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Original Article

Evaluation of the Relationship Between Systemic Hypertension and Subfoveal Choroidal Thickness Using Optical Coherence Tomography in Pediatric Patients

Pediyatrik Hastalarda Optik Koherens Tomografi Kullanılarak Sistemik Hipertansiyon ile Subfoveal Koroid Kalınlığı Arasındaki İlişkinin Değerlendirilmesi

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ABSTRACT

Objective: Hypertension (HT) can cause vascular and microvascular changes. There is no barrier between systemic blood and ocular region. Changes in choroidal perfusion pressure due to HT may impair retinal function and oxygenation, and subfoveal choroidal thickness (SCT) may be affected by these changes. The aim of this study was to evaluate the effect of arterial HT on SCT in children.

Method: The study was performed on 102 cases (51 patients and 51 controls), prospectively. Optical coherence tomography was used for the measurement of SCT and mean values of 3 consecutive measurements were evaluated. All cases had blood pressure measurements during all day via ambulatory blood pressure monitoring. Also, both groups were evaluated for the target organ damage.

Results: There were 51 cases in patient group with the average age of 14.4±2.8 years, and the rest of 51 control cases were meanly 14.5±2.8 years in age (p=0.980). SCT was measured thinner in patients with target organ damage than the cases without target organ damage (p=0.027). SCT measurements of patients and control cases were not statistically significant different (p=0.569). Especially SCT was statistically significantly thinner in cases with increased left ventricular mass, left ventricular mass index and hypertensive nephropathy (p=0.02, p=0.00, p=0.039, respectively).

Conclusion: Choroidal thickness decreases in patients with HT who develop target organ damage. Therefore, close follow-up of hypertensive patients with appropriate life changes and medical treatments is important before target organ damage develops.

Keywords: Hypertension, subfoveal choroidal thickness, optical coherence tomography, target organ damage, ambulatory blood pressure monitoring

ÖZ

Amaç: Hipertansiyon vasküler ve mikrovasküler değişikliklere neden olabilir. Sistemik kan ile oküler bölge arasında bir bariyer olmayıp hipertansiyona bağlı koroid perfüzyon basıncındaki değişiklikler retina fonksiyonunu ve oksijenasyonu bozabilir ve subfoveal koroid kalınlığı bu değişikliklerden etkilenebilir. Bu çalışmanın amacı çocuklarda arteriyel hipertansiyonun subfoveal koroid kalınlığı üzerine etkisini değerlendirmektir.

Yöntem: Çalışma prospektif olarak 102 olgu (51 hasta ve 51 kontrol) üzerinde gerçekleştirildi. Subfoveal koroid kalınlığının ölçümü için optik koherens tomografi kullanıldı ve 3 ardışık ölçümün ortalama değerleri değerlendirildi. Tüm olgulara ambulatuvar kan basıncı takibi ile gün boyu kan basıncı ölçümleri yapıldı. Ayrıca, her iki grup da hedef organ hasarı açısından değerlendirildi.

Bulgular: Hasta grubunda yaş ortalaması 14,4±2,8 yıl olan 51 olgu bulunurken, 51 kontrol olgusunun geri kalanı ortalama 14,5±2,8 yaş idi (p=0,980). Subfoveal koroid kalınlığı hedef organ hasarı olan hastalarda hedef organ hasarı olmayanlara göre daha ince ölçüldü (p=0,027). Hasta ve kontrol olgularının subfoveal koroid kalınlığı ölçümleri istatistiksel olarak anlamlı farklılık göstermedi (p=0,569). Subfoveal koroid kalınlığı özellikle sol ventrikül kitlesi, sol ventrikül kitle indeksi artmış ve hipertansif nefropatinin olduğu olgularda istatistiksel olarak anlamlı derecede daha inceydi (sırasıyla; p=0,02, p=0,00, p=0,039).

Sonuç: Hedef organ hasarı gelişen hipertansiyonlu hastalarda koroid kalınlığı azalmaktadır. Bu nedenle, hedef organ hasarı gelişmeden önce hipertansif hastaların uygun yaşam değişiklikleri ve tıbbi tedavilerle yakın takibi önemlidir.

Anahtar kelimeler: Hipertansiyon, subfoveal koroid kalınlığı, optik koherens tomografi, hedef organ hasarı, ayakta kan basıncı takibi

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INTRODUCTION

Hypertension (HT) may cause many eye changes and variety of ocular disorders, such as retinopathy, choroidopathy, vascular pathologies [1-3]. Early diagnosis is important in the treatment and to determine the reversibility of target organ damage. Eye is a critical organ reflecting hypertensive microvascular effects and allows direct observation. Evaluation of these impacts provides predictive and prognostic value in the management of systemic complications secondary to HT, diabetes mellitus, cardiovascular, cerebrovascular and other systemic vascular diseases. HT can induce many eye diseases. It has been observed that ocular findings of especially severe HT may be more pronounced and these changes may be indicative of optic neuropathy, choroidopathy and retinopathy [2,3]. Although advanced routine ophthalmoscopic evaluation is not mandatory for managing HT, digital imaging and computer analysis, which are new methods, provide early recognition of microvascular changes that are very important for ocular disorders and cardiovascular risk factors. While subfoveal choroidal thickness (SCT) has been investigated in several studies in adults, SCT has not been evaluated in children [4]. Advances in imaging technology can show important changes such as thickening, thinning, and vascular insufficiency in the choroidal layer. Optical coherence tomography (OCT) is becoming a new and important tool for obtaining cross-sectional images from chorioretinal region. Additional priorities of OCT are its being a noninvasive method which provides high resolution images. With the aid of near infrared 840 nm diode laser light, OCT uses optically reflective properties of tissues to provide detailed information about inner retinal structures. In this study, we aimed to evaluate SCT via spectral domain OCT and determine the relationship between HT, and SCT in children.

MATERIALS and METHODS

The population of this prospective study consisted of 51 hypertensive (32 male, 19 female) children followed up in Pediatric Cardiology Clinic in Medical Faculty of Manisa Celal Bayar University, Turkey between 15 November 2016-17 April 2017. Fifty-one age-, and gender-matched healthy children (33 male, 18 female) were included in the study as a control group.

The participants had chronic hypertensive patients, receiving medical treatment with cardiology follow-up. The criteria established by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents were used for the diagnosis of HT (2004) [5]. All hypertensive cases underwent blood pressure measurements during all day via ambulatory blood pressure monitoring (ABPM), achieved using a portable device (Del Mar Reynolds Tracker NIBP 2 Model no: 90207, Hertford, England UK) that recorded data every 30 min from 24.00 to 8.00 a.m. and every 15 min from 08.00 a.m. to 24.00. The measurements were taken on normal working days, and patients were advised to keep on with their daily routines. Evaluation of ABPM was made according to the American Heart Association ABPM measurement guidelines [6].

The cases with a decrease in blood pressure measurements (systolic and diastolic) more than 10% at night (compared to day) was defined as "dippers". HT patients were first classified as those with primary or essential HT. Then, they were grouped according to their ambulatory blood pressures, as being dippers and non-dippers. All patients were asked about lifestyle assessment (avoidance of inactivity and obesity, salt and alcohol-free diet, sodium-potassium intake), drug use, family history and smoking. Physical examination and anthropometric measurements including body mass index (BMI) calculation were performed. In laboratory evaluation, in addition to routine tests, fasting glucose, glycated hemoglobin and lipids were studied. The following definitions were used.

- Underweight-BMI <5th percentile for age and sex,

- Normal weight-BMI between the 5th and <85th percentile for age and sex,

- Overweight-BMI between >85th and 95th percentile for age and sex,

- Obese-BMI ≥95th percentile for age and sex,

- Severely obese-BMI ≥120 percent of the 95th percentile values, or a BMI ≥35 kg/m^2 (whichever was lower) [7,8].

National Cholesterol Education Program's adult Treatment Panel III (NCEP_ATPIII) and International Diabetes Federation (IDF) criteria were used for diagnosis of cases with metabolic syndrome [9,10].

For ocular measurements, patients with a present or past history of macular abnormality, glaucoma, amblyopia, Type 1 diabetes mellitus, autoimmune thyroiditis, surgery or trauma, and incompatible to standard deviation (SD)-OCT examination were excluded from the study. Each participant underwent a complete ocular examination to determine the best-corrected visual acuity. SD-OCT

(Retinascan RS-3000; NIDEK, Gamagori, Japan) was used for measuring SCT of right eyes between 10.00 a.m. and 11.00 a.m., day time (Figure 1). SCT was evaluated according to Macula Line Raster scan protocol. SCT was measured as the perpendicular distance between hyperreflective border of retinal pigment epithelial-Bruch membrane (automatically detected by the SD-OCT device) and sclero-choroidal interface manually drawn by two experienced ophthalmologist who were blinded to the study protocol. All cases had 3 consecutive measurements, then highest signal strength was recorded.

Evaluation of Target Organ Damage: Target organ damage was defined as the involvement of kidney(s), eye(s), blood vessel(s), heart or one or more target organs. Diagnosis of target organ damage was established in all children as noted below.

Kidneys: For the evaluation of renal damage as a target organ damage caused by HT, microalbuminuria was measured. Microalbuminuria was defined as a urinary albumin excretion rate of 30-300 mg (20-200 µg/min) in 24-hour urine samples and 2-30 mg/mmoL creatinine (20-300 mg/g creatinine) in the first urine sample collected in the morning [11].

Blood vessels: Common carotid artery, carotid bulb and internal and external carotid artery diameters were measured by ultrasound in the target-diastolic phase from all patients, and normal measurements of carotid intima-media thickness (cIMT) in healthy children were used as reference [12].

Heart: In all patients transthoracic echocardiogram was performed by the same cardiologist, using the 3S-RS (3.5 MHz) probe via GE-Vingmed Vivid 7 system (GE-Vingmed Ultrasound AS, Horten, Norway). We used standard methodology for all echocardiographic data. All cases had 3 consecutive measurements, then the mean values of them were recorded. We calculated the left ventricular mass and mass index using the Devereux formula. Following the formula validated by Devereuz and Reichek was used to calculate left ventricle (LV) mass [13]. To prevent alterations according to age, sex and weight, LVmass was indexed for height$^{2.7}$ [14]. We used 95th percentile values for the definition of left ventricular hypertrophy as LVmass index left ventricular mass index ≥36.88 g/m$^{2.7}$ in girls and ≥39.36 g/m$^{2.7}$ in boys [15].

Eyes: Detection of the findings of hypertensive retinopathy on funduscopic examination was considered the presence of hypertensive retinopathy.

This study was approved by the Manisa Celal Bayar University Faculty of Medicine Clinical Research Ethics Committee (approval number: 20.478.486-385, date: 23.11.2016), and informed consent was taken from all participants.

Statistical Analysis

All data were analyzed with SPSS for Windows 15.0. Data were expressed as mean and SD. An independent t-test was performed in independent groups for normal distribution parameters. Mann-Whitney U test was performed in the independent groups with non-

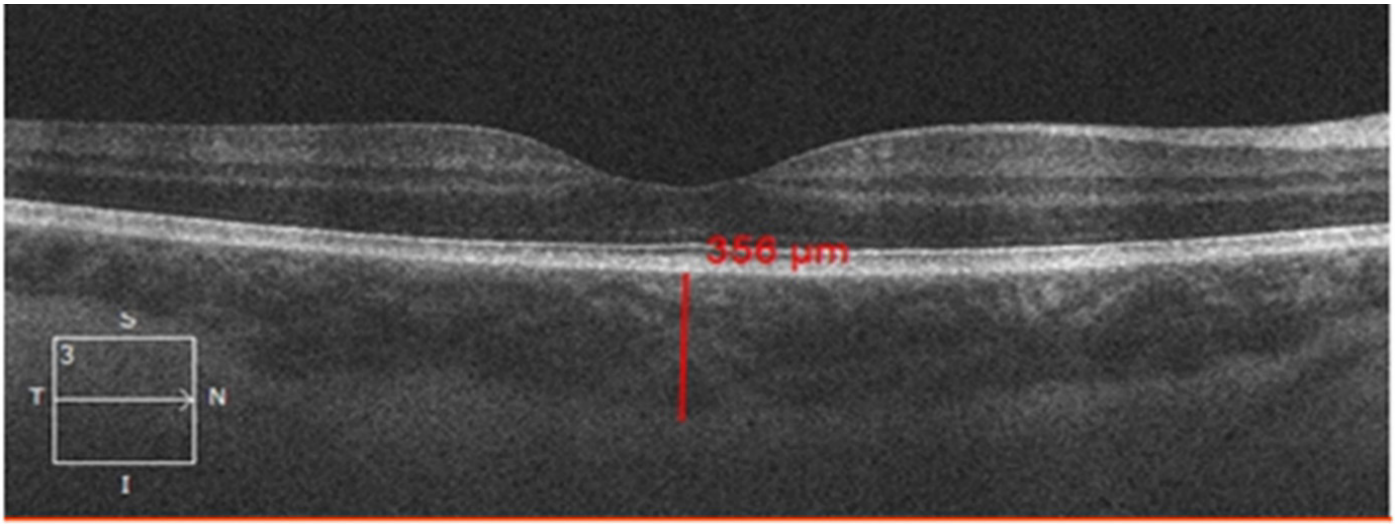

Figure 1. Measurement of subfoveal choroidal thickness with OCT

OCT: Optical coherence tomography

normal distribution. Pearson correlation was used for the comparison of two continuous variables. P<0.05 was accepted as the level of statistical significance.

RESULTS

Our study included 51 right eyes of 51 hypertensive children (32 male, 19 female) and 51 right eyes of age- and gender- matched healthy control children (33 male, 18 female). The mean ages of the patients were 14.4±2.8 years (4-19) and 14.5±2.8 years (5-19) in hypertensive and control groups; respectively, without any significant intergroup difference. When systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements were evaluated in the hypertensive and control groups, SBP and DBP measurements were found to be higher in the patient group with a statistically significant intergroup difference (p=0.000). The BMI values were higher in the hypertensive group than the control group without any statistically significant intergroup difference (p=0.051). The clinical characteristics of groups are documented in Table 1.

Primary and secondary HT patients were detected in 39 of 51 (76.5%) and 12 of 51 (23.5%) cases, respectively, without any statistically significant SCT difference (p=0.549). All HT patients were divided into groups of dippers (37 patients) and non-dippers (14 patients) in terms of mean blood pressure decreases overnight according to ambulatory measurements, and any statistically significant intergroup difference was not found in terms of SCT measurements (p=0.160) (Table 2).

We documented hypertensive cases according to the presence of cardiovascular or metabolic risk factors. There was no statistically significant difference in terms of SCT, whether cardiovascular or metabolic risk factors are present or not (Table 3).

All HT patients were divided into those with and without target organ damage. Among all 51 cases with HT, only 9 of them (17.6%) had target organ damage. These patients had hypertensive retinopathy (n=3; 5.8%), microalbuminuria (n=1; 1.9%) and increased

Table 1. Demographic characteristics and SCT of HT and control group

	Systemic HT group (n=51)	Control group (n=51)	p
Age (year)	14.4±2.8	14.4±2.8	0.917
Gender (male/female) (%)	32 (62.7)/19 (37.3)	33 (64.7)/18(35.3)	0.837
BMI (kg/m^2)	25.79±5.79	20.45±4.14	0.051
Systolic BP	126.27±15.87	114.70±13.57	0.001
Diastolic BP	83.33±12.51	73.72±11.12	0.001
Mean subfoveal CT (mμ)	400±71.37	404±67.73	0.569

SCT: Subfoveal choroidal thickness, BMI: Body mass index, BP: Blood pressure, HT: Hypertension, CT: Choroidal thickness

Table 2. Comparison of the effect of the distribution of patients in the HT group on SCT

	Mean SCT (mμ)	p
HT etiology		
Primer (n=39)	403±72.39	0.549
Seconder (n=12)	388±69.71	
Dipper group (n=14)	374±72.98	0.160
Non dipper group (n=37)	409±69.22	
Smoking (pack-year)		
Ever (n=2)	409±18.38	0.917
Never (n=49)	399±72.77	
Treatment of HT		
Yes (n=30)	396±68.49	0.730
No (n=21)	405±76.64	

SCT: Subfoveal choroidal thickness, HT: Hypertension

Table 3. Comparison of the HT group on SCT according to presence of cardiovascular and metabolic risk factors

	Mean SCT (mμ)	p
NCEP-ATPIII		
Yes (n=15)	391±70.21	0.515
No (n=36)	403±72.54	
IDF		
Yes (n=12)	422±65.90	0.210
No (n=39)	393±72.38	

NCEP-ATPIII: The National Cholesterol Education Program's adult Treatment Panel III, IDF: The International Diabetes Federation criteria for metabolic syndrome, SCT: Subfoveal choroidal thickness, HT: Hypertension

LVmass index (n=5; 9.6%). There was a close relationship between target organ damage and SCT (p=0.027). SCT was thinner in patients with target organ damage (increased LVmass, LVmass index, hypertensive retinopathy and nephropathy) than the cases without target organ damage (p=0.027) (Table 4).

We compared choroidal thickness (CT) results of patients receiving only non-pharmacological treatment (41.2%) or add-on drug management (58.8%), and no statistically significant difference was found between both groups (p=0.730). The duration of HT had not any statistically significance impact on CT (p=0.966).

DISCUSSION

The estimated prevalence of HT ranges between 2% and 5% and it is a common chronic disease in children [16]. Pediatric HT may be secondary to another disease process, or it may be essential. Parallel to the increment of obesity, prevalence of pediatric HT is increasing. Renal disease, endocrine disease and coarctation of aorta are commonly observed as the causes of secondary HT in children [17]. There are pores on choroidal vessels, thus there is no barrier between systemic blood and ocular region and these vascular differences of retina, choroid and optic nerve cause each region to respond differently to HT [18]. It has been noted that a reduction in choroidal blood flow triggers sympathetic activation and noradrenaline discharge, stimulating alpha-1 receptors that in turn trigger vasoconstriction [19,20]. Wang et al. [21] reported a close relationship between regulation of HT and vascular alterations, such as microvascular changes and focal arteriolar narrowing and concluded that vascular spasm led to focal contraction that could become permanent with fibrosis. SD-OCT has been successfully used in the early diagnosis of most ocular changes in primary and secondary HT caused by chronic cardiovascular diseases, diabetes, and neurodegenerative disorders [22]. Akay et al. [4] reported that choroidal thickness decreases in patients with systemic arterial HT because of arteriolar sclerosis and vascular contraction caused by high intravascular pressure in the choroid. However, target organ damage was not taken into consideration in their study.

Table 4. Comparison of choroidal thickness of HT group with and without target organ damage

	Mean SCT (mμ)	p
Target organ damage		
Yes (n=9)	354±67.63	0.027
No (n=42)	409±68.90	
Retinopathy		
Yes (n=3)	435±20.00	0.285
No (n=48)	397±72.92	
Nephropathy		
Yes (n=1)	244±0.0	0.039
No (n=50)	403±68.43	
Cardiopathy		
Yes (n=5)	327±8.5	0.02
No (n=46)	407±70.70	

HT: Hypertension, SCT: Choroidal thickness

Gök et al. [19] did not find any difference in SCT measurements in adult HT patients. Except for hypertensive patients with target organ damage, we found no difference between HT cases and controls in terms of SCT measurements. We reported that SCT decreased significantly in hypertensive patients with target organ damage. We thought that fibrosis resulting from decreased choroidal blood flow caused by vasoconstriction in patients with target organ damage due to prolonged or poorly controlled HT may play a role in SCT thinning. Chen et al. [23] and Hsu et al. [24] reported about SBP, CT, and myopic maculopathy and found an inverse correlation between SCT and SBP. Donati et al. [25] showed a significant reduction in SCT in hypertensive patients. Zhang et al. [26] found statistically significant difference between BMI and macular thickness in school-age children in contrast to our findings. Kong et al. [27] showed that HT had a negative relationship with macular thickness in most subfields except for the fovea especially in subjects with an elevated fasting glucose level. Yumusak et al. [28] also found a correlation between BMI and CT in obese women. In our study, we did not find any difference between BMI and SCT. We found that SCT decreased in hypertensive patients with target organ damage, especially in patients with increased left ventricular mass, left ventricular mass index and hypertensive nephropathy. However, SCT values were not different between patients with hypertensive retinopathy and-those with normal cIMT.

Whereas, SCT values were not also different between patients with hypertensive retinopathy. There are only a few studies on SCT in HT patients, but not in pediatric HT patients. The present study aims to evaluate SCT and reveals the relationship between SCT and arterial HT children. It was found that the duration of HT had no statistically significant effect on SCT. Even when pediatric patients are diagnosed at the first onset of HT, signs of target organ damage can be found.

Therefore, SCT scans can be meaningful. Since OCT is a reproducible, easily performed, noninvasive and reliable imaging technique, it can be used as a screening method for early detection of microvascular changes, especially ocular complications of HT.

Study Limitations

Our scarce number of cases with target organ damage is the limitation of the study.

CONCLUSION

This study has demonstrated the presence of a negative correlation between SCT and target organ damage, particularly with increased LVmass, LVmass index and hypertensive nephropathy. The aim of effective HT treatment is to provide normotensive values before target organ damage develops. While SCT in HT has been investigated in several studies in adults, SCT has not been evaluated in children. Considering that onset of HT in childhood may cause more destructive and irreversible damages in later life, it will be important to evaluate all effects of HT. The data suggest that irrespective of the duration of HT, SCT measurement has a predictive role in pediatric systemic arterial HT. Therefore, close follow-up of hypertensive patients with appropriate life changes and medical treatments is important before target organ damage develops. Larger, prospective studies are needed to support our study and specifically evaluate the relationship between HT and SCT using OCT.

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Ethics

Ethics Committee Approval: This study was approved by the Manisa Celal Bayar University Faculty of Medicine Clinical Research Ethics Committee (approval number: 20.478.486-385, date: 23.11.2016),

Informed Consent: Informed consent was taken from all participants.

Peer-review: Externally and internally peer-reviewed.

Author Contributions

Surgical and Medical Practices: F.A., Ş.C., Concept: F.A., S.Ş., E.Ç., H.M., Ş.C., Design: T F.A., S.Ş., E.Ç., H.M., Ş.C., Data Collection and/or Processing: F.A., S.Ş., E.Ç., H.M., Analysis and/or Interpretation: F.A., H.M., Literature Search: F.A., H.M., Writing: F.A.

Conflict of Interest: The authors have no conflict of interest to declare.

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REFERENCES

1. Wong TY, Mitchell P. The eye in hypertension. Lancet. 2007;369(9559):425-35. doi: 10.1016/S0140-6736(07)60198-6.
2. Tso MO, Jampol LM. Pathophysiology of hypertensive retinopathy. Ophthalmology. 1982;89(10):1132-45. doi: 10.1016/s0161-6420(82)34663-1.
3. Hammond S, Wells JR, Marcus DM, Prisant LM. Ophthalmoscopic findings in malignant hypertension. J Clin Hypertens. 2006;8(3):221-3. doi: 10.1111/j.1524-6175.2005.04147.x.
4. Akay F, Gundogan FC, Yolcu U, Toyran S, Uzun S. Choroidal thickness in systemic arterial hypertension. Eur J Ophthalmol. 2016;26(2):152-7. doi: 10.5301/ejo.5000675.
5. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics. 2004;114(2 Suppl 4th Report):555-76.
6. Flynn JT, Daniels SR, Haymann LL, Maahs DM, McCrindle BW, Mitsnefes M, et al. FAHA on behalf of the American Heart Association Atherosclerosis, Hypertension and Obesity in Youth Committee of the Council on Cardiovascular Disease in the Young. Update: ambulatory blood pressure monitoring in children and adolescents: a scientific statement from the American Heart Association. Hypertension. 2014;63:1116-35. doi: 10.1161/HYP.0000000000000007.
7. Kelly AS, Barlow SE, Rao G, Inge HT, Hayman LL, Steinberger J, et al. Severe obesity in children and adolescents: identification, associated health risks, and treatment approaches: a scientific statement from the American Heart Association. Circulation. 2013;128(15):1689-712. doi: 10.1161/CIR.0b013e3182a5cfb3.
8. Skinner AC, Skelton JA. Prevalence and trends in obesity and severe obesity among children in the United States, 1999-2012. JAMA Pediatr. 2014;168(6):561-6. doi: 10.1001/jamapediatrics.2014.21.
9. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation. 2002;106(25):3143-421. doi: 10.1161/circ.106.25.3143.
10. Alberti KG, Zimmet P, Shaw J. Metabolic syndrome--a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet Med. 2006;23(5):469-80. doi: 10.1111/j.1464-5491.2006.01858.x.
11. KDOQI. KOQI Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic Kidney Disease. Am J Kidney Dis. 2007;49(Suppl 2):12-154. doi: 10.1053/j.ajkd.2006.12.005.
12. Zakopoulos N, Papamichael C, Papaconstantinou H, Dubbins PA, Burrell CJ, Lekakis J, et al. Isolated clinic hypertension is not an innocent phenomenon: effect on the carotid artery structure. Am J Hypertens. 1999;12(3):245-50. https://doi.org/10.1016/S0895-7061(98)00257-X

13. De Simone G, Daniels SR, Devereux RB, Meyer RA, Roman MJ, de Divitiis O, et al. Left ventricular mass and body size in normotensive children and adults: assessment of allometric relations and impact of overweight. J Am Coll Cardiol. 1992;20(5):1251-60. doi: 10.1016/0735-1097(92)90385-z.

14. Riggio S, Mandraffino G, Sardo MA, Iudicello R, Camarda N, Imbalzano E, et al. Pulse wave velocity and augmentation index, but not intima-media thickness, are early indicators of vascular damage in hypercholesterolemic children. Eur J Clin Invest. 2010;40(3):250-7. doi: 10.1111/j.1365-2362.2010.02260.x.

15. Daniels SR, Kimball TR, Morrison JA, Khoury P, Meyer RA. Indexing left ventricular mass to account for differences in body size in children and adolescents without cardiovascular disease. Am J Cardiol. 1995;76(10):699-701. doi: 10.1016/s0002-9149(99)80200-8.

16. Moore WE, Stephens A, Wilson T, Wilson W, Eichner JE. Body mass index and blood pressure screening in a rural public school system: the Healthy Kids Project. Prev Chronic Dis. 2006;3(4):A114.

17. Sinaiko AR. Hypertension in children. N Engl J Med. 1996;335(26):1968-73. doi: 10.1056/NEJM199612263352607.

18. Oh KT. Ophthalmologic Manifestations of Hypertension. (Retrieved: March 29, 2018). https://emedicine.medscape.com/article/1201779-overview

19. Gök M, Karabas VL, Emre E, Aksar AT, Aslan MS, Ural D. Evaluation of choroidal thickness via enhanced depth-imaging optical coherence tomography in patients with systemic hypertension. Indian J Ophthalmol. 2015;63(3):239-43. doi: 10.4103/0301-4738.156928.

20. Kawarai M, Koss MC. Sympathetic vasoconstriction in the rat anterior choroid is mediated by alpha1-adrenoceptors. Eur J Pharmacol. 1998;363(1):35-40. doi: 10.1016/s0014-2999(98)00790-0.

21. Wang S, Xu L, Jonas JB, Wang YS, Wang Yx, You QS, et al. Five-Year Incidence of Retinal Microvascular Abnormalities and Associations with Arterial Hypertension: The Beijing Eye Study 2001/2006. Ophthalmology. 2012;119(12):2592-9. doi: 10.1016/j.ophtha.2012.06.031.

22. Paunescu LA, Schuman JS, Price LL, Stark PC, Beaton S, Ishikawa H, et al. Reproducibility of nerve fiber thickness, macular thickness, and optic nerve head measurements using StratusOCT. Invest Ophthalmol Vis Sci. 2004;45(6):1716-24.

23. Chen SJ, Cheng CY, Li AF, Peng KL, Chou P, Chiou SH, et al. Prevalence and associated risk factors of myopic maculopathy in elderly Chinese: the Shihpai Eye Study. Invest Ophthalmol Vis Sci. 2012;53(8):4868-73. doi: 10.1167/iovs.12-9919.

24. Hsu CC, Chen SJ, Li AF, Lee FL. Systolic blood pressure, choroidal thickness, and axial length in patients with myopic maculopathy. J Chin Med Assoc. 2014;77(9):487-91. doi: 10.1016/j.jcma.2014.06.009.

25. Donati S, Maresca AM, Cattaneo J, Grossi A, Mazzola M, Caprani SM, et al. Optical coherence tomography angiography and arterial hypertension: A role in identifying subclinical microvascular damage? Eur J Ophthalmol. 2021;31(1):158-65. doi: 10.1177/1120672119880390.

26. Zhang Z, He X, Zhu J, Jiang K, Zheng W, Ke B. Macular measurements using optical coherence tomography in healthy Chinese school age children. Invest Ophthalmol Vis Sci. 2011;52(9):6377-83. doi: 10.1167/iovs.11-7477.

27. Kong M, Kwun Y, Sung, Ham DI, Song YM. Association Between Systemic Hypertension and Macular Thickness Measured by Optical Coherence Tomography. Invest Ophthalmol Vis Sci. 2015;56(4):2144-50. doi: 10.1167/iovs.14-16080.

28. Yumusak E, Ornek K, Durmaz SA, Cifci A, Guler HA, Bacanli Z. Choroidal thickness in obese women. BMC Ophthalmol. 2016;16(1):48. doi: 10.1186/s12886-016-0227-z.