic muscle fiber, hyperechogenic muscle fiber and fiber-calcium-like intervals. Therefore, 14 ranges of B-mode brightness intervals were characterized with similar ranges without distorting the original objective of blood, fat, muscle, fiber, and calcium characterization proposed by Lal. The new scale, used to standardize images of different origins, was slightly modified to black or blood representing zero and to arterial adventitia or fascia representing 200.

Statistics

Frequencies of various ranges were compared by chi-square test available on Excel. Data from the first and second US examinations were compared with data obtained from a representative normal, young kidney.

Results

Figure 1 shows differences in B-mode images and USHV in days 1 and 7 compared with a normal kidney. Table 1 summarizes the percentage of USVH echo intervals obtained in the first and second examinations, compared with average values obtained for a representative normal, young kidney.

Kidney echogenicity was abnormally high on day 1, as represented by GSM = 60. Echogenicity increased even further on day 7, with a GSM = 88. Frequencies of muscle-like plus fiber-like echoes, day 1, $46 + 10 = 56\%$, were higher than expected for a normal young kidney, $34 + 3 = 37\%$, respectively ($p = 0.0071$). Frequency of fiber-like echoes increased significantly to 29% in 6 days ($p = 0.0011$). Low-echo (0–27) frequencies, 4 and 8% on days 1 and 7, were less than expected, 27% ($p < 0.001$).

Kidney length was 9.7 and 11.7 cm in the first and second US examinations. Resistivity indices at the segmental, interlobar, and arcuate arteries increased from 0.67, 0.66 and 0.70 to 0.93, 0.88 and 0.81, respectively.

Discussion

This case demonstrated that USVH may be a sensitive technique to detect renal transplant rejection. Decrease in fat-like and increase in hyperechogenic muscle-like echoes were already noted on day 1 posttransplant. Decrease in prevalence of low echogenic pixel brightness resulted in a concomitant increase in prevalence of high echogenic pixel brightness. Detection of changes in day

1 apparently showed more sensitivity than the RI. It seemed clear that tissue changes preceded hemodynamic alterations and signs and symptoms. This case suggests that renal USVH, particularly of the transplanted kidney, deserves to be investigated extensively.

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