



The Mixed Sellar Barrier: A New Subtype of this Novel Concept

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■ **BACKGROUND:** The use of the recent concept of sellar barrier revealed that a specific group of patients were difficult to categorize. For this reason, we propose to add a new subtype: the mixed sellar barrier. The aim of this work was to define the new mixed barrier subtype and analyze this in a series of operated patients.

■ **METHODS:** A retrospective study was carried out. From January to December 2018, 72 patients with pituitary adenomas underwent surgery by transsphenoidal approach. Patients with more than 1 surgery were excluded. Each patient's magnetic resonance imaging (MRI) was analyzed and classified using the following criteria: strong barrier (>1 mm), weak barrier (<1 mm), and mixed barrier (<1 mm in one region and >1 mm in another part).

■ **RESULTS:** Mixed sellar barrier is the coexistence of 2 types of sellar barrier (strong and weak). The presence of a mixed sellar barrier on MRI was associated with the presence of a mixed sellar barrier intraoperatively ($P < 0.0001$). By using the new MRI classification that includes the mixed sellar barrier, we found a stronger statistically significant association regarding the risk of cerebrospinal fluid leak (for the extreme categories; i.e., strong and weak) compared to the original work.

■ **CONCLUSIONS:** The new mixed sellar barrier subtype was precisely defined and illustrated. The correlation between MRI and intraoperative findings for this new subtype has been demonstrated in this study. A prospective study with a larger series of patients is required for validation.

INTRODUCTION

At the beginning of 2019, our team in Tucumán published the first study that introduces the concept of the sellar barrier.¹ It is classified into 2 types according to the anatomic constitution of the roof of the pituitary fossa²⁻⁸: strong (pituitary gland/dura mater and arachnoid) and weak (only arachnoid). Also, there is a correlation between these subtypes and the characteristics in the preoperative magnetic resonance imaging (MRI). According to the thickness of the sellar barrier in T1 gadolinium sequence, classification into 2 categories was devised: strong (>1 mm) and weak (<1 mm). Patients with a weak barrier have an increased risk of intraoperative cerebrospinal fluid (CSF) leak.¹

Seen in this way, it seems a clear concept and easy to use. However, in practice, it was not so in all cases. A worldwide reference team in pituitary surgery⁹ (University of Naples Federico II, Italy) informed us of the difficulty in categorizing a specific group of patients. In these patients, there was a small segment of the barrier <1 mm thick and a large segment >1 mm thick; or vice versa. For this reason, we propose to add a new subtype of sellar barrier to the category: a mixed sellar barrier.

The purpose of this work was to define the new mixed barrier subtype and analyze this in a series of operated patients.

METHODS

A retrospective study was carried out. From January to December 2018, 72 patients with pituitary adenomas underwent surgery by transsphenoidal approach: 40 assisted by microscope and 32 purely endoscopic.

Patients with more than 1 surgery were excluded. All surgeries were performed in Argentina by the senior authors of each team (LINT in Tucumán and FLENI in Buenos Aires). Both surgeons, despite using different techniques, share the same philosophy:

Key words

- Endoscopic endonasal approach
- Pituitary adenomas
- Sellar barrier
- Skull base
- Surgical treatment

Abbreviations and Acronyms

BMI: Body mass index

CI: Confidence interval

CSF: Cerebrospinal fluid

MRI: Magnetic resonance imaging

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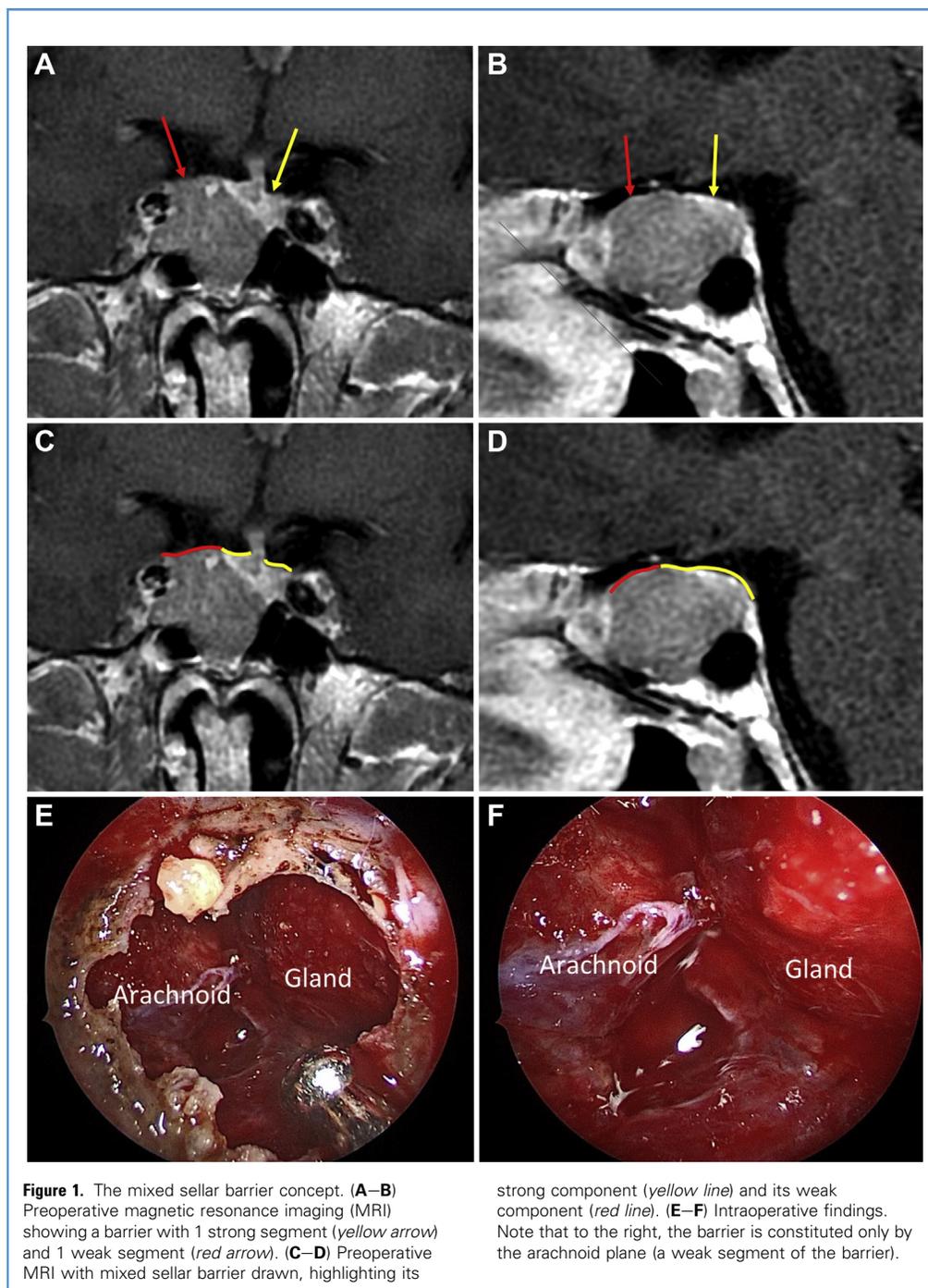
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preserve the nasal structures and avoid the use of flaps in the reconstructive phase of a standard pituitary surgery. In the case of patients operated with a microscopic technique, a classic endonasal approach was used. In the case of patients operated by endoscopic endonasal approach, a “one and half” technique was used. Fat (abdominal or crural, depending on the surgeon’s

preference) and fibrin glue were placed in all patients of the series that presented intraoperative CSF leak.

From each patient, the demographic characteristics, BMI, tumor status and size, intraventricular extension, type of sellar barrier (radiologic and intraoperative), and presence of CSF leakage were recorded.

Table 1. Patient's Preoperative Characteristics and Its Relationship with Cerebrospinal Fluid Fistula

Tumor Characteristics		BMI			
		Normal or Underweight n = 46		Overweight n = 26	
Size	Hormone Status	With CSF Leak n = 11	Without CSF Leak n = 35	With CSF Leak n = 11	Without CSF Leak n = 15
Microadenoma n = 19	GH secretion, n = 6	0	5	0	1
	ACTH secretion, n = 10	0	2	2	6
	PRL secretion, n = 3	1	2	0	0
Macroadenoma n = 53	Nonfunctioning, n = 34	7	19	4	4
	GH secretion, n = 11	1	4	2	4
	ACTH secretion, n = 2	0	0	2	0
	PRL secretion, n = 6	2	3	1	0

BMI, body mass index; CSF, cerebrospinal fluid; GH, growth hormone; ACTH, adrenocorticotropic hormone; PRL, prolactin.

A specific MRI protocol of the sellar region was performed: sagittal and coronal slices of T1-weighted volumetric sequences, with and without contrast; and axial and sagittal slices of T2-weighted and fluid-attenuated inversion recovery (with different 1.5 and 3.0 Tesla resonance).

Considering the T1-weighted volumetric sequences, a measurement of the sellar barrier was made with the Kodak Carestream PACS-Client Suite version 10 software (Carestream Health, Inc., Rochester, New York, USA) as explained in the original article.¹ It was considered a strong barrier (>1 mm), weak barrier (<1 mm), and mixed barrier (<1 mm in one part and >1 mm in another part).

Statistical Analysis

The categorical variables were presented as absolute frequency and percentages, with 95% confidence interval (CI). Continuous variables were presented as a median and interquartile range because the sample was not normally distributed. The statistical analysis between the type of preoperative sellar barrier on MRI (weak, strong, or mixed) and the presence of CSF fistula (yes or no) was performed by the Fisher exact test. For the statistical analysis, we used STATA IC/15.1 (StataCorp LLC, College Station, Texas, USA).

RESULTS

Mixed Sellar Barrier Concept

Radiologic Definition. T1-weighted volumetric sequences that were part of the sellar barrier had >1 mm of thickness, and the other part had <1 mm of thickness (Figure 1A–D).

Intraoperative Definition. The coexistence of 2 types of sellar barrier. After tumor resection, one part of the sellar barrier shows the existing gland and dura mater, and the other part is confirmed by just arachnoid tissue (Figure 1E–F).

Population

From January to December 2018, 72 patients with pituitary adenomas and transsphenoidal surgery were analyzed. The median age of the sample was 43.5 years (36–62 years), 48 (66.6%) were women, and 24 (33.3%) were men.

Regarding the size, 19 (26.3%) were microadenomas and 53 (76.3%) were macroadenomas. The hormone producing status was nonsecretory in 34 (47.2%) cases, 17 (23.6%) secreted growth hormone, 12 (16.6%) secreted adrenocorticotropic hormone, and 11 (12.5%) secreted prolactin (Table 1).

The body mass index (BMI) of the sample, defined as underweight (BMI <18.5), normal weight (BMI 18.5–24.9), and overweight (BMI >25), was in 0 (0%) cases underweight, in 46 (63.8%) cases normal weight, and in 26 (36.1%) cases overweight (Table 1).

MRI Classification and Intraoperative Correlation

After analyzing the MRI, 20 (27.7%) cases had a weak sellar barrier, 15 (20.8%) had a mixed sellar barrier, and 37 (51.3%) had a strong sellar barrier (Table 2).

Table 2. Magnetic Resonance Imaging Classification and Intraoperative Correlation

	Subtype of Intraoperative Sellar Barrier		
	Weak (n = 20)	Mixed (n = 15)	Strong (n = 37)
Subtype of preoperative sellar barrier (by magnetic resonance imaging)			
Weak (n = 20)	20 (100%)	0 (0%)	0 (0%)
Mixed (n = 15)	0 (0%)	11 (73.3%)	4 (26.6%)
Strong (n = 37)	0 (0%)	4 (10.8%)	33 (89.1%)

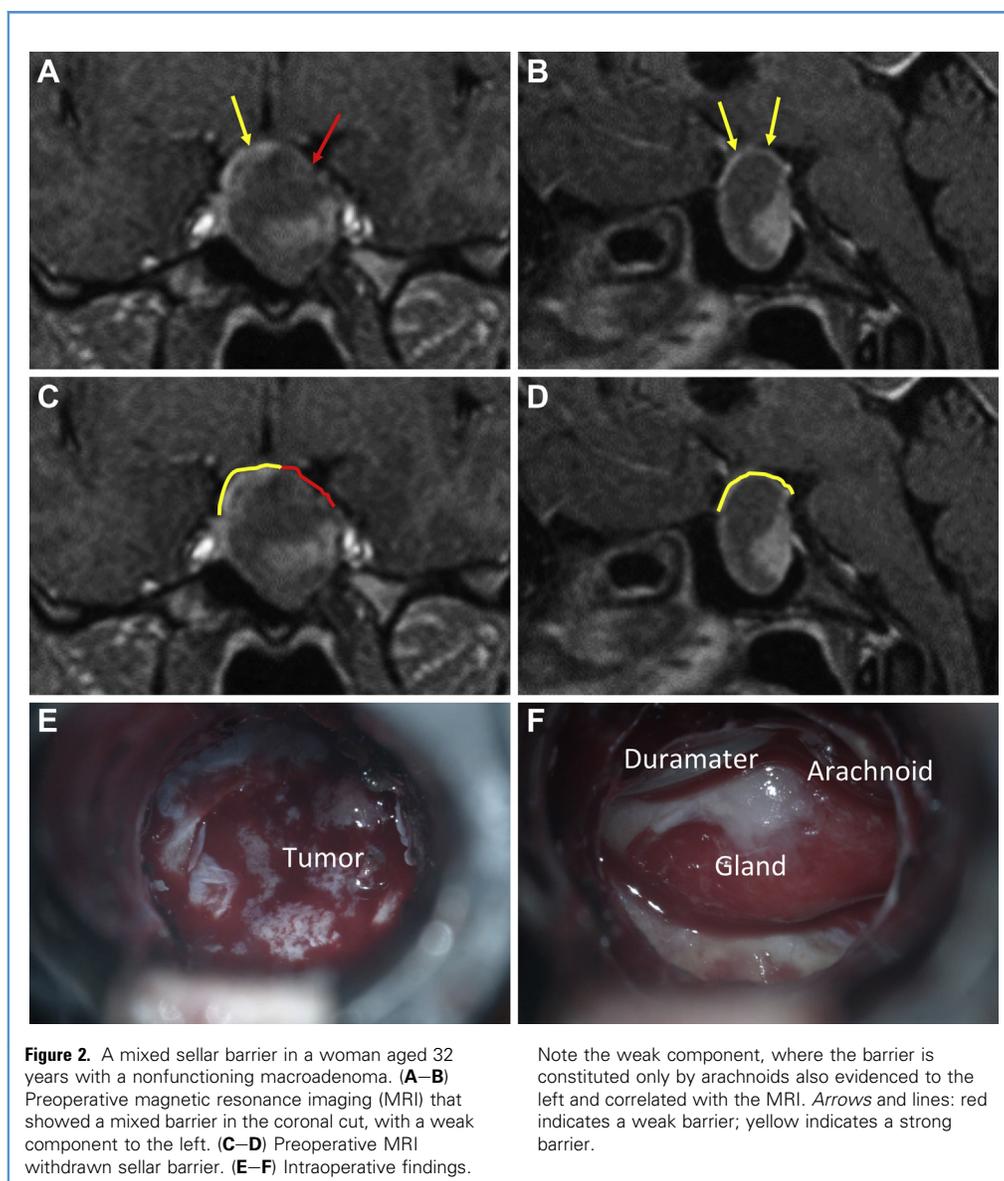


Figure 2. A mixed sellar barrier in a woman aged 32 years with a nonfunctioning macroadenoma. **(A–B)** Preoperative magnetic resonance imaging (MRI) that showed a mixed barrier in the coronal cut, with a weak component to the left. **(C–D)** Preoperative MRI withdrawn sellar barrier. **(E–F)** Intraoperative findings.

Note the weak component, where the barrier is constituted only by arachnoids also evidenced to the left and correlated with the MRI. Arrows and lines: red indicates a weak barrier; yellow indicates a strong barrier.

Of the total amount of patients ($n = 37$) with a strong sellar barrier on MRI, 33 (89.1%; 95% CI, 74.1%–95.1%) cases had an intraoperative strong sellar barrier, and 4 (10.9%; 95% CI, 4.2%–27.1%) cases had a mixed sellar barrier. The presence of a strong sellar barrier on MRI was associated with the presence of a strong sellar barrier intraoperatively ($P < 0.0001$).

Of the total amount of patients ($n = 15$) with a mixed sellar barrier on MRI, 11 (73.3%; 95% CI, 46.1%–89.8%) cases had an intraoperative mixed sellar barrier, and 4 (26.6%; 95% CI, 10.1–53.8) cases had a strong sellar barrier. The presence of a mixed sellar barrier on MRI was associated with the presence of a mixed sellar barrier intraoperatively ($P < 0.0001$) (Figures 2–5).

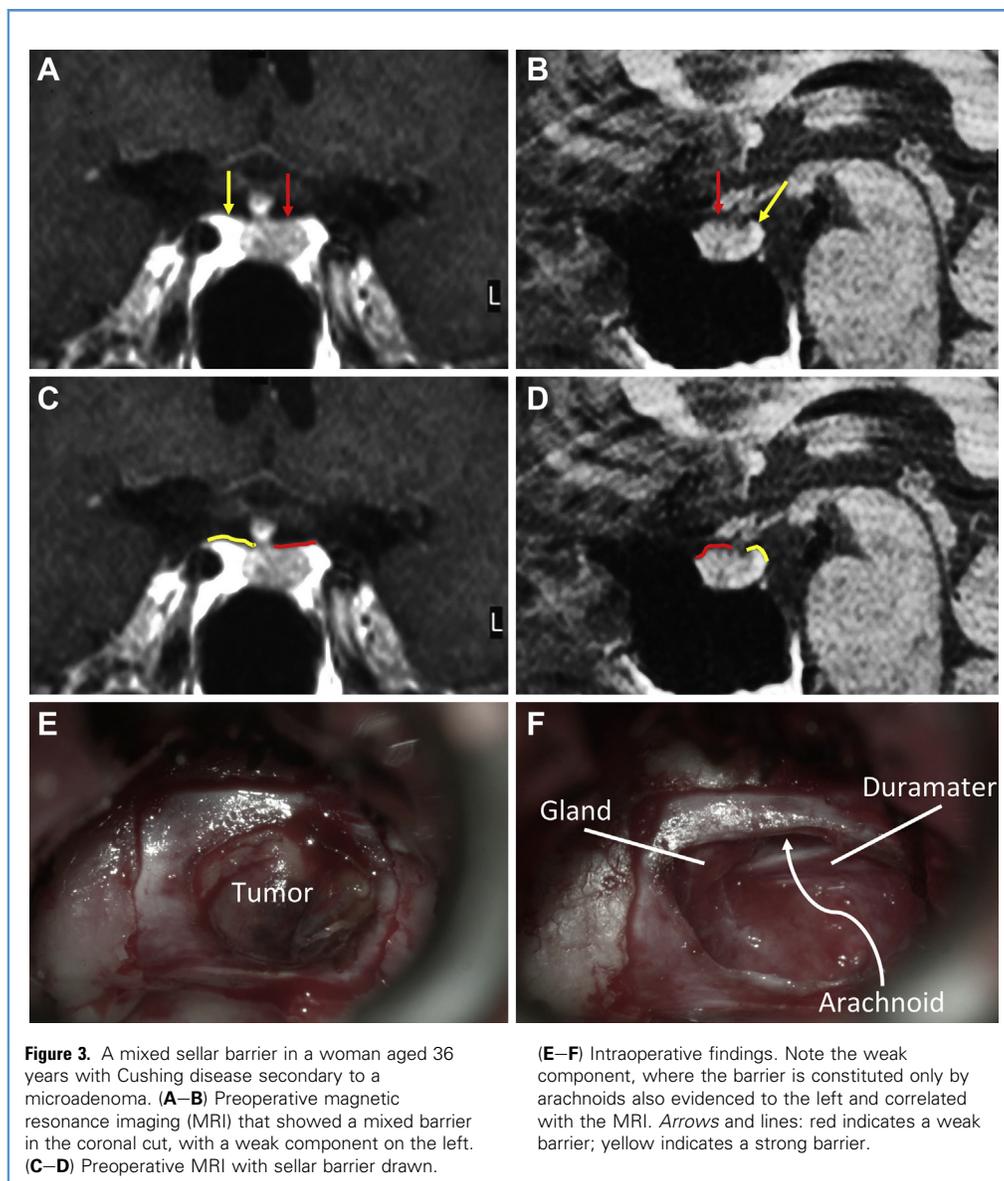
Of the total amount of patients ($n = 20$) with weak sellar barriers on MRI, 20 (100%) cases had an intraoperative weak

sellar barrier. The presence of a weak sellar barrier on MRI was associated with the presence of a weak sellar barrier intraoperatively ($P < 0.0001$).

MRI as a Predictor for Intraoperative CSF Leak

CSF intraoperative leak was found in 22 (30.5%) patients, whereas 50 (69.4%) cases did not present it.

When analyzing the sellar barrier classification based on MRI images, we observed that of the total number of patients ($n = 37$) with strong sellar barrier, 35 (94.5%; 95% CI, 80.4%–98.6%) did not present intraoperative CSF fistula, whereas 2 (5.4%; 95% CI, 1.3%–19.5%) did present. The presence of strong sellar barrier by MRI was a protective factor for the presence of CSF fistula (94.5% vs. 5.4%; $P < 0.0001$).



Of the total number of patients ($n = 15$) with a mixed sellar barrier, 6 (40%; 95% CI, 18.9%–65.5%) presented CSF fistula, whereas 9 (60%; 95% CI, 34.4%–81.09%) did not. No statistically significant association was found between the presence of a mixed sellar barrier by MRI and CSF fistula (60% vs. 40%; $P = 0.36$).

Of the total amount of patients ($n = 20$) with a weak sellar barrier, 14 (70%; 95% CI, 46.8%–86.05%) presented CSF fistula, whereas 6 (30%; 95% CI, 13.9%–53.1%) did not. The presence of a weak sellar barrier by MRI was associated with CSF fistula (70% vs. 30%; $P < 0.0001$).

DISCUSSION

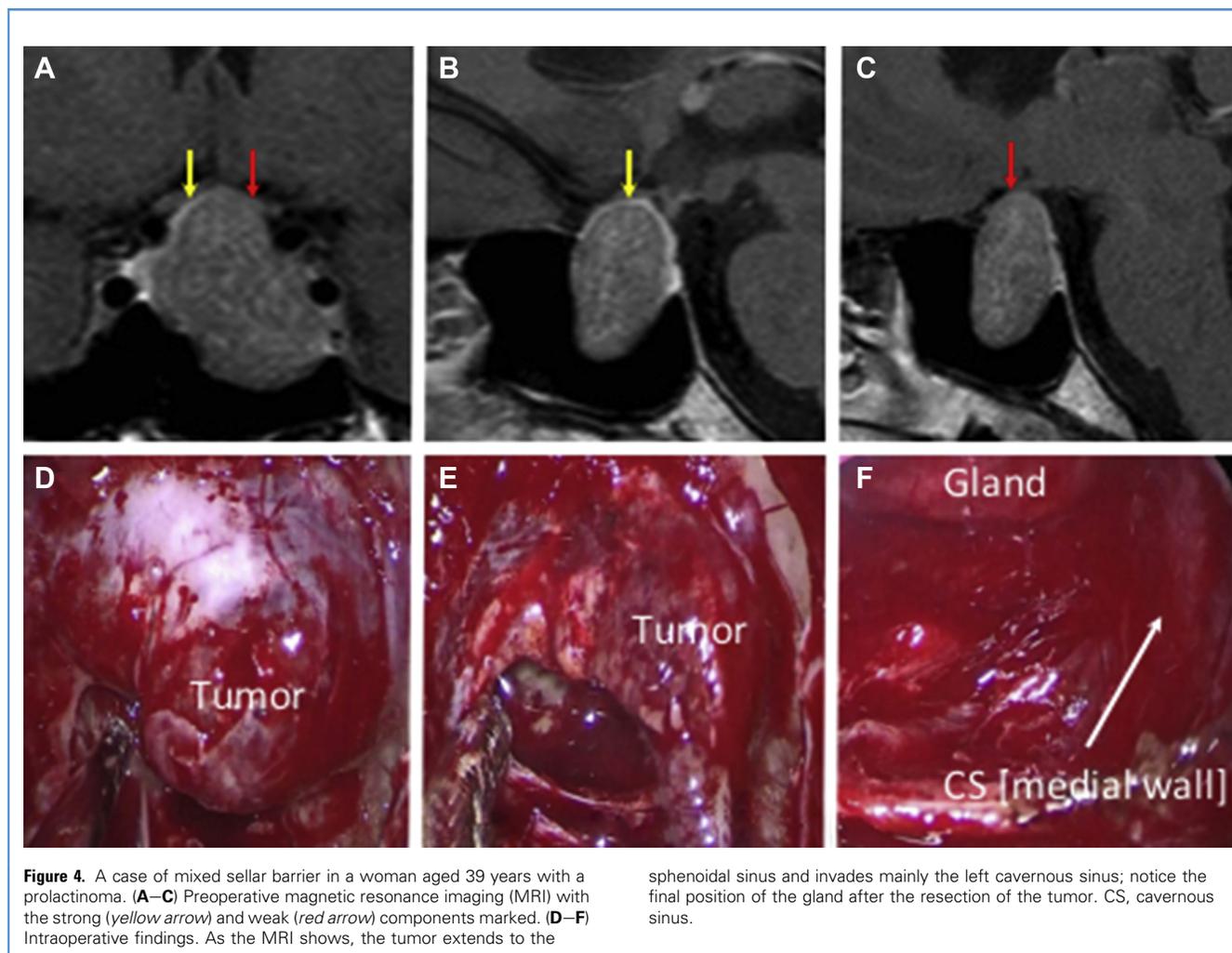
Pituitary adenomas are a frequent neurosurgical pathology in the adult population.¹⁰ In recent years, there has been an almost quadrupled increase in the prevalence of this disease.¹¹

Surgery continues to be a mainstay in the treatment of this pathology.¹² Postoperative CSF leak is a significant complication in transsphenoidal surgery, such as in microscopic, assisted endoscopic, or purely endoscopic surgery.^{13–16} In this sense, having a CSF leak predictor factor is relevant, as it allows the surgeon to 1) inform the patient or his family about the risk of intraoperative and postoperative CSF leakage; and 2) select an adequate surgical technique with the future use of crural fat¹⁶ or flaps.¹⁷

Tips to Understanding the Concept of Mixed Sellar Barrier in MRI

It is much easier to understand the concept of a mixed barrier if we contrast it with that of a strong or weak barrier (Figure 6G–I).

It is important to note that we must always observe the constitution of the entire sellar barrier in a coronal cut that passes



at the height of the pituitary gland and stalk. The mixed subtype is easy to see in this cut.

Then, we must make its correlation with the sagittal plane. We will be able to observe how in a parasagittal cut, the barrier is weak (Figure 6H) and in the contralateral parasagittal cut, the barrier is weak (Figure 6I).

MRI as a Predictor of the Type of Intraoperative Sellar Barrier

This study showed a statistically significant association between the 3 subtypes of sellar barrier in MRI and the intraoperative findings. This could justify the new subtype of a mixed sellar barrier.

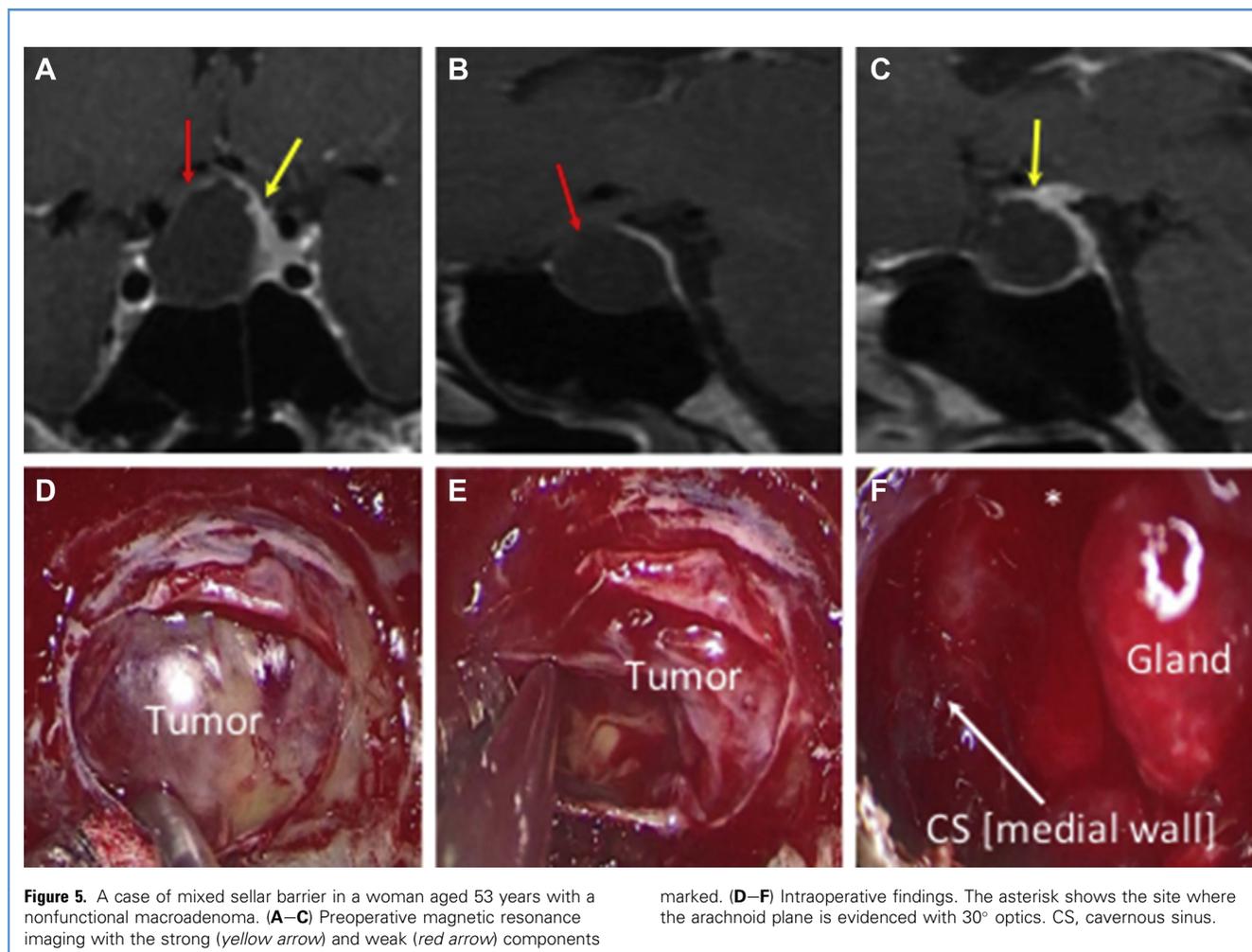
In this study, the presence of a mixed barrier by MRI was evidenced in 20.8% (n = 15) of the patients (Figure 2–5). Of the patients with a mixed barrier on MRI, it was evidenced: intraoperative mixed barrier in 73% (n = 11), strong barrier in 27% (n = 4), and weak in 0% (n = 0). The fact that there were 4 patients with a mixed barrier on MRI that were categorized as strong intraoperative barrier has a logical explanation: after the resection, the lower portion of the adenoma the gland (that is

displaced to one side) begins to descend and focus, and thus becomes a strong barrier (Figure 4).

We consider of great importance that in no case of a preoperative mixed barrier was a weak sellar barrier objective in the intraoperative. According to the results, if the surgeon observes a strong or mixed sellar barrier on MRI, he will never find a weak intraoperative barrier. Another fact to emphasize is that in 100% of cases in which a weak sellar barrier is targeted on MRI, the intraoperative finding after resection of the tumor was only an arachnoid layer (i.e., weak barrier).

The Relevance of the Incorporation of this New Category in the Classification

Compared to the original study,¹ a statistically stronger association was obtained between the type of sellar barrier on MRI and CSF leak. Therefore the ends of the classification were more differentiated: a strong barrier is a protective factor for CSF leak, whereas a weak barrier is a risk factor for CSF leak. This is explained because a more refined categorization was performed by adding the subtype



mixed sellar barrier. The strong and weak subtypes were further “purified” with this new classification into 3 categories.

MRI as a Predictor Factor of CSF Leakage: New Advances

The association between the kind of intraoperative sellar barrier and CSF leak was key to our first research. However, the association between MRI and CSF leak is what gives applicability in the daily life of neurosurgeons. This study demonstrates again MRI as a reliable tool for predicting the risk of CSF leak. The neurosurgeon will be able to show the MRI to the patient and explain about their eventual risk of CSF leak. Also, the neurosurgeon will be able to discuss with his or her team the different reconstructive phase

variables that the surgery could have. All this, with a simple study in your hand: the MRI.

Limitations

This is a retrospective study with a nonlarge series of patients. A prospective multicenter study with a more extensive patient series is required to validate this concept and its clinical applicability.

CONCLUSIONS

The new mixed sellar barrier subtype was precisely defined and illustrated. The correlation between MRI intraoperative findings for this new category was demonstrated.

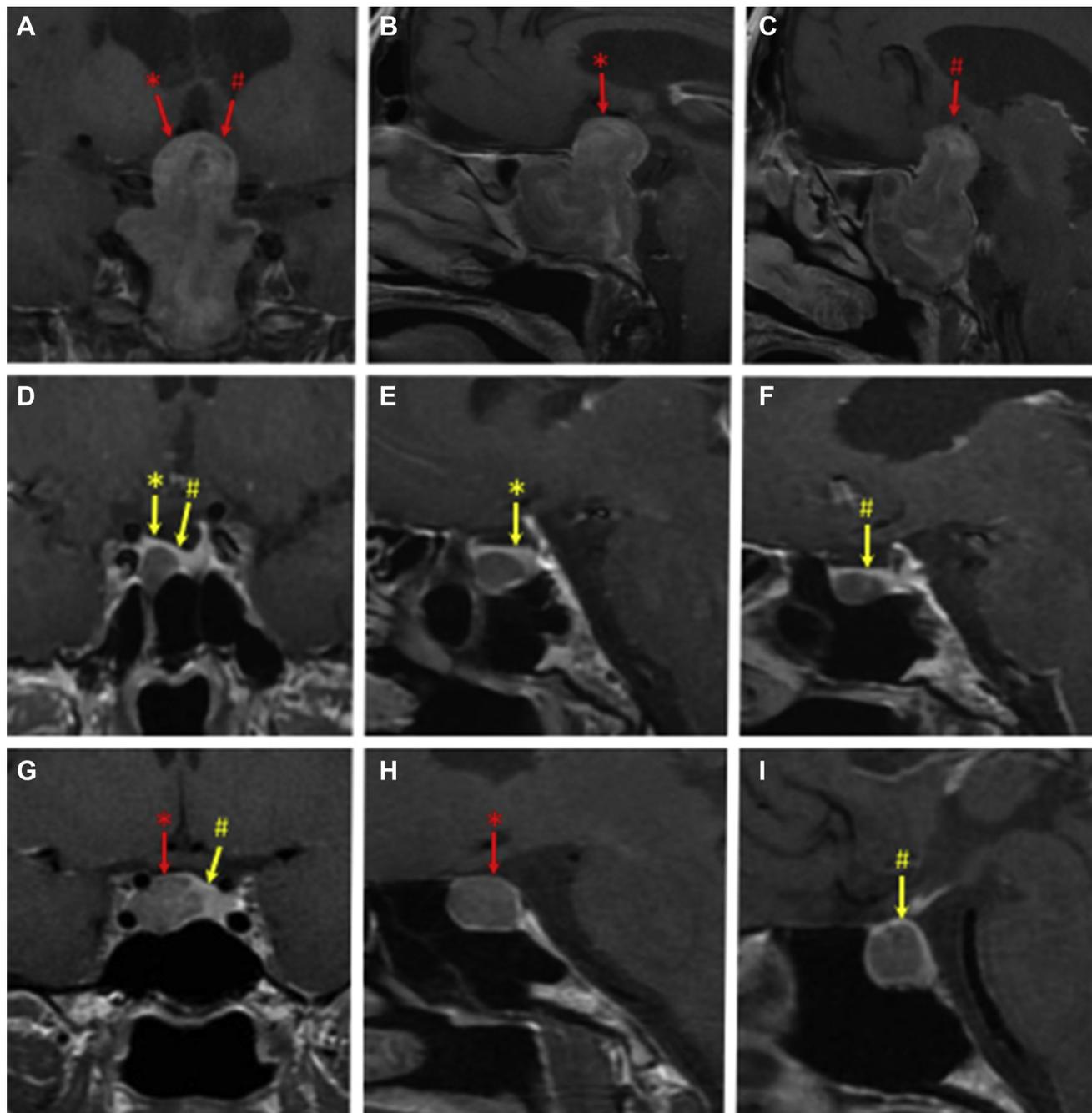


Figure 6. Definition by the contrast of the mixed sellar barrier in preoperative magnetic resonance imaging. (A–C) Subtype weak; (D–F)

subtype strong; (G–I) subtype mixed. *Red arrow*, weak component; *yellow arrow*, strong component; *right side; #left side.

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