

# Preoperative and postoperative features of non-functioning pituitary adenomas: a single center experience

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## ABSTRACT

**Objectives:** The main purposes of surgical treatment for non-functioning pituitary adenomas are removal of the pressure on the surrounding structures, especially the hypophyseal gland and visual tissue, and the normalization of hypophyseal functions. In our study, we retrospectively reviewed postsurgical follow-up of patients with non-functioning pituitary adenoma treated at our institution in a period of 15 years of monitoring and evaluated surgical success, complication rate and recurrence rates in accordance with the literature.

**Methods:** This study included 55 patients who had undergone surgery between 2000 and 2014 and who were followed-up postoperatively at our center. Preoperative and postoperative anterior pituitary hormones, complete resection and recurrence and also postoperative recovery of endocrinological and ophthalmological functions were statistically evaluated using file data of the patients.

**Results:** There were 33 (60%) males and 22 (40%) females. It was observed that the adenoma caused pressure on the optic chiasm in 11 patients and infiltrated cavernous sinus in 9 patients. Postoperative mean follow-up was  $75.14 \pm 43.01$  months. Seventeen (30.9%) patients had recurrence after complete resection. Postoperative persistence and deterioration rates were 12.2% and 26.6% in adrenal insufficiency, 12.2% and 26.6% in central hypothyroidism, respectively, while 12.2% worsening in central hypogonadism. Ophthalmologic findings were resolved in 62.5% of patients and persisted in 37.5% of the patients.

**Conclusions:** The adenoma size and experience of the surgeon in non-functioning pituitary adenomas are the most important factors affecting surgical success. We recommend that operations should be performed in experienced centers, preoperative and postoperative endocrinological evaluations and long-term follow-up should be done.

**Keywords:** Pituitary adenoma, non-functioning, surgery

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The prevalence of pituitary adenomas ranges from 1 in 865 adults to 1 in 2688 adults and 15-54% of all pituitary adenomas constitute non-functioning pituitary adenomas (NFPA) [1]. In a study of Swedish Pituitary Registry, it is observed that NFPA was the

most common cause of pituitary adenomas (54%), followed by prolactinomas (32%), acromegaly (9%), Cushing's disease (4%), thyroid stimulating hormone (TSH) secretory pituitary adenomas (0.7%); respectively [2]. Of the pituitary adenomas detected in au-



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topsy series, 40% constitute NFPA [3].

Because of NFPA do not cause excessive hormone secretion, patients are often diagnosed when the symptoms due to the pressure effect of the mass are under investigation [4]. The most important symptoms and findings are the bitemporal hemianopsy that develops due to the mass effect on the surrounding tissues such as optic chiasm and hypophyseal insufficiency in varying degrees due to pressure-dependent destruction of the hypophyseal cells [5]. Hemorrhagic infarction (hypophyseal apoplexy) in the tumor can be observed as an initial finding in NFPA and causes severe headache, visual impairment and hypopituitarism due to sudden intra-sella pressure increase [6, 7]. However, with the increasing use of imaging modalities in recent years, NFPA can be detected in the asymptomatic period. Hypophyseal lesions detected on cranial images without symptoms are called hypophyseal incidentalomas. Lesions smaller than 1 cm are classified as microinsidentalomas and lesions larger than 1 cm are classified as macroinsidentalomas [8].

Surgery is recommended in symptomatic patients with impaired vision in the ophthalmologic examination or hypophyseal insufficiency in the evaluation of the hypophyseal functions [7]. Nevertheless, in a retrospective evaluation of surgical outcomes in asymptomatic and symptomatic NFPA, Messerer *et al.* [9] found that total resection success of adenoma in asymptomatic patients was statistically significantly higher (82% vs. 58%) than symptomatic patients [9]. In the same study, the risk of developing postoperative hormonal insufficiency was found to be 10 times lower in asymptomatic patients. In asymptomatic NFPA, surgical decision is recommended to be based on tumor size, age of the patient, localization of the tumor, and accompanying comorbidities [9].

The main purpose of surgical treatment is removal of the pressure on the peripheral structures, especially the hypophyseal gland and visual tissues, normalization of hypophyseal function and prevention of tumor recurrence [10]. However, surgical success is primarily associated with preoperative adenoma size [11].

In our study, we retrospectively reviewed postsurgical follow-up of patients with NFPA at our institution in a period of 15 years of monitoring and evaluated surgical success, complication rate and recurrence rates in the view of the literature.

## METHODS

This study included 55 patients (33 males and 22 females) who had undergone surgery due to NFPA between 2000 and 2014 and who were followed-up postoperatively at our center. The complaints of the patients at the time of first admission were evaluated using the patients' file data. In preoperative endocrinological examination prolactin, growth hormone (GH), insulin like growth factor-1 (IGF-1), adrenocorticotrophic hormone (ACTH), cortisol, TSH, free T4 (fT4), follicle-stimulated hormone (FSH), luteinizing hormone (LH), estradiol in women and testosterone levels in men were evaluated. Acromegaly was excluded in patients with presence of clinical findings of acromegaly and high serum IGF-1 levels based on age and sex. Cushing disease and prolactinoma were also excluded in patients with clinical findings and high serum ACTH, cortisol and prolactin, respectively. The age, sex, and postoperative follow-up period of the patients included in the study were analyzed using file data. The presence of hypopituitarism was also investigated by evaluating the preoperative pituitary hormones of the patients. In preoperative hormonal evaluation morning serum cortisol  $< 3 \mu\text{g/dl}$ , accompanied by low or inappropriate normal ACTH levels were defined as central adrenal insufficiency. Adrenal insufficiency was excluded if serum cortisol was  $\geq 18 \mu\text{g/dl}$  and low dose ACTH stimulation test was performed between 3-18  $\mu\text{g/dl}$  of cortisol. Adrenal insufficiency was excluded if the serum cortisol level was  $\geq 18 \mu\text{g/dl}$  at one of the 0, 30, 60 and 90. minutes values after 1  $\mu\text{g}$  ACTH stimulation. TSH and fT4 levels were evaluated in the diagnosis of central hypothyroidism. If sT4 level was low, TSH was low or inappropriate, central hypothyroidism was diagnosed. Concomitant low testosterone in men and low estrogen in women with low or inappropriate normal FSH and LH levels were defined as central hypogonadism. Panhypopituitarism was assessed as the insufficiency of all pituitary hormones.

Preoperative sella magnetic resonance imaging (MRI) was used to assess the diameter of adenoma based on the longest diameter. The presence of extracellular expansion, cavernous sinus invasion and compression of optic chiasm were examined on MRI.

**Table 1.** Characteristics and follow-up results of patients (n = 55)

Characteristics	Data
Gender, n (%)	
Female	22 (40%)
Male	33 (60%)
Age (years) mean $\pm$ SD (range)	54.27 $\pm$ 10.75 (30-75)
Preoperative adenoma size (mm) mean $\pm$ SD (range)	28.91 $\pm$ 9.67 (11-52)
Postoperative complete resection, n	
Yes	39 (70.9%)
No	16 (29.1%)
Postoperative follow-up (month) mean $\pm$ SD (range)	75.14 $\pm$ 43.01 (34-233)
Postoperative recurrence, n (%)	
Yes	17/39 (43.6%)
No	22/39 (46.4%)

SD = Standard deviation

The presence of visual field loss was evaluated in preoperative visual field examination using file data of all patients. Patients who had lost preoperative visual field were reevaluated postoperatively and the improvement and persistence rates of visual impairment were recorded. Pathological immunohistochemical examination of postoperative material was examined. In the early postoperative period, all patients were examined for diabetes insipidus (DI). Detection of polyuria (> 3 lt/24 h) and low urine osmolality (< 300 mOsm) in the presence of normal or high serum sodium levels was interpreted as DI. Patients who developed DI were reevaluated in the follow-up and temporary or permanent DI were investigated. Postoperative hypopituitarism development, postoperative complete resection rates and recurrence rates were analyzed.

### Statistical Analysis

Statistical evaluations were performed on IBM SPSS version 21 (IBM Acquires SPSS Inc., Somers, NY, USA). Frequency values and/or descriptive statistics were calculated for variables that showed clinical characteristics of patients. The descriptive statistics of the continuous variables of the patients are given as the mean and standard deviation in the appropriate data or as the minimum-maximum.

## RESULTS

There were 33 (60%) males and 22 (40%) females. The mean age was 54.27  $\pm$  10.75 years (Table 1). All patients underwent pituitary surgery due to macroadenoma. Preoperative complaints of patients are given in Table 2. MRI and ophthalmologic examination was performed in 47 patients. The mean

**Table 2.** Preoperative clinical findings of patients (n = 55)

Clinical Findings	Data
Visual field disturbance	30 (54.5%)
Headache	20 (36.4%)
Loss of vision	7 (12.7%)
Diplopia	2 (3.6%)
Fatigue	13 (23.6%)
Dizziness	3 (5.4%)
Nausea-vomiting	2 (3.6%)
Diminished libido	7 (12.7%)
Menstrual irregularities	3 (5.4%)
Ptosis	1 (1.8%)
Tinnitus	2 (3.6%)
Weight gain	1 (1.8%)

**Table 3.** Preoperative MRI and ophthalmological data of patients (n = 47)

<b>MRI</b>	No extrasellar extension	12 (25.5%)
	Suprasellar extension	35 (74.5%)
	Infrasellar extension	5 (10.6%)
	Compression of optic chiasm	11(23.4%)
	Invasion of cavernous sinus	9 (19.1%)
<b>Ophthalmologic examination</b>	Normal	10 (21.3%)
	Temporal hemianopsia	2 (4.3%)
	Bitemporal hemianopsia	24 (51.0%)
	Quadranopsia	2 (4.3%)
	Concentric narrowing	5 (10.6%)
	Total loss of vision	4 (8.5%)

MRI = Magnetic rezonance imaging. MRI and ophthalmologic examination was performed in 47 patients.

adenoma size in preoperative sella MRI was  $28.91 \pm 9.67$  (11-52) mm. Sellar localization without expansion in MRI was observed in 12 (25.5%) patients. Suprasellar expansion was observed in 35 (74.5%) patients and both supra- and infrasellar expansion in 5 (10.6%) patients. In 11 (23.4%) patients, adenoma caused pressure on the optic chiasm and in 9 (19.1%) patients adenoma infiltrated cavernous sinuses. In the evaluation of the preoperative visual field, the visual field was normal in 10 (21.3%) patients, while the remaining patients had visual field defects (Table 3). Central adrenal insufficiency was present in 6 patients (10.9%), central hypothyroidism in 7 patients (12.7%), central hypogonadism in 1 patient (1.8%) and DI in 2 patients (3.6%) in preoperative endocrinological evaluation. None of patients had preoperative panhypopituitarism. Postoperative mean follow-up was  $75.14 \pm 43.01$  (34-233) months.

Among 55 patients included in our study 54 were treated surgically at our center and one patient had a surgery at a different center. In 51 (94.4%) patient the surgical method was chosen to be transsphenoidal surgery and 3 (5.6%) patient underwent transcranial surgery in our center. In pathological immunohistochemical evaluation positive staining was not detected in 13/48 (25.5%) patients, whereas FSH positivity in 19 (34.5%) patients, LH positivity in 12 (21.8%) patients, ACTH positivity in 6 (10.9%) patients, prolactin positivity in 5 (9.0%) patients, TSH positivity in 5 (9.0%) patients and GH positivity in 1 (1.8%) patient were detected (Table 4). Complete

resection was achieved in 39 patients (70.9%) postoperatively, while residual adenoma was detected in 16 patients (29.1%) in pituitary MRI performed at 3 months postoperatively (Table 1). Two patients did not undergo postoperative MRI evaluation at the third month. In the patients who had complete resection, recurrence was seen in 17/39 patients (43.6%) (see Table 1). In the follow-up, 12 patients had 2nd operation and 2 patients had 3rd operation (Table 5). All the patients included in the study were examined for the development of electrolyte disturbances, especially DI during the postoperative hospitalization. 12 (21.8%) patients had postoperative DI. Six (10.9%) patients were observed to develop permanent DI. Sixteen (29.0%) patients had central adrenal

**Table 4.** Immunohistochemical staining patterns of adenomas

FSH	19 (34.5%)
LH	12 (21.8%)
GH	1 (1.8%)
ACTH	6 (10.9%)
TSH	5 (9.0%)
Prolactin	5 (9.0%)
Negative	13 (27.1%)

Immunohistochemical staining was performed in 48 patints. More than one immunohistochemical staining positivity can be found in adenomas. FSH = follicle-stimulated hormone, LH = luteinizing hormone, GH = growth hormone, ACTH = adrenocorticotrophic hormone, TSH = thyroid stimulating hormone

**Table 5.** Operation techniques of the patients

	Male	Female	Total
<b>First surgery (n = 54)</b>			
TSS	31 (93.9%)	20 (95.2%)	51 (94.4%)
TCS	2 (6.1%)	1 (4.8%)	3 (5.6%)
<b>Second surgery (n = 12)</b>			
TSS	5 (62.5%)	3 (75%)	8 (66.7%)
TCS	3 (37.5%)	1 (25%)	4 (33.3%)
<b>Third surgery (n = 2)</b>			
TSS	1 (100%)	1 (100%)	2 (100%)
TCS	-	-	-

TSS = Transsphenoidal surgery, TCS = Transcranial surgery

**Table 6.** Data of preoperative and postoperative endocrinological and ophthalmological findings

<b>Adrenal insufficiency</b> (n = 49)	None <sup>a</sup>	30 (61.2%)
	Persistence <sup>b</sup>	6 (12.2%)
	Recovery <sup>c</sup>	0
	Impairment <sup>d</sup>	13 (26.6%)
<b>Central hypothyroidism</b> (n = 49)	None	29 (59.1%)
	Persistence	6 (12.2%)
	Recovery	1 (2.1%)
	Impairment	13 (26.6%)
<b>Central hypogonadism</b> (n = 49)	None	42 (85.7%)
	Persistence	0
	Recovery	1 (2.1%)
	Impairment	6 (12.2%)
<b>Oftalmologic</b> (preop.) (n = 47) (postop) (n = 16)	None <sup>e</sup>	10/47 (21.3%)
	Persistence	6/16 (37.5%)
	Recovery	10/16 (62.5%)

Preop. = Preoperative, Postop. = Postoperative. <sup>a</sup>There are no pathologic findings in preoperative and postoperative examination. <sup>b</sup>There are pathologic findings in preoperative and postoperative examination. <sup>c</sup>There are pathologic findings in preoperative examination and there are no pathologic findings in postoperative examination. <sup>d</sup>There are no pathologic findings in preoperative examination and there are pathologic findings in postoperative examination. <sup>e</sup>There are no pathologic findings in preoperative examination.

insufficiency, 16 (29.0%) patients had central hypothyroidism, 3 (5.4%) patients had central hypogonadism and 6 (10.9%) patients had panhypopituitarism. The rates of improvement, persistence and deterioration of endocrinological and ophthalmological findings at postoperative evaluation are given in Table 6.

Gammaknife was given to 9 (16.3%) patients (and

conventional radiotherapy was given to 3 (5.4%) patients in postoperative period. After gammaknife and conventional radiotherapy treatments, central hypothyroidism was observed in 1 (8.3%) patient, central hypothyroidism and adrenal insufficiency in 1 (8.3%) patient, central hypothyroidism and hypogonadism in 1 (8.3%) patient and panhypopituitarism was observed in 1 (8.3%) patient.

## DISCUSSION

NFPA constitutes approximately one third of all pituitary adenomas. In a recent autopsy study, adenoma frequency was found to be 10.5% and 35% of adenomas were observed to be composed of NFPA. In this study, the median tumor diameter was found to be 1.6 mm, and macroadenomas were detected in only two patients [3]. Our study included patients with non-functional pituitary macroadenomas with a mean tumor diameter of  $28.91 \pm 9.67$  mm. The mean age at diagnosis at NFPA is around 50-55 years and the frequency is slightly higher in males (56.7%) [18]. In our study, the frequency of male gender was found to be more frequent (60%) and the mean age of diagnosis was  $54.27 \pm 10.75$  (30-75) years.

NFPA is rarely seen as a component of multiple endocrine neoplasia-1 (MEN-1) and familial idiopathic pituitary adenoma (FIPA) [12]. Atypical pituitary adenomas and pituitary carcinomas are characterized by Ki-67 index  $\geq 3$  and p53 protein positivity and are resistant to conventional treatments. Pituitary carcinomas also cause cerebrospinal and/or systemic metastases. While atypical pituitary adenomas are observed at 2.7%, the incidence of carcinomas (0.1-0.2%) is very low [13]. In our study atypical pituitary adenomas were present in 3 (5.4%) patients and no pituitary carcinoma was found.

According to the structural and immunohistochemical characteristics, NFPA are divided into 3 groups (gonadotropic adenomas, null cell adenomas and oncocytomas). Gonadotropic adenomas show positive staining with FSH, LH or subunits, while null cell adenomas and oncocytomas are not stained. These three groups constitute 85% of all NFPA, while the remaining 15% constitute silent adenomas, which are immunohistochemically positive and do not cause any symptom [14, 15]. In our study, immunohistochemical evaluation was performed in 48 patients. Immunohistochemical staining was negative in 13 (27%) patients. Gonadotropic adenomas were detected in 25 (52%) patients while silent adenomas were detected in 10 (21%) patients.

NFPA are usually diagnosed by symptoms such as headache, visual disturbances, cranial nerve palsy, and hypopituitarism, which are caused by mass pressure on the surrounding tissues [16]. Depending on the mass effect of adenoma, headache may occur in 25%

of the macroadenoma patients, most likely due to the expansion of the sella. Suprasellar enlargement in the tumor leads to pressure on the optic chiasm, leading to visual field defects, primarily bitemporal hemianopsia. Prolonged compression of the optic nerve can lead to atrophy of the nerve resulting in decreased visual acuity. Extension of the adenoma to the lateral lobe and invasion of the cavernous sinuses does not always result in clinical signs, but may result in ptosis, ophthalmoplegia, and diplopia, leading to involvement in the 4th and 6th nerves, primarily cranial nerve 3. Rarely, parasellar enlargement can cause compression in the temporal lobe and seizure development, inferior enlargement to the sphenoid sinus may cause rhinorrhea very rarely [12, 17, 18]. Among the patients included in the study, the most common complaint was visual impairment (54.5%) and headache (36.3%). In MRI, compression of optic chiasm was detected in 11 (23.4%) patients. Ptosis was present in 1 (1.8%) patient and diplopia in 2 (3.6%) patients. The most common findings in ophthalmologic examination were bitemporal hemianopsia (51.0%) and concentric narrowing (10.6%) in the visual field. No ophthalmologic problem was found in 21.3% of the patients.

Pituitary apoplexy is a rare condition characterized by sudden hemorrhage into the pituitary macroadenoma. It causes severe headache and impaired vision. It can be developed spontaneously however may be associated with pregnancy, surgery and anticoagulant use [19, 20]. Pituitary apoplexy was not observed in the patients included in our study.

The purpose of treatment in patients with symptoms is to provide rapid decompression and relieve symptoms [18]. Successful total surgical resection of NFPA can be achieved in the literature with a wide spectrum, varying between 18-81% [21, 22]. In our study, total surgical resection was observed in 39 (73.5%) of the 53 patients whose evaluation was performed.

Radiotherapy may be effective in residual tumor patients with postoperative growth potential. Radiotherapy is recommended to patients which has a tendency to grow in post-operative follow-up, residual tissue remaining and life expectancy is more than 10 years [23]. However, there is a risk of hypopituitarism in the long term. It may also lead to visual deterioration, secondary brain tumor development,

seizure and possibly neurocognitive and neuropsychological impairment [16, 24]. In our study, 9 (16.3%) patients were treated with gamma knife and 3 (5.4%) patients were treated with radiotherapy.

Total or partial improvement is seen in 80-90% of cases after surgery. This improvement continues up to 1 year after surgery. The urgency of the surgery is related to the severity of visual impairment [25, 26]. In our study, preoperative ophthalmological evaluation was performed in 48 patients and pathological findings were found in 38 (79.2%) of the patients. At postoperative 3rd month, only 16 of 38 patients had reevaluation and 10 (62.5%) patients had total or partial healing and 6 (37.5%) patients had persistent findings. It is thought that the low number of patients with post-operative evaluation may be due to insufficient file records.

30-40% of macroadenomas are accompanied by partial or total hypophyseal insufficiency and there is a risk of developing 12% hypophyseal insufficiency every year in macroadenomas [27, 28]. Loss of hypophyseal functions can be explained by the expanding adenoma leading to pressure on pituitary stalk and portal veins [29]. The development of hypopituitarism occurs in GH, FSH/LH, TSH and ACTH hormones respectively. Clinical findings are associated with the type and severity of hormonal deficiencies and may be nonspecific [30]. In the patients included in our study, TSH deficiency was the most prominent findings, followed by ACTH and FSH/LH deficiency. None of patients had preoperative panhypopituitarism.

In cases with preoperative hypophyseal insufficiency, surgery achieves to lead an improvement in the anterior pituitary hormones in 30% of the patients during one year follow-up after surgery [9]. The risk of postoperative hypophyseal insufficiency is approximately 10% [31]. Pituitary insufficiency develops due to the resection or injury of anterior pituitary or stalk. Risk is variable due to the adenoma size, extent of resection and the experience of the surgeon. Stalk injury or resection results in DI. Temporary DI is approximately 10-20% while permanent DI is 2-7%. Surgical mortality is below 2% in experienced centers [32]. Twelve (21.8%) of the patients included in our study had temporary DI and 6 (10.9%) had persistent DI in postoperative period. According to the literature in the

patients included in our study, high DI ratios can be explained by the large adenoma size and the high extracellular expansion rates.

In postoperative follow-up at 3-6. month and at 1 year pituitary MRI control is recommended [33]. Imaging is not routinely recommended in the early postoperative period, but it may be helpful to remove the suspicion of postoperative complications and early surgical revision [34]. Unless a postoperative residual is detected, long-term follow-up of the first 5 years is recommended every year, followed by imaging at 7, 10 and 15 years. In the presence of postoperative residue or residual doubt, it is recommended to determine the MRI control intervals in the first 5 years every year, if there is no progression in the next period, once every 2-3 years, considering the tumor diameter, distant to the optic nerve and progression suspicion [35].

Control of the anterior pituitary hormones is recommended at 3rd month postoperatively to assess possible hypopituitarism. At the same time, ophthalmologic evaluation should be performed at postoperative 3rd month in patients with preoperative ophthalmologic abnormalities and should be followed every 6 months until maximum improvement is achieved. Follow-up can be discontinued in patients who have no abnormalities at the first postoperative follow-up and those who do not have a residual tumor close to the optic nerve [35].

Surgical revision may be required in 30-48% of NFPA patients due to the presence of large residual tumor in the early period or progression in follow-up after transsphenoidal surgery [36]. In the series published in the literature, it was observed that in a series with 160 microadenomas, MRI showed more than 10.6% tumor growth, 6.3% tumor shrinkage and 83.1% tumor size change in a longer follow-up than 8 years. In the same period follow-up of 353 patients with macroadenoma, 24.1% of the patients had tumor size growth, 12.7% had tumor size reduction and 63.2% of the patients showed similar persistence in the tumor size [37]. In a study conducted by Losa *et al.* [37], postoperative recurrence was found to be lower in patients undergoing early surgery. In the present study the mean postoperative follow-up time was  $75.14 \pm 43.01$  months and 43.5% of the patients had recurrence. It has been showed that the risk of mortality was higher in NPHAs than in healthy

control. The causes of mortality were cardiovascular diseases, respiratory diseases and infections [38]. It has been also found that overall survival in patients with pituitary carcinomas was significantly worse than in patients with invasive pituitary adenomas [39]. In our study, no pituitary carcinoma was found.

### Limitations

The retrospective nature of our study, the low number of patients and the possible deficits in patient file data are among the limitations of our study. We believe that prospective studies with more patient numbers will provide clearer results on postoperative monitoring and follow-up of NFPAs.

### CONCLUSION

As a result, NFPAs are often asymptomatic and are frequently diagnosed as incidental because of the increased imaging modalities currently available. The decision of the treatment is based on adenoma size, growth potential and presence of symptoms. Preoperative detailed endocrinological evaluation is very important in preventing complications due to operation and anesthesia. The urgency of the surgery is related to the severity of visual impairment. Adenoma size and experience of the surgeon are the most important factors affecting surgical success. Hypopituitarism may be developed in patients with normal hypophyseal functions, and also, hypopituitarism may be resolved with surgery. Operation performed in experienced centers, preoperative and postoperative endocrinological evaluation and long-term follow-up are recommended.

### Authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript

### Conflict of interest

The author disclosed no conflict of interest during the preparation or publication of this manuscript.

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## ERRATUM

In the original article “*Preoperative and postoperative features of non-functioning pituitary adenomas: a single center experience*” published in *The European Research Journal*, September 2019, vol. 5, Iss. 5, pp. 827-835, the second author is Buket Biçer instead of Buket Özbiçer.



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