Chapter

Renal Elastography for the Assessment of Chronic Kidney Disease

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Abstract

For the assessment of chronic kidney disease, point shear wave elastography (pSWE) and shear wave speed imaging (2D-SWE) are suitable, but the use of elastography in the assessment of the kidneys is more difficult compared to the use in other organs, because of the complex architecture of the kidneys, characterized by a high anisotropy and also by the limited size of the renal parenchyma, where the measurements are performed. Despite the difficulties of renal elastography, the reproducibility of the method is good. Kidney shear wave speed values are influenced mainly by age and gender, while in chronic kidney disease, renal stiffness is sometimes decreased in more advanced disease and is not influenced mainly by the progression of fibrosis. There are studies proving that a decreased renal blood flow is associated with a decrease in kidney shear wave speed, the fact that could explain why patients with CKD tend to have lower kidney stiffness. Elastography is a real-time imaging method that could be useful in the assessment of the kidneys, but more extensive studies and even some improvements of the processing algorithms of raw data of elastography machines seem to be needed to implement the use in clinical practice.

Keywords: chronic kidney disease, kidney shear wave speed, renal stiffness, point shear wave elastography, shear wave speed imaging

1. Introduction

Chronic kidney disease (CKD), a progressive disease, with high morbidity and mortality, therefore associated with increased health costs, is becoming a public health problem because of the increasing incidence and prevalence. For the diagnosis of CKD, biochemical markers are used—glomerular filtration rate, estimated from the level of serum creatinine and urinary albumin/creatinine ratio. For the assessment of the progression of CKD histology can often be helpful, and different new biomarkers are emerging as important tools as well [1].

The use of imagistic methods in the early diagnosis, or to assess the progression of CKD is very limited. Conventional ultrasound is helpful in diagnosing cystic kidney diseases, which represent a small proportion of the causes of CKD. Regarding the most frequent etiologies of CKD (diabetes mellitus, arterial hypertension, glomerular diseases, or chronic tubulointerstitial diseases) information provided by ultrasound

is of limited help. Using conventional ultrasound we can quantify the renal size and parenchymal thickness, both decreasing in advanced stages of CKD, when due to the progression of fibrosis, the echogenicity of the renal cortex is increasing [2].

The increased echogenicity, observed by the investigator is however not quantifiable using conventional ultrasound, being therefore subjective. An ultrasound-based method that has proven its utility in the assessment of fibrosis in different other organs (liver in both, diffuse [3, 4] or focal lesions [5], spleen [6, 7], thyroid [8, 9] or prostate [10]), by measuring the stiffness of the tissue is elastography.

2. Renal elastography- method

Elastography is a method used to quantify the elasticity of tissues. Elasticity is an intrinsic property of tissue, that permits after initial stress, the deformation with a subsequent return to the normal shape [11].

2.1 The types of elastography

Different methods, corresponding to different technologies can be used to measure tissue elasticity:

1. Strain elastography (SE) is a qualitative method, the strain images being obtained from the tissue displacement, due to pressure applied by the transducer. SE is mentioned in experimental studies performed in renal transplant recipients when the assessed kidney is superficial [12].

2. Shear wave elastography

This is a quantitative method, that in contrast to SE does not use the transducer pressure, but high-intensity pulses that generate shear waves in the different tissues. The tissue shear wave speed (SWS) is expressed in m/s and is correlating with tissue stiffness expressed by Young's modulus (kPa). Performing this method in a stiffer tissue leads to a higher SWS.

a. Transient elastography (TE) or Fibroscan is known from liver stiffness assessment. Shear waves in TE are generated by controlled external vibration, however, the fact that the obtained image is not superimposed on an ultrasound image, makes it difficult to use in renal assessment. The conclusions of the few published studies using TE in kidneys, underline the fact that the results can be affected by the heterogeneous kidney morphology [13–15].

b. Acoustic radiation force impulse (ARFI), in contrast to TE, uses the same transducer to generate shear waves and to image their propagation. The system is integrated into an ultrasound machine, and the ultrasound image is used to guide the site of elastography measurements. As a principle, in ARFI, shear waves are generated inside the organ due to focused acoustic radiation force pushing pulses. After generation the shear waves propagate through the soft tissue, their speed represents the SWS and are progressively attenuated due to their absorption in the soft tissue [16]. There are two different types of ARFI, corresponding to the different methods of obtaining and reporting information:

- Point shear wave elastography (pSWE): The result is an average value inside a region of interest (ROI) and the systems/machines that use pSWE are: Virtual touch quantification (VTQ) (Siemens S2000, S3000) (**Figure 1**), elastography point quantification (ElastPQ) (Phillips Affiniti) (**Figure 2**).

- Shear wave speed imaging (2D-SWE). Instead of an average value, the ROI appears as a color-coded map mosaic inside which the measurement is performed. The systems that use this method are: 2D SWE.SSI technique (Aixplorer) (**Figure 3**) and 2D SWE.GE (General Electric) (**Figure 4**).

Only the two ARFI-based shear wave elastography methods (pSWE and 2D-SWE) seem to be suitable for the assessment of renal diseases.

2.2 Method description

Both mentioned renal elastography methods (pSWE and 2D-SWE) are ultrasound-based. The image obtained is a normal ultrasound image, and superimposed on it there is the region of interest (ROI), inside which the kidney shear wave speed is measured (**Figures 1**–**4**). The result is displayed on the screen and is expressed either in m/s or in kPa.

The preparation of the patient should be the one used for a conventional ultrasound examination, but because the results obtained with elastography are quantifiable, the position of the examined subject should be standardized. Renal elastography should be thus performed with the patient in lateral decubitus, asked to stop breathing for a moment, to minimize breathing motion (**Figure 5**). Because the elastography method is ultrasound-based, the obtained B-mode US image should have a good quality, to obtain a reliable elastography measurement. Thus, before starting elastography acquisition, the correct scan of the kidneys should be obtained, using the best acoustic window.

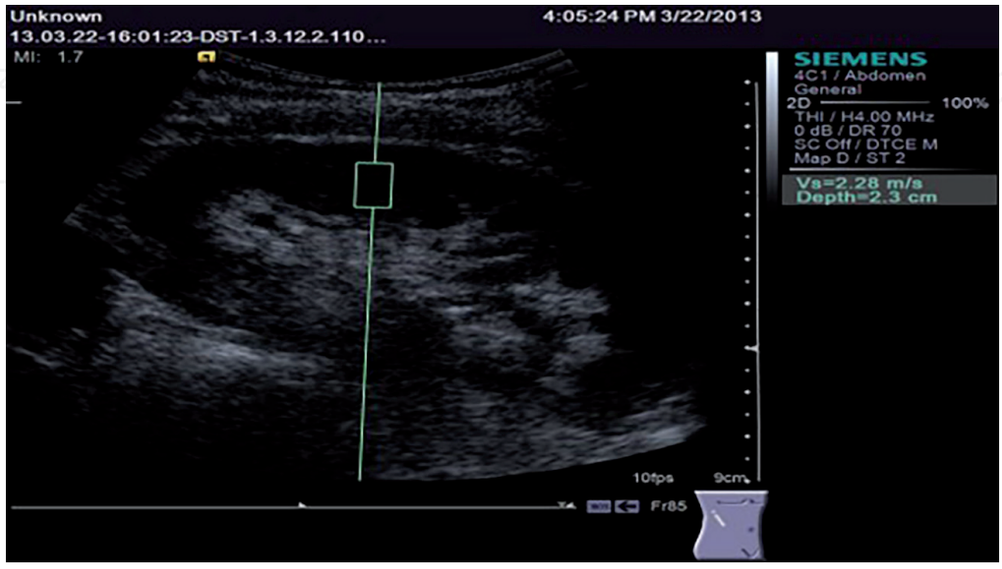

Figure 1.
Kidney SWS (expressed in m/s) measured with a pSWE method: Virtual TouchTM tissue quantification (VTQ), software version 2.0, on a Siemens Acuson S2000TM ultrasound system (Siemens AG, Erlangen, Germany) with a 4CI transducer.

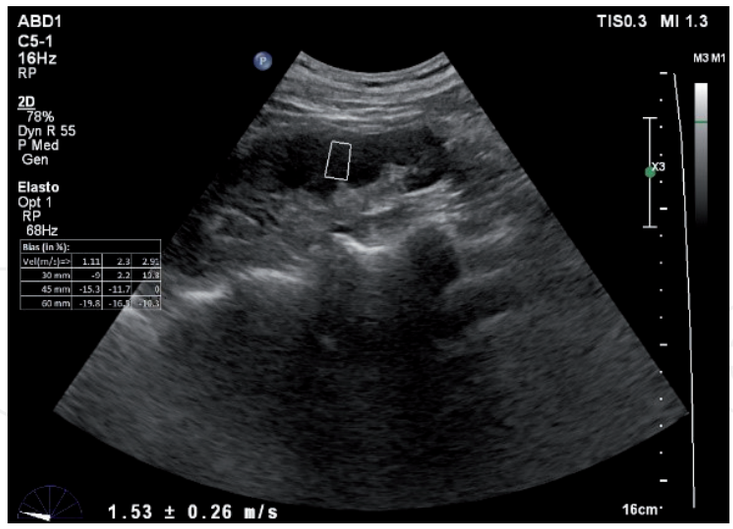

Figure 2.
Kidney SWS (expressed in m/s) measured with a pSWE method: Elatography point quantification system (ElastPQ) on a Phillips Affiniti ultrasound system with a 4CI transducer.

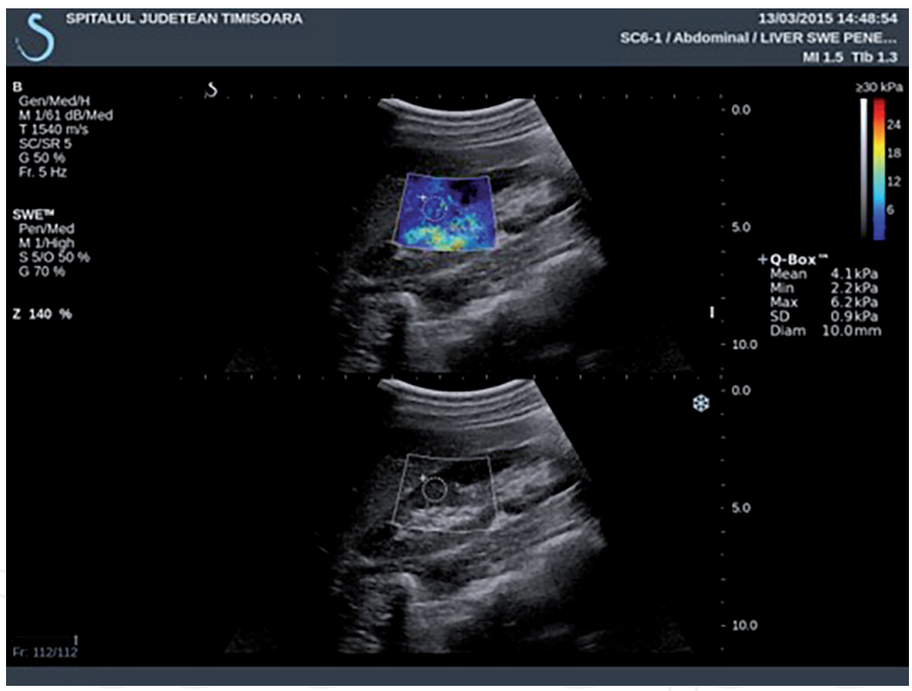

Figure 3.
Kidney stiffness (expressed in kPa) measured with a 2D-SWE method: 2D-SWE.SSI technique on a SuperSonic imagine Aixplorer® ShearWave™ Elastography machine with a SuperCurved™ SC6-1 transducer.

The need for a good standardization of this method comes from the complex architecture of the kidney, which is composed of cortex, medulla, central fat, vasculature, collecting system, and a capsule [17]. This complex structure leads to a high degree of anisotropy, especially at the level of the medulla, composed of tubules that are aligned perpendicular to the renal capsule [17]. Anisotropy is present at the level of the renal cortex as well and is due to the spherical glomeruli and proximal and distal tubules which have a convoluted shape [18].

The consequence of anisotropy of the renal structure is represented by the influence on the kidney stiffness measured using elastography [19]. The results are influenced

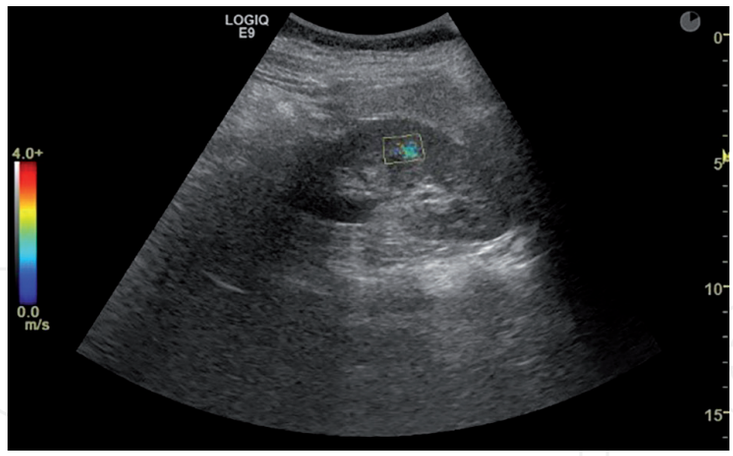

Figure 4.
Kidney SWS measured with a 2D SWE.GE technique using a Logiq E9- General Electric ultrasound system.

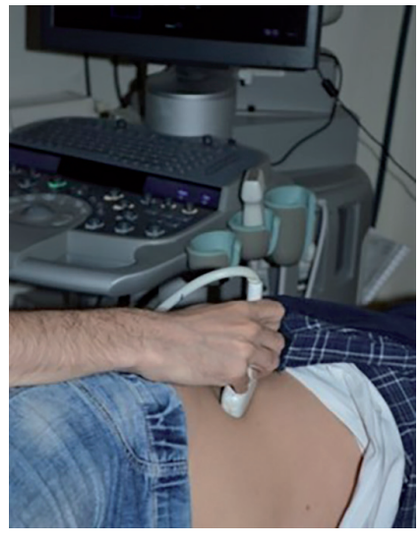

Figure 5.
For elastography, the patient should be examined in lateral decubitus, to obtain the best acoustic window.

by the relationship between the direction of the ultrasound main axis and the renal pyramid axis. Thus, if the ROI is put in the mid-portion of the renal parenchyma the two axes are parallel, while if the ROI is at the level of the renal poles the two axes are perpendicular and the obtained SWS is different [20]. To have a standardized approach and because the placement of the ROI in the poles is sometimes difficult, the most common way to place the ROI is in the mid-portion of the renal parenchyma.

Anisotropy of the renal tissue can however be beneficial and used as a diagnostic tool. Standardizing the variation of SWS in the kidney can be used to obtain an anisotropic ratio, that could represent a diagnostic and monitoring marker in CKD [21].

When performing renal elastography, another important issue is the one regarding the positioning of the ROI, because theoretically the measurements should be performed in the renal cortex. It is known that the stiffness of the cortex is higher compared to the stiffness of the medulla [22]. In practice, however, because of the fixed dimension of the ROI, of 1 cm, it is difficult to differentiate between cortex and medulla, and therefore, the measurements will be performed in the renal parenchyma, which contains both cortex and medulla. This difficulty resulting from the

dimension of the ROI is further increased in patients with advanced CKD, that have thin parenchyma (sometimes below 1 cm), and elastography results could be biased.

The limited size of the renal parenchyma (compared to the size of the ROI), even in normal kidneys, leads to the necessity of positioning the ROI just beneath the renal capsule. The vicinity of the renal capsule can lead to the appearance of some common ultrasound artifacts that occurs when a sound pulse reverberates back and forth between two strong parallel reflectors, and that leads to increased measured values. These reverberation artifacts are the reason for the recommendation in liver elastography, for example, to put the ROI 1.5–2 cm beneath the capsule to avoid these artifacts, a recommendation that is impossible to use in renal elastography [23].

Despite the above-mentioned difficulties in performing renal elastography, if the approach of the kidneys is standardized, it has been proven that the method has good inter-observer reproducibility, and thus has the potential to be used in clinical practice [24, 25].

3. Renal elastography- normal values

In practice and considering the results of the majority of published studies the kidney shear wave speed value should be reported as the median value of five valid measurements, although it has been proven that even three valid measurements are enough [26].

It is difficult to establish the normal values of kidney shear wave speed because even if the measurement is performed at the same cortical level, the reported results are different depending on the different elastography systems used. For pSWE, the normal values range between 2.15 and 2.54 m/s (for the VTQ system) and between 1.23 and 1.54 m/s (for the ElastPQ system) [27]. For 2DSWE-GE, normal values range between 1.71 and 1.79 m/s [28].

An important limitation of elastography is the fact that the different methods that are available, and that have been mentioned previously, are coming from different providers and no correlation tables are available to compare results obtained with different transducers from different manufacturers.

Kidney shear wave speed seems to be influenced by age, with a decrease of renal stiffness in older subjects, and also by gender, with men showing lower values compared to women [29, 30].

The results obtained when performing renal elastography are influenced also by the depth of the kidneys. Kidney shear wave speed is decreasing with increasing organ depth [29, 31, 32]. The assessment becomes difficult in very deep kidneys because the maximum depth of the ROI is 8 cm.

But very superficial kidneys can be difficult to assess as well, because the results are potentially biased due to the different compression of the transducer, being thus operator dependent. It has been proven in a study published by Correas et al., that cortex stiffness is increasing with the increased transducer compression [22]. This problem could influence especially measurements performed in superficial kidneys when the different non-quantifiable transducer force applied, could intervene, leading to different SWSs.

4. The assessment of chronic kidney disease

The most promising use of elastography in the hands of a nephrologist should be for the assessment of CKD, to diagnose and quantify the progression, as it has been mentioned in the introduction of this chapter.

There are several studies that are showing that kidney SWS values are significantly increased in patients with CKD compared to normal controls, pointing out that kidneys are stiffer because of chronic disease [33–37]. These observations are, however, not confirmed in every published study. Other authors have shown that renal stiffness is significantly lower in patients with CKD [24, 38, 39]. A statistically significant relationship between kidney shear wave speed values and renal function, expressed by estimated glomerular filtration rate (eGFR), has been shown as well, with lower kidney SWS associated with lower eGFR [40–42].

Despite the decrease of kidney SWS with the decrease of eGFR, mentioned in some studies, it was not possible to use elastography to differentiate between the different stages of CKD, because no significant differences could be found between the SWS levels in the different CKD stages [28, 43].

In a meta-analysis comprising seven studies including 639 patients with CKD and 640 normal controls, it has been shown that kidney SWS is decreased in patients with CKD, and there is a decrease of kidney SWS with the progression of CKD (decrease of eGFR). However, the included studies showed an increased heterogeneity [44].

To implement the use of renal elastography in the current practice, for the diagnosis of CKD for example, the finding of cut-off values would be important. However, the attempts published so far are presenting cut-off values for the diagnosis of more advanced stages of CKD, and not for incipient CKD.

Thus, diabetic kidney disease with an eGFR of below 60 ml/min could be predicted using the VTQ system (pSWE) with a sensitivity of 67.4% and a specificity of 67.8%, if kidney SWS was less than 2.32 m/s [45]. Better sensitivity (89.2%) and specificity (76.9%) have been obtained with 2D SWE GE, which predicted CKD if SWS was 1.47 m/s or below [28].

When combining elastography with clinical parameters, such as albuminuria or diabetes duration, and using a logistic regression model, the accuracy of diagnosing even early stages of diabetic kidney disease could be significantly improved, in contrast to the independent use of the different methods [36].

5. Fibrosis and elastography

From the studies using liver elastography, we know that fibrosis, which occurs due to the progression of liver disease, leads to an increase in liver stiffness. Because the histological background of chronic kidney disease is renal fibrosis, and especially tubulointerstitial fibrosis, it can be hypothesized that similar changes occur in the kidneys, and therefore, the progression of kidney disease should lead to an increase of SWS. However, as mentioned in the previous chapter, the studies published so far, that compare elastography performed in patients with CKD and normal controls, have shown that not always CKD is associated with an increase in renal stiffness.

Therefore, it would be useful to take a look at those studies that compare histological changes with results obtained using elastography, and to see if there is a relationship between fibrosis and kidney SWS, and to find an explanation to the observation mentioned in some studies that kidney SWS is decreasing in advanced stages of CKD.

The first studies that compare elastography with histological parameters have been performed in renal transplant recipients. Those studies using transient elastography (TE) show a positive correlation between renal stiffness and fibrosis [13–15, 47], but as already mentioned the use of Fibroscan in the assessment of the kidneys is especially biased by the renal structure. In the studies using pSWE or 2D

SWE in transplanted patients, there was a lack of correlation between fibrosis and renal stiffness [48–51].

In native kidneys, there are studies using different elastography systems (VTQ, ElastPQ) that show, as expected, that severe histological changes, both glomerular and tubulointerstitial, are associated with a statistically significant increase in kidney SWS [33, 52]. Moreover, in a study performed using the 2D-SWE – SSI elastography method, it has been shown that the degree of glomerulosclerosis and tubulointerstitial fibrosis is associated with higher levels of kidney stiffness and that patients with lower kidney SWS showed a better response to corticotherapy [53]. This observation could be explained by the fact that corticotherapy is not effective on fibrosis, but on active glomerular lesions, which probably do not influence renal stiffness.

However not all published studies sustain the mentioned conclusions regarding the relationship between kidney elastography and histological changes, and thus in some studies, no correlations at all have been found between histology and elastography. This is the case of a small study performed in 45 patients with CKD in which no statistically significant correlation of kidney SWS with the studied histological parameters (glomerulosclerosis index, tubular atrophy, interstitial fibrosis) has been found [54]. In another study that has been performed in kidneys used for transplant from living donors, elastography and renal biopsies have been performed before nephrectomy. Although the kidneys with more pronounced interstitial fibrosis had a lower SWS, none of the correlations between histology and elastography was statistically significant [31].

Even more surprising are those studies that show an association of a decreased renal stiffness with fibrosis, for example, that severe histological impairment in CKD is associated with significantly reduced kidney SWS [41], or even that the presence of tubulointerstitial fibrosis or arteriolar hyalinosis leads to significantly decreased values of SWS [55].

Combining elastography with conventional ultrasound features (renal length, parenchymal thickness, resistance index) can improve the predictive value and offer better diagnostic performance in the evaluation of pathological changes in CKD., as it has been shown in a study performed in patients with IgA nephropathy, that had a significantly lower kidney SWS in more severe diseases [56].

One explanation for the different pattern of results and the different relationship between renal stiffness and elastography provided by the different studies could be the fact that histological changes in renal diseases are heterogenous, showing a non-uniform involvement of the compartments of the renal tissue (glomerular, vascular, or tubulointerstitial). However, another explanation could be the fact, that maybe other factors, besides histological changes (renal fibrosis) are involved in influencing renal stiffness.

6. Urinary pressure or renal blood flow

Besides fibrosis, the stiffness of the renal tissue could be theoretically influenced by urinary pressure, which could be increased in case of urinary obstruction, but again the results of the published studies that are addressing this topic are not consistent. As expected, kidney SWS was increased in children with different degrees of hydronephrosis compared to normal controls, as it has been shown in a study performed on 51 children [57]. But, however, in another study performed on 88 children with vesicoureteric reflux, SWS decreased with the increasing grades of the reflux [58], while a

third smaller study (37 children) was not able to discriminate between obstructive and unobstructive hydronephrosis using shear wave elastography [59].

Another factor, besides the structure of the renal tissue and urinary obstruction, that could influence renal tissue stiffness could be renal blood flow. The background for this hypothesis is represented by the fact that the vascularization of the kidney is increased, with 20% of the cardiac outflow running into the kidneys [60, 61].

The relationship between renal blood flow and elastography has been hinted at by experimental data using an *ex vivo* kidney that has been cannulated and in which an increased renal pressure has been obtained by introducing saline into the kidney. The result was an increase in renal stiffness measured using 2D-SWE (Aixplorer) [62]. When performing elastography in experimental animal kidneys, the ligation of the renal artery, with the subsequent reduction of renal blood flow, leads to a decrease of SWS. The ligation of the renal vein, however, leads to an increase of renal SWS [63, 64].

A similar situation to the latter one mentioned above has been reported in a patient with renal vein thrombosis, which led to an increased value of kidney shear wave speed compared to the contralateral kidney [65].

There are also clinical studies that are sustaining the renal blood flow hypothesis. Asano et al. show in a study performed in over 300 CKD patients that increased arterial stiffness, measured through pulse wave velocity (PWV), is associated with a low kidney SWS [60]. These results have been confirmed in another study performed in patients with diabetic kidney disease, that showed a negative, statistically significant correlation of kidney SWS not only with PWV but with the aortic augmentation index as well [66]. This means that in patients in whom there is a progression of arteriosclerosis in the large vessels (high PWV and aortic augmentation index), which leads to a decreased renal blood flow, the kidney SWS is subsequently low.

There are also indirect proofs of the validity of the hypothesis of an existing relationship between renal blood flow and renal stiffness. In patients with gestational hypertension, characterized by renal hypoperfusion, it has been shown that high blood pressure was associated with a low renal elasticity [67].

A study performed in renal transplant recipients showed that interstitial fibrosis/tubular atrophy has no influence on kidney SWS, but adaptive glomerular hyperfiltration leads to an increase in kidney SWS. This observation is in favor of the hypothesis that renal hemodynamics influences renal stiffness [50].

Considering the supposed relationship between renal blood flow and elastography findings, it has been proposed to use pre-procedural elastography to predict the risk of bleeding after renal biopsy, but the results show a low sensitivity, with high specificity for the method [68].

A new experimental elastography-based method that could explain the described results and relationships is two-dimensional time-harmonic ultrasound elastography. When using this method, the patient is placed on a vibration bed that produces continuous vibrations and thus the 2D-SWE elastography covers the entire kidney and is not limited to a superficial ROI [69]. Performing this enhanced elastography Grossman et al. showed that renal SWS decreased significantly in CKD stage 1 (patients with glomerulonephritis) compared to normal controls. Moreover, there was a statistically significant negative correlation with the resistive index, the fact that could underline that renal blood flow is influencing renal stiffness [70].

The decrease of renal blood flow could have a higher influence on renal stiffness, compared to fibrosis, leading to the decrease of kidney SWS. The progression of renal fibrosis, which should increase renal stiffness, is on the other hand associated with a

	Study	Elastography method	Patient population (number, type of subjects)	Histology	SWS in CKD*
1	Arndt et al. [13]	TE	57 transplant patients (20 with renal biopsy)	yes	increase
2	Syversveen et al. [48]	VTQ	30 transplant patients	yes	no relationship
3	Stock et al. [51]	VTQ	18 transplant patients	yes	moderate positive
4	Grenier et al. [49]	SSI	43 transplant patients	yes	no relationship
5	Sommerer et al. [14]	TE	164 transplant patients	yes	increase
6	Guo et al. [30]	VTQ	64 CKD patients/327 healthy subjects	no	decrease
7	Lukenda et al. [15]	TE	52 (23 with renal biopsy)	yes	increase
8	Hu et al. [41]	VTQ	163 CKD patients/32 healthy subjects	yes	decrease
9	Yu et al. [34]	VTQ	120 diabetic patients/30 healthy subjects	no	increase
10	Asano et al. [60]	VTQ	309 CKD patients/14 healthy subjects	no	decrease
11	Wang et al. [54]	VTQ	45 CKD patients	yes	no relationship
12	Cui et al. [33]	VTQ	76 CKD patients	yes	increase
13	Nakao et al. [47]	TE	35 transplant patients (27 with renal biopsy)	yes	increase
14	Lee et al. [50]	VTQ	73 transplant patients	yes	no correlation
15	Bob et al. [42]	VTQ	46 CKD patients/58 healthy subjects	no	decrease
16	Samir et al. [36]	2D SWE-SSI	25 CKD patients/20 healthy subjects	no	increase
17	Alan et al. [40]	VTQ	76 coronary artery disease patients/79 healthy subjects	no	decrease
18	Bob et al. [45]	VTQ	80 diabetic kidney disease patients/84 healthy subjects	no	decrease
19	Bilgici et al. [38]	VTQ	30 CKD patients/38 healthy subjects - pediatric patients	no	decrease
20	Bob et al. [55]	VTQ	20 CKD patients	yes	moderate decrease
21	Sasaki et al. [43]	VTQ	187 CKD patients	no	no relationship
22	Yang et al. [35]	VTQ	90 idiopatic nephrotic syndrome CKD patients/30 healthy subjects	no	increase
23	Grosu et al. [39]	Elast PQ	102 CKD patients/22 healthy subjects	no	decrease

	Study	Elastography method	Patient population (number, type of subjects)	Histology	SWS in CKD*
24	Liu et al. [46]	Elast PQ	69 diabetic kidney disease patients/40 diabetic controls	no	increase
25	Hu et al. [56]	VTQ	146 IgA nephropathy patients/39 healthy volunteers	yes	decrease
26	Grosu et al. [28]	2D SWE- GE	42 CKD patients/50 healthy subjects	no	decrease
27	Sumbul et al. [37]	Elast PQ	125 diabetic, prediabetic patients and controls	no	increase
28	Yang et al. [53]	2D-SWE- SSI	120 idiopathic nephrotic syndrome - CKD patients	yes	increase
29	Lee et al. [31]	VTQ	73 (biopsies of kidney donors before transplant)	yes	no (tendency of SWS to **decrease** with advanced renal changes)
30	Leong et al. [52]	ElastPQ	75 CKD patients	yes	increase

**The terms "increase" or "decrease" are representing a statistically significant change of SWV in CKD compared to healthy subjects, or in more severe CKD compared to less advanced stages.*

Table 1.
Main published studies on renal elastography.

decrease in intrarenal blood flow, leading to opposite effects on renal SWS. This could explain why renal fibrosis is not associated with an increase in renal stiffness in some of the cited studies (**Table 1**) [41, 55, 56].

7. Conclusions and future perspectives of renal elastography

Shear wave elastography could be an ideal imaging modality to assess CKD because it combines all the well-known advantages of ultrasound examination, which is noninvasive, performed in real time, and does not imply high costs with the possibility to deliver quantifiable results. However, because of the complexity of the kidney architecture and its tissue properties, it seems that the results obtained using renal SWE are affected by numerous confounding elements, a fact that affects the reliability of the method and limits its application to clinical trials [71]. Therefore, it is very important to try to find those methods that could improve the use of SWE (**Figure 6**).

It has already been shown that combining SWE with other US methods (B-mode ultrasound and color Doppler) increases the prognostic value. The combination of the different ultrasound-based methods could be a step toward the use of multiparametric ultrasound imaging in the assessment of the kidney.

Another step forward could be the use of artificial intelligence. In a study performed in 208 CKD patients machine learning techniques have been used to combine multiple ultrasound characteristics of SWE, B-mode, and color Doppler flow imaging to assess the prognostic value of SWE for kidney tubulointerstitial fibrosis grades among the studied CKD patients. SWE ultrasound fitting machine learning improved

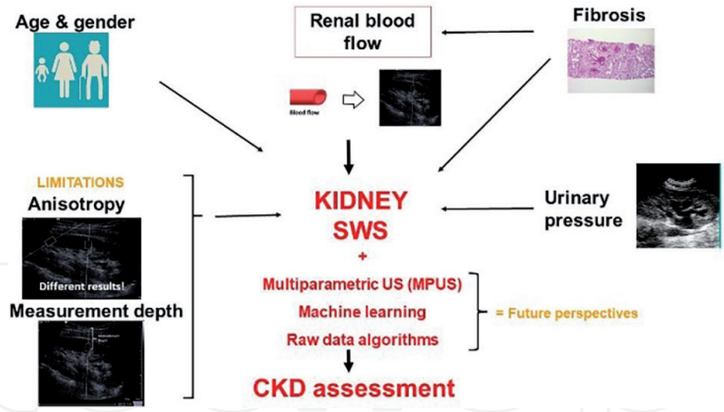

Figure 6.
Factors that influence kidney shear wave speed (SWS).

the diagnostic performances and also explained the lack of a linear correlation between kidney stiffness and CKD stages [72].

An improvement of the use of renal elastography could emerge from the analysis of raw data of the different systems used. Such an analysis has recently been published by Richard Barr using raw data of different three machines (Siemens, Phillips, and Aixplorer), and the conclusion was that an improvement of processing algorithms could lead to more accurate renal stiffness data from an elastographic system [73]. It is possible that assessing raw data with a new algorithm can overcome the existing limitations of the method, and make kidney elastography a feasible method [17].

Considering all the presented aspects, at the moment, no evidence-based recommendations can be offered for the use of SWE in the assessment of the kidneys [27]. Therefore, more extensive studies are needed to find the place and indication of renal elastography in clinical practice.

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Conflict of interest

The author declares no conflict of interest.

Appendices and Nomenclature

2D SWE	shear wave speed imaging
CKD	chronic kidney disease
eGFR	estimated glomerular filtration rate
ElastPQ	elastography point quantification
pSWE	point shear wave elastography

PWV	pulse wave velocity
ROI	region of interest
SWE	shear wave elastography
SWS	shear wave speed
VTQ	virtual touch quantification

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