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The Effects of the Amount of Fluid Used in Epiduroscopic Laser Neural Discectomy Procedures on Intraocular Pressure and an Evaluation of the Ocular Findings

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Abstract

Introduction. During epiduroscopic laser neural discectomy (ELNP) procedures, the amount of fluid used in the epidural area may cause increased intracranial pressure. This study aimed to investigate the effect of increased epidural pressure on intraocular pressure and other ocular findings due to the amount of fluid delivered to the epidural area and the rate of delivery of the fluid. **Material and Methods.** After obtaining approval from the Ethics Committee of Sakarya University Faculty of Medicine, patients who underwent ELNP in the Department of Anesthesiology and Reanimation Department, Algology Clinic, between January 2017 and May 2017 were included in this retrospective study. To evaluate the ocular findings after the operation, measurements obtained using an optical coherence tomography device were retrieved from the patient files and evaluated. **Results.** Data from the medical files of 52 patients from the hospital system were evaluated. There was no significant difference between preoperative and postoperative retinal nerve fiber layer (RNFL) thickness, mean central macular thickness, optic disk area, and vertical cup-to-disk ratio ($P > 0.05$). **Conclusions.** Epiduroscopy procedures include intermittent or continuous infusion of saline into the epidural area. Currently, the volume of fluid that should be given to the epidural area in epiduroscopy procedures is very controversial. As a result of this study, we concluded that the amount of fluid used during ELNP, at 107.25 mL and 8.33 mL/min, had no effect on the intraocular pressure, optic disk diameter, macular thickness, or peripapillary RNFL thickness; thus, it was safe for ELNP.

Key Words: Epiduroscopy; laser; optic disc; intraocular pressure; discectomy

Introduction

Epiduroscopy, or spinal (canal) endoscopy, is defined as percutaneous, minimally invasive endoscopic investigation of the epidural space with the assistance of a flexible endoscope introduced through the sacral hiatus [1]. The procedure can be used for the diagnosis and treatment of lumbar spine disorders, especially radicular pain [2]. A particular application is endoscopic epidural laser decompression (EELD), through which disk herniations can be ablated using a holmium (Ho: YAG) laser [3].

In epiduroscopy, physiological fluid infusion is performed so that the inside of the epidural space can be clearly viewed with a camera. Physiological saline is used during the procedure, so the adhesions are mechanically cleaned, the nerve compressions are relieved, and the drug can be injected to improve the physiological health of the tissues [4].

Epidural fluid infusion during epiduroscopy leads to an increase in the pressure of the epidural area. This infusion displaces cerebrospinal fluid (CSF), producing a transitory increase in CSF pressure. Gill and Heavner [5] concluded that the injection rate is more important than volume regarding the pressure increase. Increased CSF pressure may be conducted via the subarachnoid extension around the optic nerve and may cause compression of the central retinal vein. Additionally, it has been

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suggested that elevated CSF pressure may trigger a reflexive increase in opthalmic artery pressure, resulting in venous collapse and capillary injury by causing rupture of capillaries [6]. Moreover, increased CSF pressure might indirectly affect the peripapillary nerve fiber layer (RNFL), macular thickness, and optic disk parameters. Spectral domain optical coherence tomography (OCT) has been widely used in ophthalmology to evaluate these parameters. This measurement method is noninvasive and reliable, and it requires less cooperation from patients [7].

The present study aimed to evaluate the changes in intraocular pressure (IOP) and peripapillary RNFL, macular thicknesses, and optic disk (OD) parameters of patients who have undergone an epiduroscopic laser discectomy procedure.

Methods

In this retrospective study, ELNP procedures that were performed between January 2017 and May 2017 at the Algology Clinic of the Department of Anesthesiology and Reanimation, Sakarya University Training and Research Hospital, were examined. After approval was received from the Sakarya University Faculty of Medicine's Ethics Committee, patient information was obtained from the KarMed (Kardelen Software, Mersin, Republic of Turkey) hospital information system. Patient files were scanned from the hospital archive. The following factors were examined: patient age and gender, the duration of the procedure, the amount of physiological saline used during the procedure, and the IOP measurement values before and after the procedure.

IOP was measured with a handheld tonometer (TonoPen, Reichert, USA) after instillation of 0.5% topical proparacaine HCl (Alcaine). The Cirrus spectral domain OCT (Carl Zeiss Meditec, Dublin, CA, USA) was used for the peripapillary RNFL measurements. RNFL thickness was measured using the Optic Disc Cube 200*200 method. The mean and four fragmented RNFL thicknesses were evaluated. Optic nerve head parameters, including the mean vertical cup-to-disk (c/d) ratio, the mean optic disk area, and the mean central macular thicknesses (CMT), were also measured using spectral domain OCT. Images with a signal quality that was worse than 7/10 were excluded. Scans with misalignment, segmentation failure, decentration of the measurement circle, and poor illumination, as well images that were out of focus, were also excluded. The preoperative and postoperative mean, nasal, temporal, superior, and inferior RNFL, mean CMT, mean disk area, and mean vertical c/d ratio were compared. Furthermore, the changes in these parameters by procedure were calculated, and the correlations between these changes in parameters and the duration, amount of saline, and the duration/saline ratio were also investigated.

The inclusion criteria were patients with low back and/or leg pain for at least three months and patients who did not benefit from conservative treatment. The exclusion criteria were patients with bleeding diathesis in preoperative laboratory tests and patients with any local or systemic infection. Patients undergoing epiduroscopic lysis due to failed back surgery syndrome (FBSS), patients with spinal stenosis, patients with a previous ocular surgery, media opacity, any disease affecting the retina, macular area, or optic disk, such as optic neuropathies and age-related macular degeneration, were excluded.

Preoperatively, the 18-G vascular access was opened; 1 g of ceftriaxone (Rocephin) was administered one hour before the procedure, and the patient was placed on the operating table. Following this, a 0.9% saline infusion was started intravenously. The patient was monitored using standardized monitoring techniques: electrocardiography, noninvasive blood pressure, and pulse oximetry. Each patient was administered 2 mg of midazolam for conscious sedation.

Aseptic conditions were maintained after cleaning the intervention area. After the patient was covered with a sterile cover, caudal region anesthesia was provided with 10 mL of lidocaine 1% with a 22-G Quincke spinal needle. The intervention was performed with a trocar inserted into the sacral hiatus. The epidurography, carried out with a C-arm scope, revealed that the trocar was in the midline. The epiduroscopy catheter was directed to the anterior epidural space, where the lumbar disk lesion was present. After the herniated disk was visualized, a laser probe was placed in the disk. Next, the Holmium laser was applied, and the data that emerged during the decompression were recorded. If a disk herniation was present in another region, the epiduroscopy catheter was advanced to the target site with the help of epiduroscopic imaging. If no other hernia was present, the procedure was terminated after a lumbar epidural steroid injection (16 mg of dexamethasone with 15 mg of bupivacaine in a volume of 7–10 mL). Finally, epidurography was performed to evaluate the effectiveness of the procedure.

The selected patients were evaluated before the procedure and one hour after the procedure. The duration of the procedure, the amount of physiological saline administered, and the total amount of fluids and drugs administered to the epidural area were recorded.

Statistical Analysis

The study was performed on 52 patients. The data were transferred to IBM SPSS, version 23. Parametric tests were used while evaluating the study data because of the numerical variables. Frequency distribution for the categorical variables and descriptive statistics for the numerical variables (mean, standard deviation, minimum, and maximum) were provided. To evaluate the difference between preoperative and postoperative values, a dependent t test and Pearson's correlation analysis were used to examine the relationship between the two numerical variables, and the results were arranged into tables.

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Results

Data for the 52 patients were attained as a result of scanning the hospital patient information system. The demographic characteristic values and mean, nasal, temporal, superior, and inferior RNFL thicknesses, mean central macular thickness, disk area, and vertical c/d ratio are defined in Table 1. No statistically significant difference was found between the preoperative and postoperative values as a result of the dependent sample *t* test. The results are shown in Table 2 ($P > 0.05$).

A statistically significant positive correlation between the duration of the procedure and the changes in mean and nasal RNFL thicknesses of the left eye measurements ($P < 0.05$) was found as a result of the Pearson correlation analysis. Statistically significant positive correlations were found between the amount of fluid used and changes in the right eye temporal RNFL and left eye nasal RNFL thickness measurements ($P < 0.05$). A low negative correlation was found between the amount of fluid used/procedure duration ratio and the change in the left eye central macular thickness (CMT) value, while a statistically significant positive correlation was found with the change in right eye temporal RNFL measurement value ($P < 0.05$). The results of the correlation analysis are detailed in Table 3. The correlations between the changes in the left eye nasal

Table 1. Descriptive values

	Mean	SD	Minimum	Maximum
Age, y	51.73	10.45	29.0	71.0
Procedure duration, min	13.27	3.47	8.0	22.0
Amount of fluid used, mL	107.25	30.46	45.0	180.0
Amount of fluid used/ procedure duration	8.33	2.44	4.8	16.9
Preoperative values				
Right eye intraocular pressure	16.31	3.20	10.0	23.0
Left eye intraocular pressure	16.62	2.96	11.0	24.0
CMT OD, μ	235.33	35.70	72.0	280.0
CMT OS	240.65	25.57	112.0	283.0
Mean RNFL thickness OD, μ	88.17	11.77	48.0	117.0
Mean RNFL OS	89.65	8.79	68.0	112.0
DISK AREA OD	2.04	0.37	1.4	2.8
DISK AREA OS	2.00	0.37	1.4	3.1
VERT. C/D RATIO OD	0.47	0.16	0.1	0.8
VERT. C/D RATIO OS	0.45	0.15	0.1	0.7
RNFL-T OD	61.77	10.28	30.0	86.0
RNFL-S OD	107.23	17.98	47.0	151.0
RNFL-N OD	69.44	10.61	52.0	97.0
RNFL-I OD	114.23	19.83	47.0	151.0
RNFL-T OS	60.62	8.36	35.0	82.0
RNFL-S OS	114.12	16.62	71.0	149.0
RNFL-N OS	67.98	8.92	51.0	97.0
RNFL-I OS	116.00	13.57	82.0	147.0
Postoperative values				
Right eye intraocular pressure	16.67	2.63	11.0	23.0
Left eye intraocular pressure	16.77	3.01	10.0	24.0
MACULA OD	235.56	35.14	44.0	286.0
MACULA OS	241.15	21.92	154.0	284.0
AV. RNFL OD	88.40	12.18	47.0	117.0
AV. RNFL OS	89.19	9.10	67.0	120.0
DISK AREA OD	1.98	0.35	1.4	2.9
DISK AREA OS	1.99	0.40	0.6	3.1
VERT. C/D RATIO OD	0.45	0.18	0.1	0.9
VERT. C/D RATIO OS	1.32	6.32	0.1	46.0
Temporal RNFL thickness OD	61.92	10.81	27.0	81.0
Superior RNFL thickness OD	107.52	19.44	46.0	155.0
Nasal RNFL thickness OD	69.13	10.41	46.0	98.0
Inferior RNFL thickness OD	114.79	20.38	46.0	153.0
RNFL-T OS	61.29	8.32	41.0	78.0
RNFL-S OS	112.81	16.37	67.0	159.0
RNFL-N OS	67.12	10.27	44.0	95.0
RNFL-I OS	115.50	15.07	85.0	150.0

C/D=cup to disk, μ; CMT=central macular thickness; disk area=optic disk area; OD=right eye; OS=left eye; RNFL=retinal nerve fiber layer thickness.

Table 2. Examination of the difference between preoperative and postoperative values

	Mean	SD	*t*	*P*
Right eye preoperative	16.31	3.203	–1.546	0.128
Right eye postoperative	16.67	2.633		
Left eye preoperative	16.62	2.965	–0.565	0.575
Left eye postoperative	16.77	3.014		
MAKULA OD-preoperative	235.33	35.701	–0.039	0.969
MAKULA OD-postoperative	235.56	35.142		
MAKULA OS-preoperative	240.65	25.570	–0.157	0.876
MAKULA OS-postoperative	241.15	21.926		
AV. RNFL OD-preoperative	88.17	11.772	–0.424	0.674
AV. RNFL OD-postoperative	88.40	12.180		
AV. RNFL OS-preoperative	89.65	8.794	0.849	0.400
AV. RNFL OS-postoperative	89.19	9.103		
DISK AREA OD-preoperative	2.04	0.370	1.481	0.145
DISK AREA OD-postoperative	1.98	0.358		
DISK AREA OS-preoperative	2.00	0.374	0.328	0.744
DISK AREA OS-postoperative	1.99	0.408		
VERT. C/D RATIO OD-preoperative	0.47	0.169	1.535	0.131
VERT. C/D RATIO OD-postoperative	0.45	0.183		
VERT. C/D RATIO OS-preoperative	0.45	0.159	–0.989	0.327
VERT. C/D RATIO OS-postoperative	1.32	6.320		
RNFL-T OD-preoperative	61.77	10.282	–0.176	0.861
RNFL-T OD-postoperative	61.92	10.817		
RNFL-S OD-preoperative	107.23	17.985	–0.206	0.837
RNFL-S OD-postoperative	107.52	19.445		
RNFL-N OD-preoperative	69.44	10.619	0.311	0.757
RNFL-N OD-postoperative	69.13	10.415		
RNFL-I OD-preoperative	114.23	19.831	–0.491	0.626
RNFL-I OD-postoperative	114.79	20.383		
RNFL-T OS-preoperative	60.62	8.369	–0.985	0.329
RNFL-T OS-postoperative	61.29	8.325		
RNFL-S OS-preoperative	114.12	16.623	0.906	0.369
RNFL-S OS-postoperative	112.81	16.374		
RNFL-N OS-preoperative	67.98	8.926	0.936	0.354
RNFL-N OS-postoperative	67.12	10.272		
RNFL-I OS-preoperative	116.00	13.578	0.443	0.660
RNFL-I OS-postoperative	115.50	15.072		

C/D=cup to disk; μ; CMT=central macular thickness; disk area=optic disk area; OD=right eye; OS=left eye; RNFL=retinal nerve fiber layer thickness.

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

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Table 3. Investigation of the relationship between the change in preoperative-postoperative retinal measurements and procedure duration, amount of fluid used and amount of fluid used/procedure duration

		Duration	Amount of Fluid Used	Amount of Fluid Used/ Procedure Duration
ΔR	*r*	–0.004	–0.006	–0.049
	P	0.979	0.964	0.729
ΔL	*r*	0.002	–0.169	–0.208
	P	0.986	0.232	0.140
ΔMAKULA OD	*r*	0.220	0.211	–0.011
	P	0.117	0.134	0.938
ΔMAKULA OS	*r*	0.241	0.030	**–0.275**
	P	0.086	0.832	**0.049***
ΔAV. RNFL OD	*r*	–0.057	–0.010	0.043
	P	0.688	0.942	0.759
ΔAV. RNFL OS	*r*	**0.316**	0.217	–0.112
	P	**0.022***	0.122	0.428
ΔDISK AREA OD	*r*	0.254	–0.016	**–0.320**
	P	0.069	0.911	**0.021***
ΔDISK AREA OS	*r*	0.040	0.070	0.053
	P	0.780	0.622	0.708
ΔVERT. C/D RATIO OD	*r*	–0.042	0.099	0.158
	P	0.767	0.484	0.263
ΔVERT. C/D RATIO OS	*r*	–0.112	–0.097	0.019
	P	0.430	0.496	0.894
ΔRNFL-T OD	*r*	–0.055	**0.285**	**0.337**
	P	0.701	**0.041***	**0.015***
ΔRNFL-S OD	*r*	–0.060	–0.062	0.018
	P	0.673	0.661	0.898
ΔRNFL-N OD	*r*	0.039	–0.202	–0.256
	P	0.786	0.151	0.067
ΔRNFL-I OD	*r*	–0.015	0.017	0.011
	P	0.914	0.905	0.941
ΔRNFL-T OS	*r*	–0.235	–0.060	0.217
	P	0.093	0.671	0.122
ΔRNFL-S OS	*r*	0.062	0.026	–0.069
	P	0.661	0.857	0.629
ΔRNFL-N OS	*r*	**0.476**	**0.390**	–0.066
	P	**0.000*****	**0.004****	0.642
ΔRNFL-I OS	*r*	0.242	0.128	–0.143
	P	0.084	0.366	0.312

C/D=cup to disk, μ; CMT=central macular thickness; disk area=optic disk area; OD=right eye; OS=left eye; RNFL=retinal nerve fiber layer thickness.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

RNFL and duration and amount of fluid were statistically moderately significant.

Discussion

In early applications of epiduroscopy, access was limited to the posterior epidural space. Adhesions in this space could be treated in patients with FBSS [1,2]. More recently, by providing access to the anterior epidural area, epiduroscopy has allowed laser ablation to be applied to patients with lumbar disk pathology, as an alternative to open surgical procedures [4,8,9], comparable to endoscopic disk surgery [3,10].

As for any invasive procedure, the potential adverse effects of epiduroscopy warrant investigation. A foremost concern is that increased intracranial pressure and undesirable complications are encountered in relation to the amount of liquid injected, the rate of delivery of the liquid, and the duration of the procedure [11]. Gill and Heavner's systematic review reported 12 cases of visual disturbances after epidural procedures [5]. However, although 17% of the procedures reviewed were epiduroscopy, the others were various forms of injections, and the review did not specify which procedures the affected patients had undergone.

The systematic review of Helm et al. [12] reported that volumes in excess of 100 mL are required to increase epidural hydrostatic pressure [12], but this conclusion might not be generalizable. In that systematic review, the epidural spaces of the patients were closed due to scarring. The conclusions might not apply to patients without scarring.

In the present study, no patient had fibrosis or scarring secondary to surgery. This allowed the direct effect on the optic nerve of the amount of fluid injected into the epidural space to be studied. An average of 107.25 mL of fluid was administered, and its effects on the optic nerve were evaluated using and optical coherence tomography device.

OCT is a fast, noninvasive, objective method of evaluating peripapillary RNFL thickness, CMT, and optic disk parameters. It allows reliable repeated measurements [13,14]. This instrument has been widely used in detecting ophthalmological diseases, and studies have also reported its use in neurological diseases such as multiple sclerosis and Parkinson's disease [15–19]. Increased cerebrospinal fluid (CSF) pressure might also have effects on the peripapillary RNFL thickness and disk area measured by OCT. Eren et al. [20] investigated RNFL thickness and disk area changes in patients with mild papilledema. Although fundus examination was insufficient, RNFL was found to increase and was correlated with increased CSF pressure. Albrecht et al. [7] found that in patients with idiopathic intracranial hypertension, the optic nerve head volume measured by OCT was increased and correlated with CSF pressure. The Optical Coherence Tomography Sub-Study Committee found a strong correlation between papilledema and peripapillary RNFL thickness in the acute phase [21]. An increase in CSF pressure after extradural injection was previously reported [22,23]. The compression of the dural sac with the fluid injected into the epidural area might cause a cephalad CSF shift; this shift, along with intracranial compliance, might determine the increase in CSF. It has also been accepted by many authors that the higher the initial CSF pressure, the greater the increase in CSF pressure [22,23]. Thus, epidural injections might cause an increase in CSF pressure, and an epiduroscopy procedure might alter peripapillary RNFL thickness and optic disk parameters.

In the present study, increases in the amount of fluid as well as the duration of the procedure caused an increase in nasal RNFL thickness in the left eye. There was

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also a positive, low correlation between changes in the temporal RNFL in the right eye and the amount of fluid and the fluid/duration ratio. These correlations might be explained by a transient increase in CSF pressure, but the influence on specific quadrants of RNFL thickness could not be explained.

A negative, low correlation was detected between changes in the right eye disk area and the fluid/duration ratio, but no statistically significant difference was found between pre- and postoperative values. Time passing between the intervention and measurements of OCT findings might be the cause of these results. If measurements could have been done immediately after intervention, the assessment might be more accurate.

A limitation of the present study is that the data collection was retrospective. Also, in the interest of patient safety, we waited for the effects of sedation to pass after the treatment procedure, so that patients were conscious and could maintain balance during OCT measurement. Temporary adverse effects might have improved during this delay.

Notwithstanding the temporary effects that were observed, or others that could not be detected, the present study found no lasting postoperative effects on intraocular pressure, optic disk diameter, macular thickness, or peripapillary RNFL thickness, when an average of 107.25 mL (45–180 mL) of fluid was administered at 8.3 mL/min during the ELNP procedures. Therefore, we believe that the eye complications reported in the literature may not occur when the safe, specified amount of fluid and rate of injection are observed. However, more rigorous controlled studies are required to define dependable safe limits.

References

1. Schuetze G. Epiduroscopy-Spinal Endoscopy. 1st ed. Germany: Springer; 2008:76–7.
2. Heavner JE, Chokhavatia S, Kizelshteyn G. Percutaneous evaluation of the epidural and subarachnoid space with a flexible fiberscope. Reg Anesth Pain Med 1991;15 (Suppl):85.
3. Park CH, Lee SH. Endoscopic epidural laser decompression versus transforaminal epiduroscopic laser annuloplasty for lumbar disc herniation: A prospective, randomized trial. Pain Physician 2017;20(7):663–70.
4. Sayhan H, Beyaz SG. Epiduroscopy (epidural endoscopy). In: Prostran M, ed. Pain Management. Croatia: InTech; 2016. p: 115–141.
5. Gill JB, Heavner JE. Visual impairment following epidural fluid injections and epiduroscopy: A review. Pain Med 2005;6 (5):367–74.
6. Amirika A, Scott IU, Murray TG, Halperin LS. Acute bilateral visual loss associated with retinal hemorrhages following epiduroscopy. Arch Ophthalmol 2000;118:287–9.
7. Albrecht P, Blasberg C, Ringelstein M, et al. Optical coherence tomography for the diagnosis and monitoring of idiopathic intracranial hypertension. J Neurology 2017;264(7):1370–80.
8. Richter EO, Abramova MV, Cantu F, et al. Anterior epiduroscopic neural decompression: Eight-center experience in 154 patients. Eur J Pain Suppl 2011;5(S2):401–7.
9. Jo DH, Yang HJ. The survey of the patient received the epiduroscopic laser neural decompression. Korean J Pain 2013;26 (1):27–31.
10. Ji GY, Lee J, Lee SW, et al. Safety and effectiveness of transforaminal epiduroscopic laser ablation in single level disc disease: A case-control study. Pain Physician 2018;21(6):E643–50.
11. Beyaz SG. Seizures and transient neurological deficits during epiduroscopy in a patient with failed back surgery syndrome. Pain Med 2015;16(4):825–7.
12. Helm S, Hayek SM, Colson J, et al. Spinal endoscopic adhesiolysis in post lumbar surgery syndrome: An update of assessment of the evidence. Pain Physician 2013;16(Suppl 2):SE125–50.
13. Wu Z, Weng DSD, Rajshekhar R, Ritch R, Hood DC. Effectiveness of a qualitative approach toward evaluating OCT imaging for detecting glaucomatous damage. Transl Vis Sci Technol 2018;7(4):7.
14. Bodis-Wollner I. Retinopathy in Parkinson disease. J Neural Transm 2009;116(11):1493–501.
15. Garcia-Martin E, Pueyo V, Pinilla I, Ara JR, Martin J, Fernandez J. Fourier-domain OCT in multiple sclerosis patients: Reproducibility and ability to detect retinal nerve fiber layer atrophy. Invest Ophthalmol Vis Sci 2011;52(7):4124–31.
16. Kirbas S, Turkyilmaz K, Tufekci A, Durmus M. Retinal nerve fiber layer thickness in Parkinson disease. J Neuroophthalmol 2013;33(1):62–5.
17. Moschos MM, Tagaris G, Markopoulos I, et al. Morphologic changes and functional retinal impairment in patients with Parkinson disease without visual loss. Eur J Ophthalmol 2011; 21(1):24–9.
18. Ucak T, Alagoz A, Cakir B, Celik E, Bozkurt E, Alagoz G. Analysis of the retinal nerve fiber and ganglion cell-inner plexiform layer by optical coherence tomography in Parkinson's patients. Parkinsonism Relat Disord 2016;31:59–64.
19. Garcia-Martin E, Ara JR, Martin J, et al. Retinal and optic nerve degeneration in patients with multiple sclerosis followed up for 5 years. Ophthalmology 2017;124(5):688–96.
20. Eren Y, Kabatas N, Guven H, Comoglu S, Gurdal C. Evaluation of optic nerve head changes with optic coherence tomography in patients with idiopathic intracranial hypertension. Acta Neurol Belg 2018;119(3):351–7
21. Auinger P, Durbin M, Feldon S, et al; Optical Coherence Tomography Substudy Committee, NORDIC Idiopathic Intracranial Hypertension Study Group. Papilledema outcomes from the Optical Coherence Tomography Substudy of the Idiopathic Intracranial Hypertension Treatment Trial. Ophthalmology 2015;122(9):1939–45.e2.
22. Hilt H, Gramm HJ, Link J. Changes in intracranial pressure associated with extradural anaesthesia. Br J Anaesth 1986;58 (6):676–80.
23. Grocott HP, Mutch WA. Epidural anesthesia and acutely increased intracranial pressure. Lumbar epidural space hydrodynamics in a porcine model. Anesthesiology 1996;85(5):1086–91.

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