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ORIGINAL PAPER

Diagnostic value of colour Doppler twinkling artefact in sites negative for stones on B mode renal sonography

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Abstract The aim of the study was to investigate the diagnostic value of the colour Doppler twinkling artefact (TA) in renal stone disease. To enhance the evidence of TA, a preliminary in vitro study was performed to optimise the setting of colour Doppler sonography. In the in vitro study, an oxen kidney was examined using an high-frequency (12.5 MHz) linear array probe in a water bath before and after the inoculation of an aliquot of powder obtained by fragmentation of a calcium oxalate stone. In the clinical study, 67 patients with diagnosis of urinary stone based on B-mode sonography and 67 matched control subjects were examined with colour Doppler sonography using a low-frequency (2.5 MHz) curvilinear phased array probe. In vitro, the injection of calcium oxalate powder in a bovine kidney sample induced the appearance of spots without any back shadowing appearance on B mode but with a large number of TA on colour Doppler. In vivo, TA was much more frequent in patients with stone disease (95.5%) compared to controls (9.0%) ($P < 0.001$). TA was highly associated to renal stone disease and was also present in renal areas where a stone was undetected with B mode approach suggesting its diagnostic role although further studies are needed to confirm its accuracy. The type of instrumentation and its setting is crucial to obtain reproducible results.

Keywords Twinkling artifact · Urinary calculi · B mode · Colour Doppler · Sonography

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Introduction

The twinkling artefact (TA) [1] is a rapidly changing mixture of colours which can be observed behind rough highly reflective structures on colour Doppler sonography. At pulsed Doppler analysis the spectrum appears as a sequence of saturation bands and the audio signal consists of treble squeaks.

Previous studies described the detection of the artefact behind urinary calculi which were recognisable on B mode [2, 3], but in our daily practice TA frequently appeared from sites of kidneys where a stone was not recognisable by B mode sonography.

The setting of the instrument seems to be critical for the production of the artefact [2–5].

The aim of this study was to investigate the diagnostic value of the colour Doppler TA in renal stone disease. To enhance the evidence of TA, a preliminary in vitro study was performed to optimise the setting of colour Doppler sonography.

Materials and methods

In this study an HDI 5000 scanner (Philips Medical Systems, Bothell, WA, USA) was utilised.

A broadband high frequency linear transducer (12.5 MHz) was used for in vitro study and a broadband low frequency curved array transducer (2.5 MHz) for in vivo examinations.

In vitro study

A preliminary in vitro study was performed to optimise the setting of the machine. Some highly reflective objects with rough surface including urinary calculi, natural crystals and metallic objects (filters, staples, clips and screws) were immersed in a tank containing water or located between two tissue-like gel pads and examined by colour Doppler.

The probe was blocked to a metallic arm in order to avoid influence of operator involuntary movements. The effect on the TA intensity was evaluated and recorded while step by step varying the colour Doppler setting options of the system including predefined combinations of parameters (such as colour maps) or single parameters (such as colour box size). The intensity of the effect was defined by the length of the colour tail, the spatial continuity on the surface and the temporal persistence of the artefact. Optimal setting was obtained on the basis of experimental data and subsequently adopted for further testing.

Furthermore an oxen kidney was examined in a water bath before and after the injection of an aliquot of tiny stone fragments obtained by crushing a calcium oxalate stone with a pestle onto a mortar. A volume of about 0.2 ml powder was aspired in a syringe and injected by a 21 G needle into a zone of the kidney at various levels of deepness. Scans of the injected zone and of non-injected zones were compared.

Clinical study

From June 2001 to December 2005, 67 consecutive patients with diagnosis of urinary stone based on B-mode sonography were examined with colour Doppler sonography. The optimal setting was obtained on the basis of the experience acquired by the in vitro study.

Only patients with at least one stone visible on B mode were included in the study. Stones were diagnosed in presence of bright images inside the central renal echoes when an acoustic shadowing was present or, if the shadowing was ambiguous, when brightness was fairly evident.

Patients with positive pattern derived from a cystic wall or renal parenchyma, medullary sponge kidneys and atrophic kidneys were excluded.

A control group composed of 67 subjects, matched to stone patients by age and gender, consecutively referred for sonographic abdomen evaluation for non-renal or urological pathologies and with a negative history for stone disease was also considered. Control subjects with calculi on B mode examination or with calcified cysts or parenchymal calcifications were also excluded.

Statistical analysis

The distribution of TA in renal stone patients and in matched control subjects was shown by using a 2×2 fourfold contingency table and the related Chi-square test with one degree of freedom was performed to investigate whether the TA phenomenon was significantly associated to stone disease. The evidence of association between TA and renal stones was obtained by rejecting the null hypothesis of equal distribution of the TA phenomenon among renal stone patients and control subjects. To reject the null hypothesis, a cut-off P value ≤ 0.05 was planned. The statistical analysis was made using SPSS for Windows, Release 14.

Results

In vitro study

The settings of the HDI 5000 scanner to optimise the demonstration of the TA in vitro are summarised in Table 1.

The intensity of the artefact was strongly affected by the acoustic power output whereas the effect of other quantitative or qualitative setting parameters seemed to be mainly correlated to the power output itself as demonstrated by the change of the maximum value of mechanic index produced.

No significant differences were obtained by variation of wall motion colour filter or pulse repetition frequency.

This optimal setting was confirmed in the clinical experience, although a higher frequency of pulse repetition could affect visibility of the artefact in vivo by reducing noise deriving from blood flow signals. In particular TAs were clearly differentiated from blood flow signal for the peculiar aspect of the twinkling mixed colours bands parallel to ultrasound beam and independent to arterial pulses. The use of pulse Doppler spectrum analysis was never requested.

Table 1 Settings of the HDI 5000 scanner in order to optimise the demonstration of the twinkling artifacts

Use of a small box area
Setting colour gain at the highest level (before background clutter appearance)
Setting grey scale gain as low as possible by using the default colour-write priority filter
Correct positioning of the focal zone at the level of the artefact source

During the testing of the bovine kidney sample (Fig. 1) non-injected zones showed on grey scale the usual sonographic anatomy of the renal parenchyma with a few echoes and containing some echogenic spots concentrated in the papillae. The injection of the oxalate powder increased the number of spots without any back shadowing appearance. On colour-Doppler a large number of TAs appeared in the injected zone, while the non-injected zones resulted colour-free.

Clinical study

In the clinical study, 67 adult stone patients (42 males, 25 females) with 80 stones and 67 matched control subjects were considered. At B mode examination, 46 out of 67 stone patients had one or more renal stones and 21 had ureteral stones (with o without renal stones).

At colour Doppler TA was clearly present distally to the whole surface of 77 out of 80 grey scale detected renal calculi (96%) and absent or faint in three out of 80 calculi (4%) (Table 2).

A correspondence between sites positive on both B mode and colour Doppler was observed in 32 patients (47.8%); in other 32 patients TA positive sites exceeded B mode positive ones (47.8%), as in Fig. 2, while in three out 67 stone patients (4.5%) a higher prevalence of positive sites resulted on B mode examination in comparison with the colour Doppler evaluation. In general, in the same patient, TA deriving by B mode mute zones were thinner than those deriving from grey scale positive zones. Conversely the length of the tail seemed non-correlated to size of stones. Interestingly, TA was much more frequent in patients with stone disease in comparison with the control subjects (Table 3) suggesting an association of TA with stone disease: 64 out of 67 stone patients (95.5%) presented with TA compared to 6 out of 67 control subjects (9.0%) with a highly significant Chi-square (99.87, $P < 0.001$).

Table 2 Presence of the twinkling artefact in 80 calculi diagnosed by B-mode examination in 67 renal stone patients

Twinkling artefact	Calculi *N* (%)
Absent or faint	3 (3.8%)
Present	77 (96.2%)
Total	80

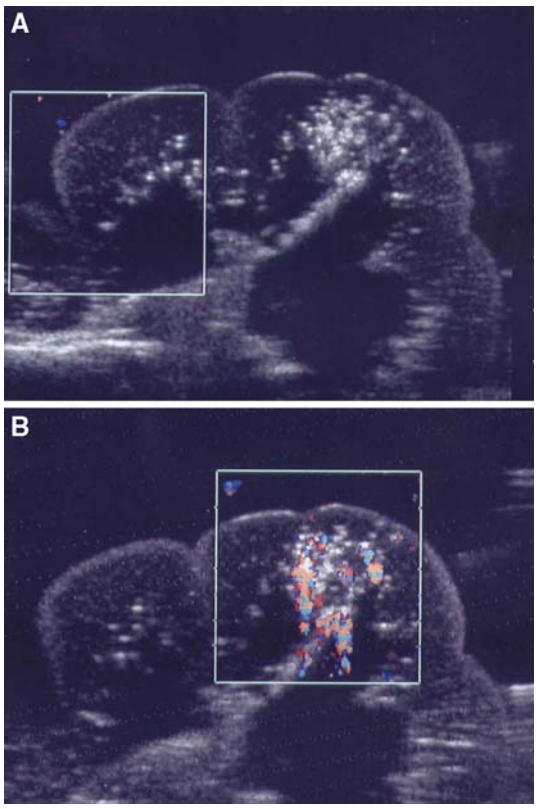

Fig. 1 Using a bovine kidney and the injection of oxalate powder, a large number of TA on *colour* Doppler appeared in the injected zone (**b**) while the non-injected zones resulted *colour-free* (**a**)

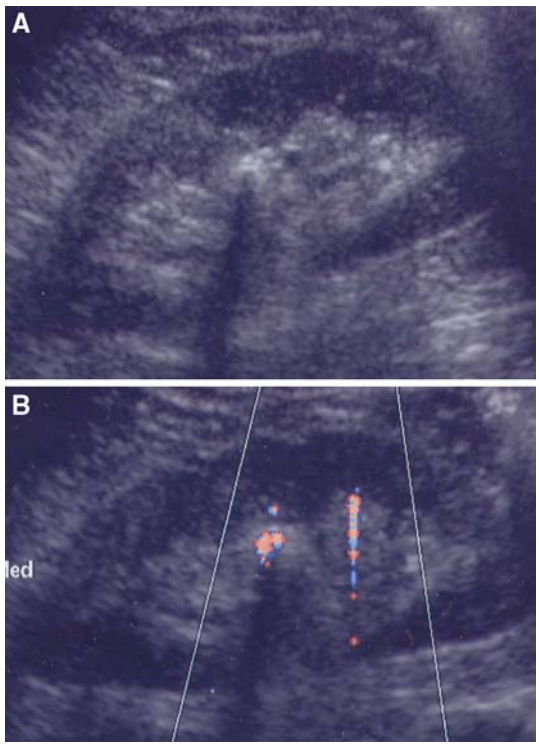

Fig. 2 A single stone of about 8 mm is detected in a kidney on B mode. It appears as a typical echogenic arch producing a back shadowing (**a**). Colour Doppler evidenced a TA behind the surface of the calculus and a second thinner and longer TA in a B mode negative zone (**b**)

Table 3 Twinkling artefact distribution in 134 subjects, 67 renal stone patients and 67 controls

Presence of twinkling artifact at colour Doppler	Presence of renal stones at B mode examination (*N*, %)		Total
	Yes (renal stone patients)	No (controls)	
Yes	64 (95.5%)	6 (9.0%)	70
No	3 (4.5%)	61 (91.0%)	64
Total	67	67	134

TA was much more frequent in patients with stone disease (95.5%) compared to control subjects (9.0%). Chi-square test 99.87, $P < 0.001$

Discussion

Colour Doppler sonography is a well known non-invasive method of vascular imaging of the kidney and other organs representing the blood flow as a colour map superimposed on a grey scale image of the examined structures. However echoes received by the transducer and imaged as colour flow are not always related to the flow of blood in vessels.

Rahmouni et al. [1] showed that an artefactual colour can be generated at random by a medium composed of individual reflectors. This artifact has been associated to the presence of renal or ureteral calculi, but also to the presence of intracorporeal metallic objects such as intracerebral coils, metallic foreign bodies or calcifications of the ocular bulb, parenchymal calcifications, bladder or gallbladder calculi or encrusted ureteral stents [6, 7].

TA may be a cause of misinterpretation but also an useful tool for better tissue characterisation.

In fact some authors warned about the bias derived by interpreting the TA as an expression of blood flow [1, 6, 7] whereas others outlined its potential utility to confirm the presence of urinary stones [2–4].

In our experience the risk of misleading the artefact was minimal when the system was correctly pre-settled because of its typical appearance. However the results were strongly dependent on the setting of the system, and an optimal preset was mandatory for a sensitive and specific detection of the artefact. On the contrary pulsed Doppler spectral analysis [2] appeared to be of little value opposite to what suggested by some authors [2].

Previous studies [2, 3] suggested the utility of TA demonstration as a tool to differentiate very small stones from other small echogenic structures within the urinary tract. The relationship between the presence and intensity of the TA and the chemical composition of urinary stones has also been used to predict fragmentation of stones by lithotripsy [4].

Our in vitro study on a bovine kidney sample confirmed that tiny stone fragments were able to produce the TA whereas the corresponding grey-scale images were non significant.

The presence of the TA in the 47.8% B-mode negative sites of the kidneys of renal stone patients suggest the presence of undetected microliths or stone fragments in an high rate of stone forming subjects. On the contrary TA is present in only 9% of controls confirming that a clinically mute microlithiasis is episodically present in general population.

Diagnosis of microliths or stone fragments less than 3 mm could be highly desirable in the diagnostic work up and follow up of patients with renal stones. In fact several studies clearly demonstrated that the persistence of the so-called "clinically insignificant residual fragments" or CIRFs in the renal cavities after lithotripsy is associated with the highest rates of re-growth or recurrence of renal stones [10–12].

An early diagnosis of their presence could identify a subgroup of patients requiring a more strict follow up or prophylactic measures. On the other hand, the presence of microliths associated to the presence of renal stones or observed at sonography after the spontaneous passage of a stone could be suggestive of a persistent and severe lithogenic activity. The adoption of an appropriate medical treatment at this stage could aim to stone dissolution in the case of radiolucent stones but even of radio-opaque ones considering the potential effect of citrate treatment [13].

Plain X-ray is effective in diagnosing stones even of the smallest dimensions, but its efficacy is highly limited by body size and by the presence of intestinal meteorism. CT demonstrated an high accuracy for the diagnosis of both radio-opaque and radiolucent stones but its use is still limited by costs and elevated X-ray exposition. Renal sonography is still the preferred examination for the follow up of stone patients being capable to show the presence of both dilatation of the collecting system or the presence of recurrent stones, reproducible and cheap. Unfortunately the diagnosis of stones is limited by their size. The use of Doppler sonography could enhance the sensitivity of sonography in order to demonstrate the presence of the smallest stones.

The confirmation of the significance of TA in zones mute to B-mode would require a comparison with spiral computed tomography (CT), which is actually considered the gold standard for imaging of stones. In particular false positives should be ruled out but the size of artefact's sources could be even beyond the limits of CT sensitivity [8, 9] so requiring a comparison with direct endoscopic visualisation.

In conclusion TA was highly associated to the renal stone disease and was present also in renal areas where a stone was not detected with B mode approach suggesting a role as a sensitive tool for renal stone diagnosis. Other studies are required to confirm its diagnostic accuracy in

comparison with other radiological and endoscopic diagnostic procedures of the urinary tract. The type and setting of instrumentation required attention to obtain reproducible results.

Manufacturers should pay more attention to this potential application of the instrumentation giving more information on the optimal setting for this peculiar application.

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