

# Penile arterial flow in men with erectile dysfunction: The use of Continuous Wave Doppler (CWD) - a statement of printing press

## *Fluxo sanguíneo arterial do pênis em homens com disfunção erétil: O uso do Doppler de fluxo contínuo – registro impresso*

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**Abstract** At present, there is not such a propaedeutic consensus or an objective and practical method to diagnose erectile dysfunction. The use of vasoactive intra-cavernous drugs alone is not able to demonstrate effectively if the positive erectile response to drug-induction in patients is physiological or functional (non-physiological). The association of a penile Continuous Wave Doppler (CWD) to the drug-induced erection test adds a hemodynamic parameter through diagnose of an arterial penile blood flow velocity. This parameter utilized in studies with the Conventional Color Doppler, the Peak Systolic Velocity (PSV) is measured by the unit PK=cm/s standardized in our study. Fifty patients with a six-month-length erectile dysfunction of unknown etiology or more were evaluated. Drug-induced erection test and vasoactive drugs. One single intracavernous injection of 0.5ml of prostaglandin (40.0µg) and phentolamine (0.33 mg) solutions in 6.0 ml of standard bidistilled water. Erections were evaluated 15 minutes later, ranked according to the performance, and considering erection rigidity or erection rigidity non-persistent (incomplete). SMART-DOP model ES-1000-PM (Continuous Wave Doppler) and a transducer of 10 MHz. were used to record the four phases corresponding graphics of the erectile cycle (flaccidity, before tumescence, tumescence and erection) in intervals of 5 minutes each. The average velocities (PKm) and standard deviations (SD) were analyzed and related only to phases one, two, and forth of the erectile cycle. The ED evaluation with continuous wave Doppler is carried out in a practical and objective way by the urologist. In conclusion, the Continuous Wave Doppler during average penile flaccidity PKm was compatible with an adequate arterial supply independently of the final erectile response, showing that this does not guarantee a rigid erection (physiological). Continuous Wave Doppler was able to demonstrate two patterns of arterial flow velocity in the fourth phase of erectile cycle: “expected velocity” and “high velocity”, related to each type of erectile performance: Rigid erections (physiological) and Incomplete or fleeting erections (functional), respectively.

**Keywords** Erectile dysfunction; Penile erection; Continuous wave doppler; Cavernous body injection test (CIBT); Velocity arterial blood flow.

**Resumo** Ainda não há um método propedêutico de consenso para diagnosticar a disfunção erétil (DE). O uso isolado de drogas vasoativas intracavernosa não é um método capaz de demonstrar objetivamente se a resposta erétil fármaco-induzida nos pacientes é fisiológica ou funcional (não fisiológica). A associação do *Doppler* de fluxo contínuo, representado pela sigla CWD (*continuous wave Doppler*), com o teste de ereção fármaco-induzida (TEFI), adiciona um parâmetro diagnóstico hemodinâmico de velocidade de fluxo sanguíneo arterial do pênis. Esse parâmetro, utilizado nos estudos com o *Doppler* convencional PSV (*Peak Systolic Velocity*), é medido pela unidade PK=cm/s padronizado em nosso estudo. No presente trabalho foram avaliados cinquenta pacientes com disfunção erétil de etiologia desconhecida, com seis meses ou mais de evolução. Para realização do TEFI foi aplicada uma injeção intracavernosa de 0,5 ml de prostaglandina (40µg) e fentolamina (0,33 mg) de uma solução padronizada em 6,0 ml de água bidestilada. A ereção foi avaliada 15 minutos após e classificada de acordo com a resposta (ereção com rigidez persistente ou ereção com rigidez não persistente ou incompleta). Com o equipamento SMART-DOP modelo ES-1000-PM e transdutor de 10 MHz (*Doppler* de fluxo contínuo) foram realizados registros gráficos correspondentes nas quatro fases do ciclo erétil (flacidez, pré-tumescência, tumescência e rigidez) sendo registrados gráficos em intervalos de 5 minutos cada um. As médias das

velocidades de fluxo sanguíneo (PKm) e o desvio padrão (SD) foram analisados e relacionados somente com a primeira, terceira e quarta fases do ciclo erétil. A avaliação da DE, com *Doppler* de fluxo contínuo no presente estudo, é realizada de modo fácil e objetivo pelo urologista. Concluiu-se que na flacidez peniana a média das velocidades de fluxo sanguíneo (PKm) foi compatível com um adequado suprimento arterial, independentemente da resposta erétil no final, não garantindo uma ereção rígida persistente. Na quarta fase do ciclo erétil, a média da velocidade de fluxo sanguíneo demonstrou a presença de dois padrões de registro gráfico: “velocidade de fluxo esperada” associados à ereção rígida persistente (fisiológica) e padrão de “alta velocidade de fluxo”, associado à ereção incompleta (funcional).

**Palavras-chave** Disfunção erétil; Ereção peniana; *Doppler* de fluxo contínuo; Indução da ereção com drogas vasoativas; Fluxo arterial do pênis.

### Introduction

Research on erectile dysfunction (ED) in the last two decades went to two extremes, starting with the use of highly complex methods and going to complete lack of research on diagnosis.

In the early eighties, VIRAG started treatment of erectile dysfunction by intra-cavernous injections of papaverin. LUE in 1988<sup>1</sup> and more recently, MEULEMAN and colleagues, in 1992<sup>2</sup> demonstrated that vasoactive drugs, injected in the intra-cavernous space dilate the cavernous arteries, thus furnishing hemodynamic parameters to be evaluated by duplex-scan. This was followed by the development of several procedures evaluated by the duplex-scan such as pharmacocavernosometry, cavernosography, nocturnal Rigi-scan, electromyography of the corpora cavernosa, which gave a highly sophisticated and expensive character to research in ED besides being difficult to be used by the medical doctor.

Association of vasoactive drugs allow for the use of lower concentrations due to a potentiation effect, like the combination of prostaglandin and phentolamine which can give the first indications about the severity of the functional incapacity of the corpora cavernosa<sup>3</sup>.

The positive test of CIBT shows a rigid erection 5-10 minutes after an intra-cavernous injection<sup>4,5</sup>; a rigid penile response indicates an adequate corporeal venoocclusive function and a satisfactory arterial response<sup>6,7</sup>.

However, a positive CIBT does not necessarily indicate that the patient is hemodynamically normal, considering an arterial point of view<sup>8,9</sup>. It is still possible that such patients will have obstructive arteriopathy with a normal venoocclusive function<sup>10</sup>.

The discovery of the effect of Sildenafil Citrate (VIAGRA), as an inducer of relaxation in smooth muscle cells and promoter of full erections in individuals with ED<sup>11,12,13</sup>, had a great impact producing a decrease of investigations by specialists. It is commonly accepted that after the age of 50, in 60% of the organic etiologies, three quarters are of vascular origin, arterial, or venous<sup>15</sup>.

The pattern of arterial blood flow velocity in the penis, in different phases of the erectile cycle was well established, in several studies, by the conventional color duplex (CCD)<sup>15,16</sup>. In normal individuals, in the phase of penile tumescence, the peak systolic velocity (PSV) is greater than 25 cm/s and after 30 minutes, it can attain 30 cm/s<sup>16</sup>; values below these and not more than 18 cm/s are encountered in severe arteriopathy. However, the studies with CCD require professional expertise in ultrasonography and are not routinely done by urologists.

In the consulting room, the Cavernous Injection Body Test (CIBT) is interpreted in a subjective manner, exclusively by palpation of the penis, a practice conducive to lack of reproducibility and controversial conclusions.

Nowadays, there is not a standard propaedeutic pattern or any artificial erection test being applied by the majority of urologists, prior to drug treatment, as it was done before prior to the use of injected drugs or the fitting of penile prostheses. In this study, we aim to evaluate the pattern of peak systolic arterial velocity in the penis of patients with erectile idiopathic dysfunction through the Continuous Wave Doppler (CWD), which can be performed by the urologist together with CIBT in the different phases of the erectile cycle. It is aimed to rescue a minimal amount of diagnostic research on ED through the characterization of a functional erection by hemodynamic parameter in the last phase of CIBT.

### Material and Methods

Fifty patients with idiopathic erectile dysfunction were evaluated; they were between 20 and 75 years old, with 67.36% between 45 to 65. The symptoms were of six to sixty months duration and the patients were assessed through a general anamnesis and classified by a predictive etiological score. Determination of free testosterone in patients was normal.

The investigation of penile response to drug stimulation was done after the patient was first seen.

### CIBT and vasoactive drugs

Basal peak systolic velocities were measured (without interference of drugs) and also after a single intra-cavernous injections (ICI) of 0.5ml of a solution of 40.0µg of prostaglandin E1 and 0.33mg of phentolamine in 6.0ml of distilled water (Deshydrater®) in intervals of 5, 10 and 15 minutes afterwards. At 15 minutes of the injection (fourth phase of CIBT), the erection was evaluated by the patient and the examiner through palpation. CIBT was considered to be positive when erection was rigidity persistent, and negative if erection was rigidity non-persistent (incomplete).

### Equipment

The equipment used was a blood flow Ultrasonographic Detector equipped with a Continuous Wave Doppler (SMART-DOP mod. ES-1000-PM®) and a 10 MHz transducer). The first tracings recorded on thermo-sensitive paper, were of the penile arterial flow in the state of flaccidity, also called basal flow. Time zero (t.0) was at the start of the recording; after 5 minutes of ICI

it was t.5 (t.5), equivalent to the before tumescence phase, after 10 minutes (t.10), equivalent to tumescence and after 15 minutes (t.15) equivalent to erection (Figure 1). Each tracing records the arterial flow during 5 seconds, showing PSV expressed as PK in centimeters per second (cm/s) and cardiac frequency in heartbeats per minute (bpm) during this time.

### Capture of the left cavernous arterial flow

The transducer is positioned to ventral region and proximal to the penis at the left, lying in the dorsal decubitus position. The transducer is positioned at an angle of approximately 30 degrees in relation to the longitudinal axis of the penis, with a distal inclination, on a drop of neutral water-soluble gel between the surface of the skin and the contact area of the transducer. The sound produced by the arterial blood flow is peculiar and captured by the transducer heard by an amplification of 100 watts and visualized through a liquid crystal screen.

The basic statistics were calculated (averages and standard deviations, SD). Data are presented in line graphs and schematic diagrams; variance analysis was used to compare group averages.

### Results

Patients were distributed in three groups according to the response to CIBT. They were, group: 1) incomplete erection, 2) rigid erection and 3) rigid erection not sustained or no persistent. The individual values of PSV in each group were averaged and the medians calculated for times t.0 at the start of the measurement (CIBT), t.10 and t.15, respectively 10 and 15 minutes later. The average differences were significant with a p=0.000 (Table 1).

Figures 2 and 3 show two patterns of printin press of patients

PHASE 1		2	3	4
t.0	ICI 5 minutes	t.5'	t.10'	t.15'
flaccidity		before-tumescence	tumescence	erection

Figure 1. Phases of the Cavernous Body Injection Test (CIBT) (t.0, t.5, t.10, t.15) associated to the Continuous wave Doppler (CWD) in intervals of 5 minutes corresponding to the four phases of the erectile cycle: 1-flaccidity; 2-before-tumescence; 3-tumescence and 4-erection. ICI: intra-cavernous injection of prostaglandin E1 and phentolamine.

TABLE-1 Average values of peak systolic velocities (cm/s) and type of erectile response.

(n)	PKm=cm/s (SD)			Type of erectile response
	t.0	t.10	t.15	
25	31.5 (2.6)	66.1 (5,4)	56.8 (3,8)	Incomplete
15	30.4 (2.2)	50.1 (4.1)	27.9 (1.4)	Rigid
10	32.0 (3.3)	65.7 (6.3)	65.1 (5.3)	Rigid, not sustained

p=0.000; t.0= time of the flaccidity; t.10= time of the tumescence and t.15= time of the erection; SD= standard deviation

submitted to CIBT during the four phases of the erectile cycle. They were: 1) Pattern of "Expected" velocity and 2) Pattern of "High velocity" respectively. "Expected velocity" referred to patients with average values of PSV of 27.9cm/s (SD=1.4) in the last phase of CIBT, and "High velocity" to an average of patients which was greater than 50cm/s. The distribution among the groups was, rigid erection in 15 patients with "Expected velocity" values, not normal or incomplete erection in 25 patients with the "High velocity" pattern also seen in the rigid erection, not sustained, group of 10 patients.

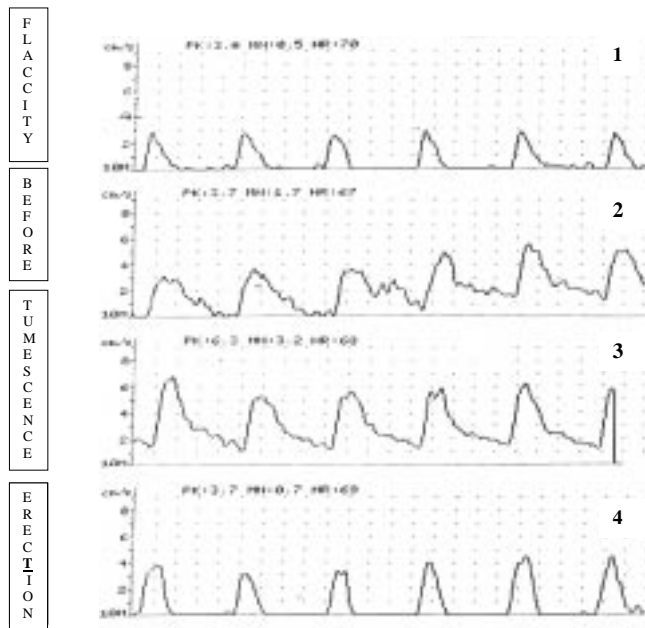


Figure 2. Recorded tracings of Peak Systolic Velocities (PSV) during the phases of the erectile cycle. Pattern of the "Expected" flow velocity. 1, 2, 3 and 4-phases of the erectile cycle: Flaccidity, Before tumescence, Tumescence and Erection. (10M=10x)

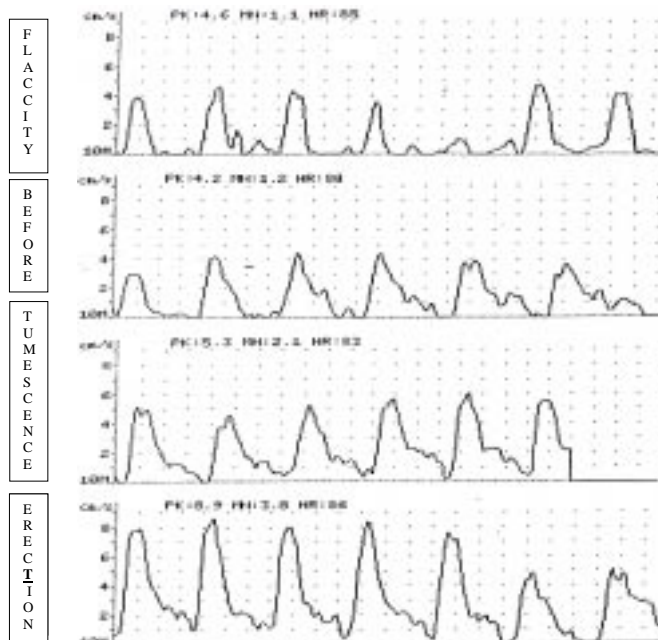


Figure 3. Printin press of Peak Systolic Velocities (PSV) during the phases of the erectile cycle. Pattern of "High" flow velocity. 1, 2, 3 and 4-phases of the erectile cycle: Flaccidity, Before tumescence, Tumescence and Erection. (10M=10x)

The averages of PSV (Pkm=cm/s) were analyzed as a function of time during CIBT in the four phases of the erectile cycle, from time t.0 to t.15. They increased steadily up to 10 minutes after ICI, but were lower between 10 and 15 minutes. Furthermore, the average of PSV values for the patients that had a rigid erection was significantly lower than the ones for the patients that did not have a rigid erection, with a  $p=0.000$ . There was not statistically significant difference between the averages of the 25 patients that had incomplete erections and the 10 patients that had a rigid, but not sustained erection. The average differences were not statistically significant with a  $p>0,05$ .

The distribution of PSV (PK=cm/s) values in the phase of penile flaccidity showed that they stayed between 20 and 40 cm/s, did not depend on the erectile response, and there was no significant difference between the averages in this phase of CIBT,  $p=0.896$  (Figure 5).

Figure 6 shows the distribution of values of PSV (PK=cm/s) in the fourth phase of CIBT. There was not a significant difference between the patients (25) that had an incomplete erection and the ones (10) with a rigid erection not sustained,  $p=0.000$ . The values for the patients<sup>15</sup> with a normal (rigid) erection were lower and significantly different from all the others with a  $p>0.05$ .

### Discussion

The etiology of ED is still not well known and due to lack of criteria and of therapeutic guidelines, recently many specialists prescribe oral drugs (Sildenafil Citrate and Phentolamine Mesylate) as a therapeutic probe, when first dealing with impotence in patients not being clear the true old enigma of the ED. However, it is felt that it is still a controversial matter and it deserves further research based on data from patients with erectile dysfunction.

The International Index of Erectile Function (IIEF) is only a general measure of sexual function and although it has been used in many countries as a clinical assay<sup>17</sup>. It does not fully satisfy the patient who wants to know more than a score on his impotence, before starting treatment.

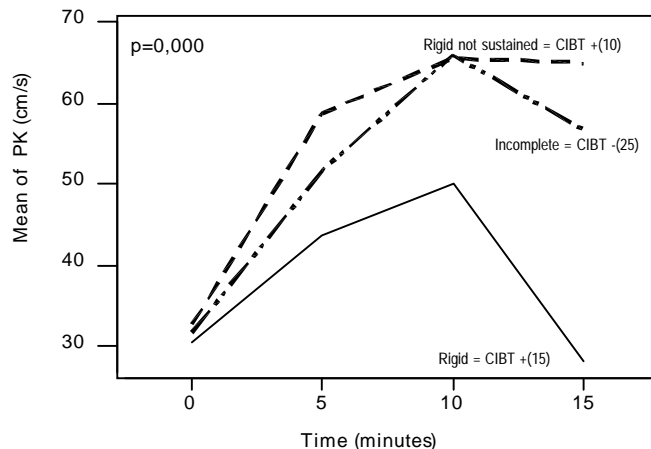
It is known that CIBT as an isolated test has a low sensitivity and can produce false-negative results. On the other hand, borderline cases or the ones with light to moderate venoocclusive dysfunction, where the systemic systolic pressure is transferred to the erectile channels with low loss of energy (borderline pressure gradient), are considered normal with a positive response to CIBT<sup>10</sup>.

We still do not have a method to quantify the pool of erectile tissue of the corpora cavernosa, in normal or pathological cases of erectile dysfunction.

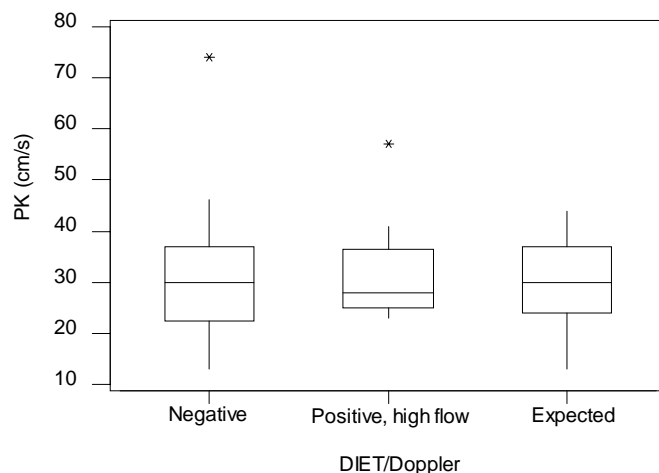
Recent studies show that an adequate arterial flow is not a guarantee of a rigid erection. The cavernous artery is involved in the beginning and upkeep of erection, but anastomotic channels (microarterioles) and other arteries (dorsal and urethral) can produce venoocclusive dysfunction<sup>18</sup>.

Considering the enigmas facing the evaluation of the impotent man, we suggest a study combining CIBT to the penile Continuous Wave Doppler (CWD), where the hemodynamic parameter (PSV) will be characterized in the last phase of CIBT.

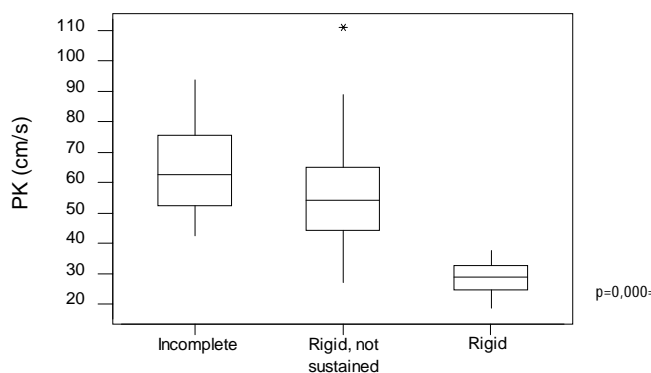
In the first stage of the study (t.0), PSV were not different, no matter what erectile response it was obtained, suggesting that the cause of ED was not primarily of obstructive arterial etiology. The peak systolic velocities were also measured at 10 minutes after ICI showing an increase of the arterial blood flow to values between 50 and 60 cm/s independently of the erectile



**Figure 4.** Average values of Peak Systolic Velocities (Pkm) in the four phases of the erectile cycle and correlations to responses in CIBT. Erection rigid, not sustained (10)=positive response; incomplete erection (25)=negative response; rigid erection (15)= positive response.



**Figure 5.** Distribution of values of PK in the stage of penile flaccidity, in the first phase of CIBT. The values are concentrated in the range of 20 to 40 cm/s, independent of erectile response. There were no statistical significant differences between the values,  $p=0.896$



**Figure 6.** Distribution of values of PK in the fourth phase of CIBT. The values of PK in patients with incomplete erection and rigid erection not sustained did not show statistically significant differences,  $p=0.000$ . In patients with rigid erection the values of PK were significantly lower when compared with the two other groups,  $p>0.05$

response, demonstrating that in these case studies the patients had a satisfactory response to the pharmacological stimulus attaining the phase of penile tumescence (Table 1).

In the last stage of CIBT (t.15) the average values of PSV were different between patients according to the erectile response. Patients with incomplete erections or erections not sustained, showed the same pattern recorded tracing of velocity of flow "High velocity" and the differences were not statistically significant. However, patients with rigid erections (normal) had the "Expected velocity", and the average PSV had a significant difference compared to the others ( $p > 0.05$ ) suggesting an adequate venoocclusive system in these patients.

Our results with the 15 patients showing "Expected" patterns of flow velocity in the fourth phase of CIBT ( $PK_m = 27.9$  cm/s,  $SD = 1.4$ ) and normal erection agree with the observations of CORMIO et al, 1996<sup>9</sup>. They studied 92 patients and obtained 18% of the values of PK lower than 35 cm/s, and a resistance index higher than 0.9 indicating normal venoocclusive functions. Ten patients in our study, who showed patterns of "High velocity" in the same phase of CIBT ( $PK_m = 65.1$  cm/s;  $SD = 5.3$ ), and rigid but not sustained erections, could be considered as borderline. In these cases, erections may occur, but they are not maintained (fleeting erection) due to a borderline pressure gradient where there is low pressure on the helicine arterioles, coexisting or not with a light venoocclusive dysfunction. Patients in this condition can overcome the low pressure on the arterioles by an exogenous vasoactive drug stimulus.

Several studies confirm our observations with these patients<sup>9,10,19</sup>, indicating that the borderlines are considered CIBT positive because they have a "functional" (non physiological) erection of short duration. Tests of artificial erection induce non-physiological erections due to a high compensatory flow added to a slightly deficient venoocclusive system.

As to the 25 patients with the "High velocity" pattern ( $PK_m = 56.8$  cm/s;  $SD = 3.8$ ) and incomplete erections, it is highly suggestive that they have a medium to severe venoocclusive dysfunction. Our results, relating abnormal erections (incomplete and rigid not sustained) to "High velocity" of flow and suggesting vascular impotence agree with the ones of BUVAT and colleagues in 1986<sup>19</sup>. By employing dynamic cavernosography and drug-induced erection test, they classified their patients in two categories according to the maintenance flow rates as moderately elevated and severely elevated. Of the 56 patients seen by these authors, 13 psychogenic ones had a normal drug-induced erection with a maintenance flow only moderately elevated, as compared with 52.5% of patients that had an abnormal drug-induced erection with presumable vascular impotence.

The correlations between PK at 15 minutes after CIBT and the erectile response indirectly reflect the integrity of the penile venoocclusive system, but one cannot discard some level of arterial lesion in these patients.

Our results superimpose the ones by HATZICHRISTOU and colleagues, 1999<sup>18,20</sup>. They evaluated the maintenance flow in ml/minute and the intracavernosa mercurial pressure (parameters of the venoocclusive function). They found an inverse correlation between intracavernosa pressure and flow velocity, that is, the intracavernosa pressure increases as the maintenance flow decreases.

The present study indicates that the research on ED through the association of CWD to the last phase of CIBT, offers a hemodynamic parameter measured in an objective manner, minimally invasive to the patient and being able to be carried out by

the urologist.

## Conclusions

Continuous Wave Doppler can be used to evaluate the idiopathic erectile dysfunction, and as a complement to CIBT, providing a hemodynamic parameter at blood flow arterial of the penile measurable in a practical and objective manner.

By analyzing averages and distribution of values of PK in the phase of penile flaccidity, it was concluded that adequate values in the arterial penile supply does not necessarily mean a rigid erection (physiological) response.

The CWD associated to CIBT showed two patterns of printing press of blood flow velocity: "Expected velocity" and "High velocity". They were characterized through values of mean peak flow ( $PK_m$ ) in the fourth phase of CIBT. "Expected velocity" and "high velocity" were associated to each type of erectile performance. Rigid erection (physiological), and Incomplete or fleeting erections (functional) showed two pattern of printing press.

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