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PENILE BLOOD FLOW INDEX (PBFI): A PARAMETER FOR THE EVALUATION OF TOTAL PENILE ARTERIAL FLOW

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Objective: *Our objective was to develop a single parameter that will adequately express the results of color duplex Doppler ultrasonography penile arterial blood flow studies.*
Material and methods: *We have studied 124 impotent patients with a mean age of 47 years (19-75, SD 13.71). Diameters of cavernosal arteries were measured using duplex Doppler ultrasound. Peak systolic velocities (PSV) were also evaluated. After the initial ultrasound, papaverine-HCl was injected into the corpora cavernosa. The arterial diameters of both cavernosal arteries, PSV and end diastolic velocity (EDV) of cavernosal arteries were measured again. Following these measurements, Penile blood flow index (PBFI) was calculated. Statistical analysis using linear discrimination, correlation coefficients and Student-t test was performed.*
Results: *According to Doppler ultrasonographic parameters, 44 out of 124 patients were classified as arteriogenic impotent and 80 as non-impotent. Screening tests were performed for PBFI and values which were greater than 210 were accepted as normal arterial vascularity and values less than 210 were accepted as arterial failure ($p<0.01$). According to the PBFI, 40 patients were classified as arteriogenic impotence. In arteriogenic patients, PBFI was found as 177.11 ± 33.65. and in non-arteriogenic patients was found as 287.12 ± 45.84. Statistically analysis was found significantly different (Student-t, $p<0.01$). In the diagnosis of arteriogenic impotence, it was seen that PBFI had 88.5 % sensitivity and 98.4 % specificity.*
Conclusion: *The increase of arterial diameter and PSV can be used for the evaluation of arterial insufficiency. PBFI is a single parameter that incorporates velocity and arterial dilatation of both cavernous arteries. Finally, we can easily say that penile blood flow index may be made great use of this functional study of the penile arteries.*

Key words: *Impotence, doppler ultrasonography, penil blood flow index*

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Penil arteryel kan akım hızı değerlendirmesinde penil kan akım indeksi (PBFI)

Amaç: *Renkli dupleks Doppler ultrasonografi ile yapılan penil arteriyel kan akımı çalışmalarının sonuçlarını açıklayabilecek tek bir parametre geliştirmekti.*
Materyal ve Metod: *Ortalama yaş 47 olan (19-75 SD 13.71), 124 empotan hasta araştırıldı. Doppler ultrasonografi kullanılarak kavernosal arter çapları ölçüldü. Peak sistolik akım hızları (PSV) değerlendirildi. Başlangıç ultrasonografisinden sonra korpus kavernozum içerisine papaverine-HCl enjekte edildi. Bu işlemden sonra kavernozal arter çapları, PSV ve end diastolik akım hızları ölçüldü. Bu ölçümlerden sonra penil blood flow indeks (PBFI) hesaplandı. Lineer diskriminasyon, korelasyon koefisenti ve Student-t testleri kullanılarak istatistik analiz uygulandı.*
Sonuçlar: *Doppler ultrasonografi parametrelerine göre 124 hastanın 44'ü arteriyojenik, 80'i ise nonarteriyojenik empotans olarak sınıflandırıldı. PBFI için tarama test uygulandı ve PBFI değeri ≥210 olanlar normal arteriyel kanlanma, PBFI değeri < 210 olanlar arteriyel yetmezlik olarak saptandı. PBFI değerlerine göre 40 hasta arteriyojenik empotans olarak yorumlandı.Arteriyojenik empotans olgularında PBFI değeri 177.11 ± 33.65, nonarteriojenik empotans olgularında 287 ± 45.84 bulundu ($p<0.01$). Arteriojenik empotans tanısında PBFI'in sensitivitesi % 88.5, spesivitesi % 98.4 olarak saptandı.*
Yorum: *Arteriyel çap artımı ve PSV empotansda arteriyel yetmezlik tanısı için kullanılmaktadır.Kavernozal arterlerdeki akım hızı ve arter dilatasyonunu bir tek parametrede birleştiren PBFI'in penil arterlerin fonksiyonel değerlendirmesinde büyük yarar sağlayacağını söyleyebiliriz.*

Anahtar kelimeler*: Empotans, doppler ultrasonografi, penil blood flow index*

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Penile erection is a haemodynamic event under autonomic neurological control mediated by changes of the cavernous smooth muscle tone. Impotence is defined as the inability to achieve or maintain an erection[1].

In recent years, studies on erectile dysfunction have focused mostly on organic etiology and there have been significant advances in our understanding of the haemodynamics of penile erectile physiology which have resulted in the identification of specific and potentially correctable vascular disease.[2,3,4] Various reports have emphasized that in 35-45 % of cases an arterial or venous system insufficiency could be identified. As more became known on this subject, new medical or surgical treatment options arose. Imagining clearly has diagnostic importance that would lead to the best treatment choice.[5,6,7]

Doppler ultrasound was utilized in the various studies of the penile vascular system. These studies indicated different values for Doppler parameters that would differentiate between normal vascular responses and vascular insufficiencies.[4,7-15]

The earlier studies relied on measurements of vessel diameter change and peak blood flow velocity to determine arterial function. The most widely used and also most controversial Doppler ultrasonography parameters for the diagnosis of arterial insufficiency are the increase of penile arterial diameter and peak systolic velocity (PSV) after intracavernosal injection.[4,8,11-13] With the results studied previously, greater than 70 % dilatation and a 25-35 cm/sec peak systolic velocity for each cavernous artery were established as normal.[7,15]

There are discrete disadvantages in using either of these criteria for establishing normal such as significant anatomical variation of penile arterial anatomy.

The aim of this study is to develop a single parameter that will adequately express the result of a color duplex Doppler ultrasonography penile arterial blood flow study.

PATIENTS AND METHODS

In this study, we have examined 124 patients with mean age of 47 years (19 -75, SD 13.71). Erectile disorders had been reported for at least two months. All patients were submitted to an extensive work-up including detailed history, physical examination, laboratory analysis (serum glucose level, cholesterol, trigliseride, AST, ALT), and hormone analysis (testosterone, FSH, LH, prolactin).

Color Doppler ultrasonography was carried out with a Toshiba 270 SSA, 7.5 MHz transducer. Cavernosal arteries were identified along their entire course from the crura to the apex of the penis and their diameters were measured on the inner output of the arterial wall. Measures were taken at the mid-shaft and PSV was also evaluated. After the initial ultrasound examination, 2 cc papaverine-HCl (60 mg) was injected into the corpora cavernosa. The arterial diameters of both cavernosal arteries, PSV and end diastolic velocity (EDV) of cavernosal arteries were measured at the mid shaft after 10 minutes of intracavernous injection.

After these measurements, penile blood flow index was calculated. Penile blood flow index, using dilatation and velocities in both cavernous arteries, was calculated as shown. If the PBFI was greater than 285, impotence was classified as nonarteriogenic.[15]

$$PBFI=(R_2-R_1)Right/R_1x100+(R_2-R_1)Left/R_1x100+PSVRight+PSV\ Left$$

R_2= Post injection diameter
R_1= Pre injection diameter
PSV= Peak systolic velocity

Statistical analysis was performed using linear discrimination, correlation coefficients and Student-t test.

RESULTS

We accepted arterial failure criteria as the cavernous artery PSV less than 35 cm/sec, the sum of peak flow velocity of both cavernous arteries less than 70 cm/sec, and the sum of the percentage of the dilation of both cavernous arteries less than 140.

According to the Doppler ultrasonographic parameters, 44 patients out of 124 were diagnosed as arteriogenic impotence and 80 as non-arteriogenic impotence. In arteriogenic patients, we found that total PSV was 11.3± 3.7 cm/sec and total arterial diameter increase was 20.84±15.45. In nonarteriogenic group total PSV was observed as 49.95±24.73 and total arterial diameter increase as 173.04± 32.08. The differences between these two groups were statistically significant (Student-t, $P<0.001$).

Screening tests were performed for PBFI and values which were greater than 210 were accepted as normal arterial vascularity and values less than 210 were accepted as arterial failure, depending on this cut-off value ($p<0.01$). According to the PBFI, 40 patients were diagnosed as arteriogenic impotence. In arteriogenic patients, PBFI was found as 177.11 ± 33.65. and in non-arteriogenic patients as 287.12±45.84. The difference was found to be significant (Student-t, $p<0.01$).

PBFI was observed to be correlated 85 % with total arterial diameters increase and 90 % with total PSV. In the diagnosis of arteriogenic impotence, it was observed that PBFI had 88.5 % sensitivity and 98.4 % specificity.

We found a signicant difference between PBFI and the increase of penile arterial diameter ($r= 0.85$, $P<0.001$), and a significant difference between PBFI and total PSV ($r= 0.90$, $p<0.001$).

DISCUSSION AND CONCLUSION

Color Doppler ultrasonography is of dramatic value in the investigation of the haemodynamics of penile erection. Duplex Doppler ultrasonography combined with pharmacological stimulation of erections appears to be the best test. Penile arterial vascularity can be exhaustively evaluated; the possible application of these diagnostic procedures in the study of veno-occlusive mechanism needs further exploration.[4,8,12,13]

The increase of arterial diameter and PSV can be used for the evaluation of arterial insufficiency. If the PSV of each cavernous artery after vaso-active agent stimulation was greater than 35 cm/sec, the impotence was classified as non-arteriogenic; otherwise, it was classified as arteriogenic. However, PSV values of 20 cm/sec, 25 cm/sec, 30cm/sec and 35 cm/sec were proposed as other cut-off values discriminating the normal from insufficient flow. [4,7,8,12,13,14] The sum of the peak blood flow velocities of both cavernous arteries after the pharmacological stimulation was used as a parameter for classification of arterial pathology.

The most widely used and also most controversial Doppler US parameter for the diagnosis of arterial insufficiency is PSV. Lue et. al reported that PSV values below 25 cm/sec are highly diagnostic of severe arterial insufficiency[10]. Later, PSV values of 20 cm/sec[11], 25 cm/sec[4,7,8,12], 30 cm/sec and 35 cm/sec (14) were proposed as other cut-off values discriminating the normal from insufficient flow. Benson[7] has defined the PSV values below 25 cm/sec as severe arterial insufficiency whereas values between 25-34 cm/sec were considered to have borderline arterial insufficiency.

There are two disadvantages in using either of these criteria for defining normal. The first disadvantage is due to the significant anatomical variation of penile arterial anatomy. These anatomical variations may affect the performance and interpretation of a Doppler study. The second disadvantage is that the number of parameters generated with either method of interpretation is cumbersome to use in statistical analysis of patient populations.[15]

If a single parameter was available to express the results of the penile duplex Doppler ultrasound study, this examination could also be used for statistical analysis to determine prognosis by comparing the results of the patients groups who had undergone treatment.

The PBFI incorporates blood flow velocity and arterial dilatation. It is more reflective of the status of the intrapenile arteries than arterial velocities alone and arterial dilatation.[15]

The accepted value of PBFI for the arteriogenic impotence is 285.[15] Using screening tests between the values of PBFI of arteriogenic and non-arteriogenic impotence patients, we found cut-off point as 210.

If the sum of the percentage of the dilatation of both cavernous arteries after the pharma-cological stimulation was greater than 200 the impotence was classified as nonarteriogenic; otherwise, it was classified as arteriogenic. But, to date, it is an unreliable parameter due to the anatomical variation of penile arteries and position of the transducer. It is reasonable to to say that PBFI is as a significant parameter on the penile haemodynamic investigation and we believe that it can be an acceptable parameter for the arterial structure.

In conclusion we can say that penile blood flow index may be made great use of this functional study of the penile arteries.

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