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# Clinical Values of Studying Kidney Elasticity with Virtual Touch Quantification in Gestational Hypertension Patients

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**Background:** The aim of this study was to investigate the differences in shear wave velocity (SWV) in renal cortex, renal medulla, and renal sinuses between gestational hypertension and normal pregnant women.

**Material/Methods:** Ninety patients with gestational hypertension and 30 women with normal pregnancy were enrolled in this study. Kidney biopsy was performed within 6 weeks to 3 months postpartum to determine the pathological nature of renal injury. According to the classification criteria for gestational hypertension, the patients were divided into 3 groups. Gestational hypertension only patients were classified as Group A; patients with mild preeclampsia as group B; patients with severe preeclampsia as group C; normal pregnant women as a control group. Virtual Touch Quantification technique was used to measure renal shear wave velocity; blood pressure, urine analysis, and renal function were also tested.

**Results:** There was no difference in renal function between patients in group A and the control group ( $p > 0.05$ ), but there was a significant difference in renal function among patients in group A, B, and C, and there was a significant difference in renal function between patients in group B and C versus control ( $p < 0.05$  for all comparisons). There was also a significant difference in SWV values of the renal cortex, renal medulla, and renal sinus between patients in group A, B, and C versus control group ( $p < 0.05$ ).

**Conclusions:** The SWV values of the renal cortex, renal medulla, and renal sinus in patients with gestational hypertension were smaller than those of normal pregnant women, and the more severe the kidney injury, the smaller the SWV value.

**MeSH Keywords:** Hypertension, Pregnancy-Induced • Kidney Concentrating Ability • Virtual Reality Exposure Therapy

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## Background

Gestational hypertension is a disease coexisting with of pregnancy and pregnancy-induced hypertension, and its incidence rate is 9.4% in China [1]. It has been well documented that gestational hypertension, especially with preeclampsia, can cause significant kidney damage [2]. So it is important to develop a non-invasive, yet sensitive technology to precisely assess kidney damage as early as possible in patient with gestational hypertension.

Virtual Touch Quantification (VTQ) technology is a new method for noninvasive assessment of tissue elasticity. It is based on the principle of imaging of acoustic radiation force impulse, where the mechanical deformation characteristics of the tissue are detected by acoustic waves to obtain parameters reflecting the elasticity and stiffness of the tissue. It has been widely used to assess the elasticity of several organs and tissues including pancreas [3], thyroid [4], liver [5], kidney [6], and tendon [7]. However, there has been no report on the use of VTQ technology to assess kidney damage associated with gestational hypertension. The objective of the current study was to assess the feasibility of using VTQ technology to examine the kidney injury in gestational hypertension.

## Material and Methods

### Study subjects

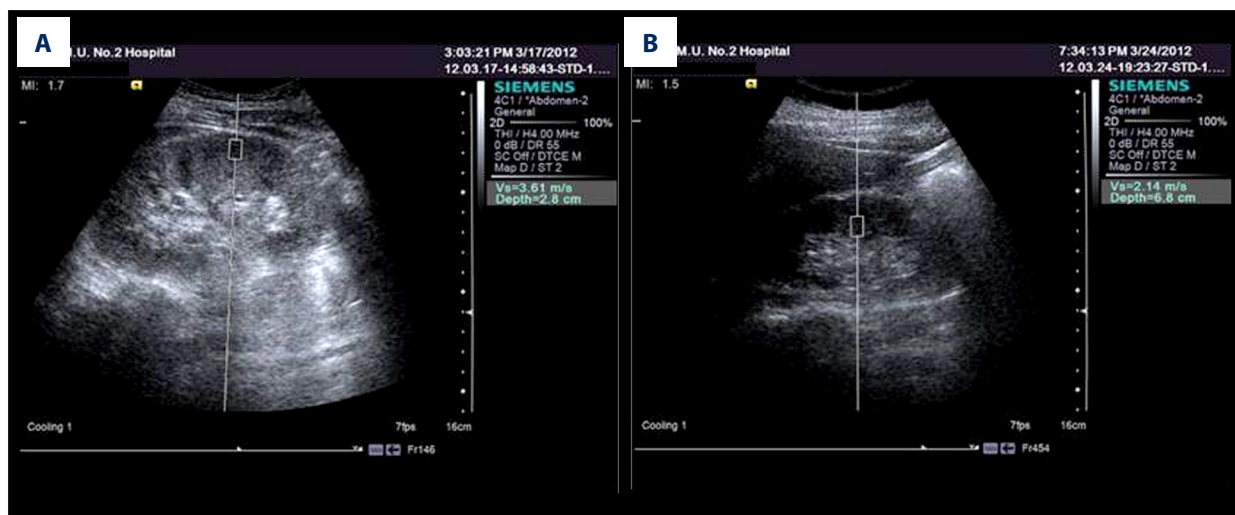
Ninety patients with gestational hypertension patients and 30 women with normal pregnancy were enrolled in this study. The inclusion criteria were: 1) No prior history of gestational hypertension; 2) No prior history of any kidney disease; 3) No

prior history of hypertension; and 4) No complication associated with gestational hypertension. This study was approved by the Hospital Ethics Committee and all patients signed informed consent to voluntarily participate in the study.

Kidney biopsy was performed within 6 weeks to 3 months postpartum to determine the pathological nature of renal injury [8]. According to the classification criteria for gestational hypertension, patients were divided into 3 groups: Gestational hypertension only patients were classified as Group A; patients with mild preeclampsia as group B; patients with severe preeclampsia as group C; and normal pregnant women as a control group. There were 30 patients in each of group. Another 30 healthy pregnant women were recruited as controls.

### Instruments and methods

Siemens ACUSON S2000™ Ultrasound system (Germany), quipped with ultrasound elastography quantitative assessment software and 4C1 probe was used in the study. The study subjects were placed in left lateral decubitus position and renal longitudinal section ultrasound was performed. The ultrasound beam was vertical to the renal capsule and renal maximum horizontal axis was used. The patient took a deep breath and then held the breath; elasticity quantitative measurement mode was started after the image was stabilized. The elasticity coefficient was measured in the renal cortex, renal medulla, and renal sinus using VTQ technology. The measurement was repeated 3 times at each location and the mean value was calculated (Figure 1). For those whose VTQ ultrasound image of epithelia and medulla boundaries was not clear, a location 8 mm under the kidney capsule or a renal sinus area of interest was used for the VTQ ultrasound study. Blood pressure, urine



**Figure 1.** Measurement of kidney injury with VTQ technology in patients with gestational hypertension. (A) Measurement of kidney injury in renal cortex with VTQ technology, SWV 3.61 cm/s, depth 2.8 cm; (B) Measurement of kidney injury in renal medulla with VTQ technology, SWV 2.14 cm/s, depth 6.8 cm.

**Table 1.** Comparison of renal function between patients with gestational hypertension and normal control.

Groups	Creatinine clearance rate (ml/min)	Serum Cr (μmol/L)	Urea nitrogen (mmol/L)	β <sub>2</sub> -microglobulin
Group A (n=30)	110.23±7.45	57.87±10.23	3.49±1.33	0.35±0.09
Group B (n=30)	76.92±10.22*	74.29±11.78*	4.34±0.67*	0.49±0.33*
Group C (n=30)	45.59±9.12*	109±10.54*	5.62±1.43*	0.71±0.22*
Control (n=30)	109.33±8.63	56.98±11.66	3.47±1.02	0.32±0.12

\* p<0.05 compared with control.

**Table 2.** Comparison of renal VTQ results between patients with gestational hypertension and normal control.

Groups	Shear wave velocity		
	Cortex	Medulla	Renal sinus
Group A (n=30)	3.40±0.34	2.34±0.46*	1.14±0.29
Group B (n=30)	3.29±0.41*	2.31±0.37*	1.13±0.26
Group C (n=30)	3.06±0.38*	2.25±0.28*	1.09±0.32
Control (n=30)	3.48±0.45	3.36±0.51	1.15±0.40

\* p<0.05 compared with control.

analysis, and renal function were also measured. Creatinine clearance, serum creatinine, blood urea nitrogen, and β<sub>2</sub>-microglobulin levels were used as references for renal function.

### Statistical analysis

SPSS 15.0 software was used for the statistical analysis. Measurement data were expressed as mean±standard deviation (X±S), and t test was used for comparison difference between 2 groups. Count data are expressed as percentages and χ<sup>2</sup> test was used for comparison of the count data. p<0.05 was taken as statistically significant.

## Results

### Demographic and general characteristics of the patients

A total of 120 pregnant women with no previous history of high blood pressure, kidney disease, diabetes, or cardiovascular disease were recruited in this study. Ages ranged from 22 to 38 years, with mean age (32.2±3.8) years. There was no significant difference in terms of age, gestational age, or medical history among all groups (p>0.05).

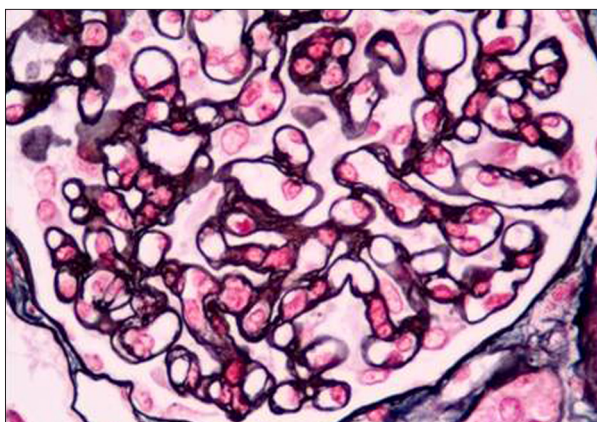
### Blood pressure and renal function of the patients

In Group A, systolic blood pressure was 149.3±4.21 mmHg, diastolic blood pressure is 98±5.10 mmHg, proteinuria is

negative; in Group B, systolic blood pressure was 156.7±3.36 mmHg, diastolic blood pressure was 105±3.84 mmHg, proteinuria was positive (+); in Group C, systolic blood pressure was 167.27±4.9 3mmHg, diastolic blood pressure was 114±2.67 mmHg, proteinuria was strongly positive (++ ~ ++++); in the control group, systolic blood pressure was 107±8.24 mmHg, diastolic blood pressure was 78±9.46 mmHg, and proteinuria was negative. There were no significant differences in terms of blood pressure, urine protein, or renal function between group A and controls (p>0.05, Table 1). However, there was a significant difference in renal function between group B and C versus control (p<0.05, Table 1).

### Shear wave velocity in renal cortex, renal medulla, and renal sinuses of patients

There was a significant difference in shear wave velocity at different parts of the kidney between Group A, B, and C versus control group (p<0.05, Table 2). The SWV values of renal cortex, medulla, and sinus in patients with gestational hypertension were gradually reduced with severity of the disease compared with that of normal pregnant women, as was the elasticity of the kidney; the more severe the kidney injury, the smaller the SWV value. Kidney biopsy was performed in the lateral parenchyma of the center of the kidney within 6 weeks to 3 months postpartum in some patients under the guidance of ultrasound to determine the types of renal injury pathologically, and the main finding was the proliferation of the glomerular capillary endothelial cell (Figure 2).



**Figure 2.** Pathological images of renal injury in patients with gestational hypertension (PASM + MASSON stain,  $\times 400$ ). Images are representative of experiments repeated at least 3 times. Proliferation of glomerular capillary endothelial cell can be seen.

## Discussion

In the current study, we used Virtual Touch Quantification (VTQ) technology to examine the kidneys of 90 gestational hypertension patients and explored that difference in shear wave velocity (SWV) in renal cortex, renal medulla, and renal sinuses between these patients and normal pregnant women used as controls. We found that there was no difference in renal function between patients in the gestational hypertension only group and the control group. However, there was a significant difference in renal function among patients in the gestational hypertension only group, patients with mild preeclampsia, and patients with severe preeclampsia, and there was also a significant difference in renal function between patients with either mild or severe preeclampsia versus controls. There was a significant difference in SWV values of renal cortex, renal medulla, and renal sinus between patients in the gestational hypertension only group, patients with mild preeclampsia, and patients with severe preeclampsia versus the control group.

A major complication of gestational hypertension is kidney injury. Gestational hypertension can cause spasmodic contraction of small arteries, which in turn cause renal hypoperfusion, decrease of excretory function, and glomerular endothelial cells lesion or necrosis [9]. Postpartum biopsy performed in some patients in this study showed significant proliferation of glomerular endothelial cells, but there was no pathological change in basal cells. The biopsy in this study was mainly performed in patients in Group B and C who had preeclampsia. Biopsy was rarely performed in patients in group A, who have only mild gestational hypertension. The kidneys have a very powerful reserve for its function, so that when mild or partial changes occur, creatinine clearance rate remains at normal levels. In the current

study, creatinine clearance rate and other laboratory indexes in group A patients did not show significant difference from those of the normal control group, but there was a difference in terms of kidney elasticity (i.e., the compliance of the kidney declined). The compliance of the kidney decreases further in patients with mild or severe preeclampsia, and the SWV values also continue to decrease. Early kidney lesions usually do not show much change in 2-dimensional ultrasound images, so it is hard to diagnose. With the further development of the disease, there are significant changes in various indicators of kidney function, which can then be detected by routine ultrasound.

Virtual Touch Quantification (VTQ) technology is a new method for noninvasive assessment of tissue elasticity. Its working mechanism is based on the principle of imaging of acoustic radiation force impulse, where the mechanical deformation characteristics of the tissue are detected by acoustic wave to obtain parameters reflecting the elasticity and stiffness of the tissue. This technology can be used to assess tissue elasticity quantitatively through detecting shear wave velocity. Elasticity is an important characteristic of biological tissue and tissues with the same structure can have different elasticity under different pathological conditions. Different from conventional imaging methods that show anatomical information and blood flow characteristics of the tissue, this technology provides a new method for the differential diagnosis of diseases [10].

In the current study, VTQ technology was able to detect the changes in tissue elasticity and compliance at an earlier stage of kidney disease; the SWV values of renal cortex, medulla, and sinus in patients with gestational hypertension were significantly decreased compared to those in normal controls. With increases in the severity of the kidney injury, the SWV values in the same region became smaller, indicating the gradual deterioration of the regional elasticity and compliance. Therefore, VTQ technology is very useful to monitor changes in tissue elasticity and compliance at an earlier stage of kidney disease; the lower the SWV, the worse the organ/tissue elasticity, the weaker its compliance, and the more severe the degree of kidney disease [11].

## Conclusions

We thus concluded that the SWV values of renal cortex, renal medulla, and renal sinus in patients with gestational hypertension were smaller than those of normal pregnant women, and more severe kidney injury was associated with smaller SWV values.

There will be significant differences in shear wave velocity measured with Virtual Touch Quantification technology between patients with gestation hypertension for over 8 weeks and normal pregnant women. If properly used, it is a valuable technology in the assessment of renal function [12].

## Conflict of interests

The authors declare that there is no conflict of interests.

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