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RESEARCH ARTICLE

RELATION BETWEEN BLADDER OUTLET OBSTRUCTION AND SYSTEMIC VASCULAR ENDOTHELIAL DYSFUNCTION IN THE MALE. A PRELIMINARY STUDY.

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Abstract

Hypothesis / aims of study: It is well recognized that endothelial dysfunction is strongly related to lower urogenital problems such as erectile dysfunction, which shortly precedes clinical coronary arterial occlusion. The study aims to investigate the potential correlation of systemic vascular endothelial dysfunction and coronary artery disease (CAD) with bladder outlet obstruction (BOO).

Study design, materials and methods: Thirty men age 50 years and older (mean=62.7 years ±14.6) with mild to severe LUTS were enrolled and gave written consent. All patients underwent pressure flow study and simultaneous non-invasive recording of detrusor tissue oxygenation and hemodynamics with Near Infrared Spectroscopy (NIRS). Systemic endothelial integrity was assessed by measurement of inflammatory and endothelial-prothrombotic markers such as Endothelin-1 (ET-1), Interleukin-6 (IL-6), Asymmetric Dimethylarginine (ADMA) and N-terminal C-type natriuretic peptide (NT-pro CNP). CAD, defined as occlusion of coronary arteries, was also recorded. IBM-SPSS ver. 22 was used for the statistical analysis.

Results:- Logistic regression model was applied to examine whether BOO – as diagnosed properly with the standard Pressure Flow study and also by estimation of detrusor muscle oxygenation with the NIRS technique – correlates with vascular lesions. Elevated values of ET-1 and IL-6 were found, but they were not statistically significant. NIRS showed a specificity of 88% and a sensitivity of 79% in diagnosing BOO. Also, a sevenfold increase was found in the likelihood of BOO in patients with CAD.

Interpretation of Results: Elevated biochemical markers of endothelial dysfunction such as ET-1, and IL-6 as well as by the sevenfold increase in the likelihood of BOO in coronary patients suggest that there may be a correlation between lower urinary tract dysfunction and vascular occlusion. With the limitation of the small sample size, a common pathophysiological background may exist such as impaired blood perfusion of the bladder and/or prostate. This is also supported by the use of NIRS that assesses obstruction through detrusor oxygenation impairment.

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Concluding Message: Bladder outlet obstruction may be related to endothelial dysfunction and coronary artery disease. Also, NIRS may be a good alternative for non-invasive urodynamic studies in the assessment of bladder outlet obstruction.

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Introduction:-

The aim of this study is to investigate the potential relationship of systemic vascular endothelial dysfunction with the function of the urinary bladder in patients with bladder outlet obstruction (BOO). Epidemiological studies suggest atherosclerosis as a common risk factor between cardiovascular diseases and erectile dysfunction (ED) (Elzanaty et al, 2016). Chronic bladder ischemia is potentially a common cause of lower urinary tract symptoms in the elderly (Nomiya et al, 2015). We examine if impaired perfusion of the detrusor muscle due to systemic vascular disease affects the function of the bladder. It is also attempted to classify patients as obstructive and non-obstructive with a non-invasive method, and to correlate the non-invasive method with the gold standard pressure flow study. Several non-invasive tests have been developed for diagnosing bladder outlet obstruction (BOO) in men, to avoid the burden and morbidity associated with invasive urodynamics. Urodynamic study, is an accurate but potentially uncomfortable test for patients in diagnosing bladder problems such as obstruction (Malde et al, 2016). With Near Infrared Spectroscopy (NIRS) the detrusor muscle perfusion is assessed in normal and obstructive patients (Vlachopoulos et al, 2008). It is one of the few studies that examines the relationship between bladder outlet obstruction, endothelial dysfunction and coronary artery disease.

In addition, systemic vascular function is assessed with measurement of inflammatory and endothelial-prothrombotic markers such as Endothelin-1, Intereleukin-6, Asymmetric Dimethylarginine and N-terminal C-type natriuretic peptide (ET-1, IL-6, ADMA, NT-pro CNP) (Vlachopoulos et al, 2008).

Patients and Methods:-

The study was performed at the Neuro-urology outpatient clinic of the First Department of Urology, Aristotle University of Thessaloniki, Greece. Thirty (n=30) consecutive male patients aged 50 and over, were enrolled from September 2012 until June 2014, with symptoms of bladder outlet obstruction. Patients with active urinary tract infection, history of radical prostatectomy, scar of previous pelvic surgery and chemotherapy for other, unrelated disease were excluded from the study (Macnab and Stothers, 2008). The protocol for this study has been approved by local Ethics Committee of Aristotle University and conforms to the provisions of the Declaration of Helsinki.

Each patient had a detailed medical history, personal history, sociodemographic data, and Body Mass Index (BMI) measurement. The Greek version of the International Prostate Symptom Score (IPSS) Questionnaire was used for the assessment of symptoms. Then, urodynamic pressure-flow study (PFS) was performed, with recording of micturition parameters such as detrusor pressure before micturition, opening pressure, opening time, time to maximal flow, and post voiding urine residual. Simultaneous transcutaneous NIRS of the bladder was performed during the PFS (URO-NIRS, Urodynamix Technologies Ltd., Vancouver, BC, Canada). (Fig 1.) This device, noninvasively, records changes in the concentration of haemoglobin and deoxyhaemoglobin in living tissues. It utilizes the emission of light (photons) through tissues and measures photon absorption by haemoglobin. NIRS optodes are placed on the abdomen 2 cm above the pubic symphysis across the midline. It is a mean of assessing tissue oxygenation and, indirectly, blood perfusion (Macnab and Stothers, 2008, Hamaoka et al, 2007, Stothers and Macnab, 2008, Fawzy et al, 2013)

Fig 1:- URO-NIRS, Urodynamix Technologies Ltd., Vancouver, BC, Canada.

All patients had a biochemical screen of blood urea, creatinine, cholesterol, triglycerides, high density lipoproteins (HDL), low density lipoproteins (LDL), Atheromatous Index (A.I.) and urinalysis. Also measurement of circulating markers of endothelial dysfunction (ADMA, ET-1, NT-proCNP, Il-6) in the peripheral blood was performed. No patient required admission to hospital for the purpose of the study.

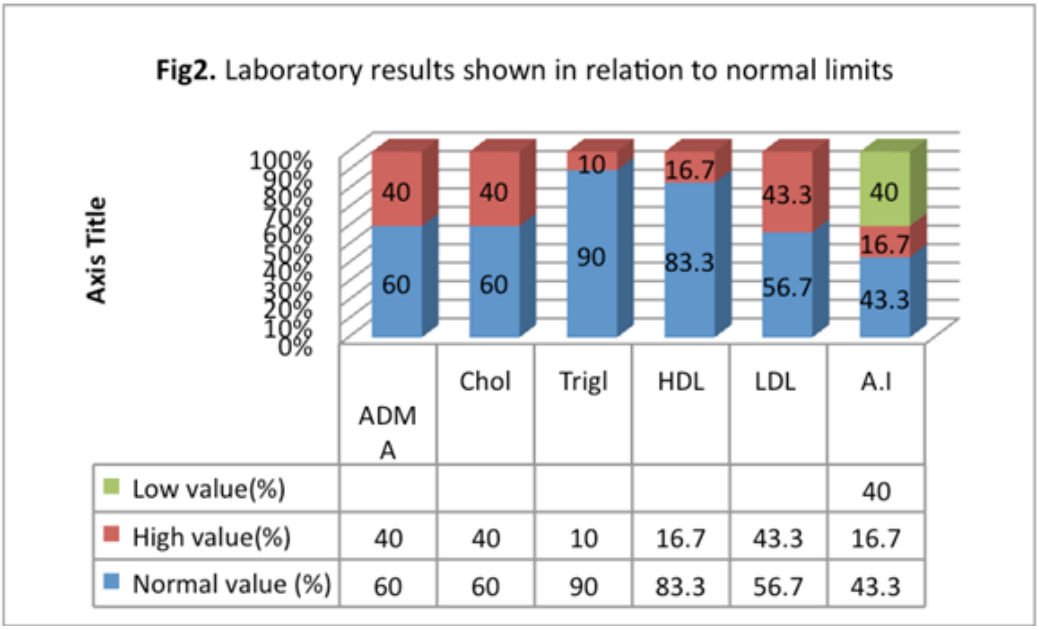
Statistical analysis was performed using IBM SPSS Statistics v.22. NIRS data was filtered using a second-order Butterworth low-pass filter, with a cut-off frequency of 0.2 Hz. Median (range) demographic, urodynamic, and NIRS parameters were calculated. The Mann Whitney *U* test was applied to test the differences between groups. Differences with *P* values less than 0.05 were considered statistically significant. We used binary logistic regression models to examine to what extent, prior CAD, can predict bladder outlet obstruction.

Results:-

The study population comprised of 30 males. The mean age was 62.7 years (±14.6). Population demographics are detailed in Table 1. Forty per cent of the participants had a body mass index (BMI) within normal limits, and the rest were overweight or obese. Eight patients were smokers, and half of the patients consumed alcohol only occasionally. Their medical histories included arterial hypertension (11/30), dyslipidaemia (7/30), and diabetes mellitus (3/30); 22/30 patients had a history of some surgical operation. Six of the 30 patients had coronary artery disease, and only 3/30 gave a family history of CAD.

To detect BOO, we used both the steady pressure-flow study (PFS) and the NIRS technique, by calculating detrusor muscle perfusion. BOO was detected in 19/30 (63%) participants with the pressure-flow study, and in 17/30 (57%) participants with the NIRS device. **(Table 2)**

The Greek version of the International Prostate Symptom Score (IPSS) Questionnaire was used for the assessment of symptoms. The mean IPSS score was 14.7±6.9 and the mean IPSS Quality index was 3.7±1.3. According to the IPSS grading, as shown in **Table 3**, more than half of the patients had moderately severe symptoms (range 8-19). As mentioned in Patients and Methods, the participants had laboratory measurements of total plasma cholesterol, triglycerides, HDL and LDL, and the Atheromatous Index (A.I.). Additionally, plasma levels of IL-6, ADMA, ET-1 and NT-proCNP, as markers of endothelial dysfunction, were measured. **Table 4** shows the mean values of the above laboratory studies for our patients. According to the laboratory reference range, most patients had values within normal limits for ADMA (18/30), total cholesterol (18/30), triglycerides (27/30), HDL (25/30), and LDL (17/30). As regards the A.I., 5/30 patients had values above 5.9 (normal range for males: 3.8-5.9), 13/30 were within normal limits, and 12/30 below 3.8. (**Figure 2**)



Comparison of laboratory values, in obstructed patients as detected with the PFS study, showed that these patients had higher mean values for ET-1, IL-6 than patients without obstruction, but these differences were not statistically significant. In all the other studies patients without outlet obstruction had non-statistically significant higher values (**Table 5**).

Comparison of laboratory values showed that patients with BOO as detected with the NIRS method, had higher mean values for ET-1, IL-6 and HDL, compared to patients without BOO. These differences were not statistically significant. In all the other studies, patients without bladder outlet obstruction had non-statistically significant higher values (**Table 6)**.

In both groups, those tested for BOO with the PFS and those tested with NIRS, it was found that obstructive patients were overweight while those without BOO had normal BMI, though the differences were not statistically significant (**Table 7**).

Table 1:- Population Demographics.

	n/N	%
SEX		
Males	30/30	100
MARRITAL STATUS		
Single	3/30	10
Married	26/30	86,7
Widow	1/30	3,3
EDUCATION		
University	8/30	26,7
High School	13/30	43,3
Elementary School	8/30	26,7
Analphabet	1/30	3,3
LIVING PLACE		
Village	2/30	6,7
Small town	5/30	16,7
City	23/30	76,7
WORKING STATUS		
Retired	18/30	60
Working	11/30	36,7

Unemployed	1/30	3,3
	Median	
AGE (years)	62,7	
YEARLY INCOME (€)	14.300	

Table 2:- Diagnosis of bladder outlet obstruction with PFS and NIRS

Bladder outlet obstruction (urodynamic study/PFS)	**n/N**	**%**
Obstructed	19/30	67
Non-Obstructed	11/30	33
Bladder outlet obstruction (NIRS)		
Obstructed	17/30	57
Non-Obstructed	13/30	43

Table 3:- Symptoms and quality of life according to the IPSS (International Prostate Symptom Score)

	Mean	**SD (95% CI)**
IPSS	14.7	±6.9 (12.1-17.3)
IPSS QUALITY	3.7	±1.3 (3.2-4.2)
IPSS grading		
Mild (Low)	5/30	16,67
Moderate	20/30	66,67
Severe (High)	5/30	16,67

Table 4:- Laboratory values in plasma (IL-6 Interleukin 6) (ADMA Asymmetric Dimethylarginine) (ET-1 Endothelin 1) (HDL High Density Lipoprotein) (LDL Low Density Lipoprotein) (AI Atheromatous Index) (NT-pro CNP N-terminal C-type natriuretic peptide)

Laboratory test	**Mean**	**SD (95% CI)**
IL-6	4.5	±3.7 (2.4-6.6)
ADMA	0.8	±0.3 (0.6-0.9)
NT-pro CNP	7.2	±4.3 (5.6-8.8)
ET-1	4.7	±3.3 (0.8-8.5)
Cholesterol	199.5	±41.9 (183.9-215.1)
Triglycerides	131	±57.7 (110.5-153.6)
HDL	48.1	±13.3 (43.2-53.1)
LDL	123.9	±35.3 (110.7-137.1)
A.I.	4.5	±1.9 (3.8-5.2)

Table 5:- Comparison of laboratory values between patients with and without bladder outlet obstruction (Pressure Flow Study)

	Obstruction	**No obstruction**	**p-value**
ET-1	6.5±12.7	1.6±0.8	0.847
ADMA	0.7±0.2	0.9±0.4	0.332
IL-6	5.6±6.6	2.8 ±3.5	0.188
NT-proCNP	7.9±5.1	6.3±2.2	0.809
Cholesterol	198±45	208.3±39.3	0.554
LDL	123.7±39.2	129.9±29.4	0.677
HDL	46.2±10.4	49.1 ±18.2	0.665
Triglycerides	131.5±46.1	148.9±75.8	0.629
AI	4.4 ±1.2	4.9±2.9	0.885

Table 6:- Comparison of laboratory values between obstructive and non-obstructive patients according to the NIRS method.

	Obstruction	No obstruction	p-value
ET-1	6.6±13.6	2.8±4.2	0.827
ADMA	0.7±0.3	0.8±0.4	0.577
IL -6	5.2±6.9	4.2 ±4.2	0.924
NT-proCNP	7.5±4.6	7.5±4.4	0.716
Cholesterol	196.8±48.8	212±31.7	0.43
LDL	121.3±42.3	134.6±24.3	0.311
HDL	49.1±9.5	45.3 ±17.5	0.517
Triglycerides	120.7±42.2	161.4±69.7	0.07
AI	4.1 ±1.1	5.3±2.6	0.078

Table 7:- Differences in BMI between obstructed and non-obstructed patients as detected by the two diagnostic methods. (BMI Body Mass Index)

BMI category	Obstruction	No obstruction	p-value
Pressure Flow Study			
Normal	26.3% (5/19)	55.6% (5/9)	0.249
Overweight	52.6% (10/19)	22.2% (2/9)	
Obese	21.1% (4/19)	22.2% (2/9)	
NIRS			
Normal	31.2% (5/16)	45.5% (5/11)	0.749
Overweight	43.8% (7/16)	36.4% (4/11)	
Obese	25% (4/16)	18.2% (2/11)	

(CAD Coronary Artery Disease)

We used binary logistic regression models to examine to what extent certain diseases, such as CAD, can predict bladder outlet obstruction. The likelihood of developing BOO, as diagnosed by urodynamic studies, was increased sevenfold in patients with coronary artery disease (p= 0.119). Finally, we used a logistic regression model to examine to what extent can bladder outlet obstruction (detected by monitoring detrusor muscle perfusion by the NIRS device) predict CAD and vascular lesions. This analysis showed that patients with BOO had a threefold higher likelihood of developing CAD (OR: 3.3 95%CI: 0.3-34.8 p= 0.315). To determine the operating characteristics of the NIRS method for the detection of bladder outlet obstruction, compared to the gold standard of the urodynamic study, we calculated the sensitivity, specificity, positive and negative predictive value, as well as the likelihood ratio. The sensitivity of the method was 79 percent, that is, NIRS detects BOO in 79 out of 100 individuals with BOO detected by the urodynamic study. The specificity of the method was 88 percent, meaning that 88 percent of individuals without bladder outlet obstruction in the urodynamic study also have negative results in the NIRS study. The positive predictive value was 93.8 percent, which means that 93.8 percent of patients with BOO in the NIRS study actually have bladder outlet obstruction. The negative predictive value was 63.6 percent, that is, 63.6 percent of patients with negative results in the NIRS study do not have bladder outlet obstruction. Finally, the likelihood ratio was 6.6, meaning that the likelihood of detecting BOO in a person with bladder outlet obstruction is 6.6 times higher than in a person without BOO.

Discussion:-

This is one of few studies that examines the relationship between bladder outlet obstruction and endothelial dysfunction. BOO is evaluated with the gold-standard pressure-flow study, and compared with NIRS. Additionally, systemic endothelial function is assessed with the measurement of the inflammatory and pro-thrombotic circulating markers ET-1, IL-6, ADMA, and NT-proCNP. Moreover, using NIRS we can assess detrusor muscle perfusion in both normal and obstructive patients (Fawzy et al, 2013). Although our sample was limited (n= 30), our study appears to have clinical implications. There is evidence that bladder outlet obstruction is related to endothelial dysfunction. This is suggested by the elevated values of ET-1, IL-6. Secondary, the sevenfold increase in the likelihood of BOO in coronary patients suggests a possible connection between the two pathological situations, result also seen in a recent review (Russo et al, 2015). Endothelial inflammation may cause endothelial dysfunction and is a risk factor for heart disease. ET-1 is a vasoconstrictive and pro-inflammatory peptide (Macnab and Stothers,

2008). Under normal circumstances this peptide is a paracrine secretion of endothelial cells, but can also by synthesized by macrophages (Gimbrone et al, 1997). Raised plasma values have been reported in patients with atherosclerosis, and may be associated with diffuse endothelial cellular dysfunction (Bocchio et al, 2004, Bohm and Pernow, 2007). Moreover, all patients with BOO are overweight; and this observation is in accordance with a large review of 2009 (Parsons et al, 2009). BOO, endothelial dysfunction and coronary disease show the same age distribution in males. It is quite significant that this distribution is between the sixth and eighth decade of life, and this should be kept in mind in the frame of the aging male (Gacci et al, 2016). Moreover, there is a recent observation that men have a greater atheromatous burden and more diffuse cardiac endothelial dysfunction than women, even in the early stage of atherosclerosis.

Bladder outlet obstruction affects a large segment of the male population above the age of 60 years. Thus, it will be very interesting if it proves to be an independent prognostic factor for the development of coronary disease. The findings so far are not statistically significant, but they seem to be clinically important.

To examine whether BOO – as diagnosed by estimation of detrusor muscle perfusion with the NIRS technique – can predict CAD and vascular lesions we used a logistic regression model. This analysis showed that patients with BOO had a threefold higher likelihood of developing CAD (OR: 3.3, 95% CI: 0.3-34.8, p= 0.315).

NIRS uses light to record, noninvasively and in real time, changes in the tissue concentration of oxyhemoglobin and deoxyhemoglobin. In Urology, infrared spectroscopy can be used in cases where detrusor muscle ischemia may coexist, as for instance during changes in local detrusor pressure in bladder outlet obstruction. NIRS can assess patients with disorders of micturition and classify them as obstructive and non-obstructive (Hamaoka et al, 2007, Stothers and Macnab, 2008, Macnab and Stathers, 2007, Stothers et al, 2008).

The initial results of comparison with the conventional and established pressure-flow study are encouraging. Its sensitivity was calculated at 79 percent, specificity at 88 percent, positive predictive value at 93.8 percent, negative predictive value at 63.6 percent, and the likelihood ratio (LR) at 6.6. Therefore, given that we can detect 80 percent of the obstructive patients non-invasively, it is possible that in the future there will be no need to submit patients to the uncomfortable and invasive urodynamic study as we will be able to classify them as obstructive and non-obstructive non-invasively and reliably (Vlachopoulos et al, 2008). These results are similar with another 2 small volume papers, found in the literature (Fawzy et al, 2013, Zhang et al, 2013, Yurt et al, 2012). Still, there are some authors, saying that the near infrared spectroscopy algorithm does not appear to provide substantial clinical usefulness in diagnosing bladder outlet obstruction in men with lower urinary tract symptoms (Chung et al, 2010).

Finally, it appears that infrared spectroscopy can monitor the physiologic changes that take place in the detrusor muscle during filling and voiding of the bladder. However, further studies are required to validate the diagnostic algorithms based on changes in the concentration of blood pigments.

Conclusions:-

Out of the small sized sample, clinical implications may rise. There is evidence that bladder outlet obstruction is related to endothelial dysfunction. This is suggested by the elevated values of ET-1, and IL-6 as well as by the sevenfold increase in the likelihood of BOO in patients with CAD.

The second important conclusion is that NIRS can assess patients with disorders of micturition and classify them as obstructive and non-obstructive. The initial results of comparison with the conventional and established pressure-flow study are encouraging. Is this the future of non-invasive pressure flow study?

The potential clinical implication of our basic research, may lead to further experimental investigations.
Conflict of interest: There is no conflict of interest.

References:-

1. Bocchio M, Desideri G, Scarpelli P, Necozione S, Properzi G, Spartera C et al. Endothelial cell activation in men with erectile dysfunction without cardiovascular risk factors and overt vascular damage. J Urol 2004; 171: 1601-1604.
2. Bohm F, Pernow J. The importance of endothelin-1 for vascular dysfunction in cardiovascular disease. Cardiovasc Res 2007; 76: 8-18.
3. Chung DE, Lee RK, Kaplan SA, Te AE. Concordance of near infrared spectroscopy with pressure flow studies in men with lower urinary tract symptoms. J Urol. 2010 Dec;184(6):2434-9.
4. Elzanaty S, Rezanezhad B, Willenheimer R, Borgquist R. Association Between Erectile Function and Biomarkers of Subclinical Atherosclerosis: A Study Based on Middle-Aged Healthy Men from the General Population. Curr Urol. 2016 Oct;9(3):119-123.
5. Fawzy F. Farag, Joseph Meletiadis, Mohamad D. Saleem, Wout F. Feitz, and John P. Heesakkers Near-Infrared Spectroscopy of the Urinary Bladder during Voiding in Men with Lower Urinary Tract Symptoms: A Preliminary Study Biomed Res Int. 2013; 2013: 452857.
6. Gacci M, Corona G, Sebastianelli A, Serni S, De Nunzio C, Maggi M et al Male Lower Urinary Tract Symptoms and Cardiovascular Events: A Systematic Review and Meta-analysis. Eur Urol. 2016 Nov;70(5):788-796.
7. Gimbrone MA, Nage T, Topper JN. Biochemical activation: an emerging paradigm in endothelial adhesion biology. J Clin Invest 1997;99: 1809-1813.
8. Hamaoka T, McCully KK, Quaresima V, Yamamoto K, Chance B. Near-infrared spectroscopy-imaging for monitoring muscle oxygenation and oxidative metabolism in healthy and diseased humans. J Biomed Optics 2007; 12(6).
9. Macnab A, Stothers L. Near-infrared spectroscopy: Validation of bladder outlet obstruction assessment using non-invasive parameters. Can J Urol 2008; 15(5).
10. Macnab AJ, Stothers L. Development of a near-infrared spectroscopy instrument for applications in urology; Can J Urol 2008;15(5):4233-4240.
11. Macnab A, Stothers L. Receiver operator curves describing near infrared spectroscopy (NIRS) changes during pressure flow studies in men with obstruction. J Urol 2007; 177 (4):502-503.
12. Malde S, Nambiar AK, Umbach R, Lam TB, Bach T, Bachmann A et al. European Association of Urology Non-neurogenic Male LUTS Guidelines Panel. Systematic Review of the Performance of Noninvasive Tests in Diagnosing Bladder Outlet Obstruction in Men with Lower Urinary Tract Symptoms. Eur Urol. 2016 Sep 26. pii: S0302-2838(16)30661-3. doi: 10.1016/j.eururo.2016.09.026.
13. Nomiya M, Andersson KE, Yamaguchi O. Chronic bladder ischemia and oxidative stress: new pharmacotherapeutic targets for lower urinary tract symptoms. Int J Urol. 2015 Jan;22(1):40-6.
14. Parsons JK1, Sarma AV, McVary K, Wei JT. Obesity and benign prostatic hyperplasia: clinical connections, emerging etiological paradigms and future directions. J Urol. 2009 Dec;182(6 Suppl): 27-31.
15. Russo GI, Castelli T, Privitera S, Fragalà E, Favilla V, Reale G et al .Increase of Framingham cardiovascular disease risk score is associated with severity of lower urinary tract symptoms. BJU Int. 2015 Nov;116(5):791-6.
16. Stothers L, Macnab AJ. Functional near infrared spectroscopy (Fnirs); dynamic topographic mapping of the human bladder during voiding. J Urol 2008; 179(4):517.
17. Stothers L, Shadgan B, Macnab AJ. Urological applications of near infrared spectroscopy (NIRS) Can J Urol 2008; 15(6):4399-409.
18. Vlachopoulos Ch, Ioakeimidis N, Terentes-Printzios D, Stefanadis C. The Triad: Erectile Dysfunction-Endothelial Dysfunction-Cardiovascular Disease. Curr Pharm Des 2008; 14:3700-3714.
19. Yurt M1, Süer E, Gülpinar O, Telli O, Arikan N. Diagnosis of bladder outlet obstruction in men with lower urinary tract symptoms: comparison of near infrared spectroscopy algorithm and pressure flow study in a prospective study. Urology. 2012 Jul;80(1):182-6.
20. Zhang P1, Yang Y, Wu ZJ, Zhang CH, Zhang XD. Diagnosis of bladder outlet obstruction in men using a near-infrared spectroscopy instrument as the noninvasive monitor for bladder function. Urology 2013 Nov;82(5):1098-102.