

## Incidental meningiomas

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With the increasing availability and use of modern brain diagnostic imaging modalities, discovery of incidental meningiomas has become fairly common. This creates a dilemma among neurosurgeons as to whether these lesions should be treated. Numerous natural history studies have been published in an effort to shed light on the potential for growth of incidental meningiomas. The available data appear to suggest that these tumors can fall into 1 of 3 main growth patterns: no growth, linear growth, or exponential growth. The therapeutic strategy selected should also consider several other factors, mainly the risk of complications from an eventual surgery, the possibility of malignancies and other pathological conditions that mimic meningiomas, and the age and medical condition of the patient. The authors believe that most asymptomatic incidental meningiomas can be observed using serial imaging and clinical follow-up evaluations. Surgical interventions are typically reserved for large, symptomatic lesions and those with documented potential for significant growth. (DOI: 10.3171/2011.9.FOCUS11220)

**KEY WORDS • incidental • meningioma • natural history • management**

**I**N recent years, there has been a progressive increase in the use of brain imaging modalities. In practice, clinicians try to maintain a high index of suspicion in an effort to diagnose intracranial lesions at an early stage based on subtle signs and symptoms. In the research field, there is an ongoing effort to understand normal brain functions, as well as diseases affecting the central nervous system. The aforementioned inquiries—whether research- or clinically based—resulted in a large number of published studies based on structural and functional brain imaging in healthy volunteers and/or patients with neurological disorders. In addition, the concern of missing a diagnosis has led physicians to order more laboratory tests and imaging. All of these factors have resulted in a substantial increase in the number of brain imaging scans performed and consequently of incidentally found abnormalities.

Incidental findings on brain imaging have been defined as “previously undetected abnormalities of potential clinical relevance that are unexpectedly discovered and unrelated to the purpose of the examination.”<sup>13</sup> Katzman et al.<sup>15</sup> reported the incidental findings on brain MR imaging from 1000 asymptomatic volunteers who participated as control subjects for research protocols at the NIH (age range 3–83 years; 54.6% male). Their participation resulted in the detection of incidental findings in several patients, some of them requiring medical referral, including 3 cases of suspected brain tumors. In another report involving 3672 people aged 65 years and older who were enrolled in a population-based study of cardiovas-

cular and cerebrovascular disease, 64 (1.74%) clinically relevant abnormalities were found, and 19 of them were meningiomas (prevalence 0.52%).<sup>35</sup> In a more recent prospective population-based study in the Netherlands involving 2000 people who were 45 years of age or older, the prevalence of benign brain tumors was 1.6%, with meningiomas as the most common (0.9%).<sup>31</sup> These meningiomas ranged from 5 to 60 mm in diameter, and their prevalence was 1.1% in women and 0.7% in men. The study also detected an increase in prevalence from 0.5% in patients 45–59 years old to 1.6% in those 75 years old or older.

With the discovery of these incidental findings, physicians are faced with several important questions. What is the clinical significance of the lesion? What is the natural history, and what are the indications for a therapeutic intervention? In this article, we will focus specifically on incidental meningiomas. Our purpose is to review the relevant medical literature related to this topic and discuss the decision-making strategy involved in their management given the available data on their natural history and potential for complications.

### Epidemiological Data

An epidemiological study conducted in Germany between 1961 and 1986 found an annual incidence of meningioma of 1.85 per 100,000 population.<sup>28</sup> The rates were 2.1 times higher in women (2.44) than in men (1.16),

and the incidence increased continuously with age. Interestingly, approximately 50% of the meningiomas in the study were discovered at autopsy. This high rate of meningiomas first found on postmortem examination can be explained by the fact that these are typically slow-growing benign tumors and that they can remain asymptomatic throughout the life of the individual. In the US, the prevalence of meningiomas is estimated to be 97.5 per 100,000 people.<sup>7</sup> Data from the Central Brain Tumor Registry of the US also showed a more than 2-fold higher incidence among females and a steady increase in incidence with age:<sup>4</sup> the incidence rates in 2002 for the age groups 20–34, 45–54, 65–74, and above 85 years were 0.74, 4.89, 12.79, and 18.86 per 100,000 individuals per year, respectively. Atypical and malignant meningiomas comprise a relatively small fraction of the total (estimated to be approximately 5%).<sup>32</sup>

### Natural History of Incidental Meningiomas

Understanding the natural history of incidentally found meningiomas is a crucial step in formulating an approach to address them and deciding whether they should be treated. Several studies have been conducted to better understand the behavior of these lesions if left untreated. Nakamura et al.<sup>19</sup> reported their results in 47 asymptomatic patients monitored with serial imaging. The absolute annual growth rate ranged from 0.03 to 2.62 cm<sup>3</sup>/year (mean 0.796 cm<sup>3</sup>/year), and the majority of tumors (66%) grew less than 1 cm<sup>3</sup>/year. The relative annual growth rates ranged from 0.48% to 2.8% (mean 14.6%). The tumor doubling time ranged from 1.27 to 143.5 years (mean 21.6 years). The authors also found a moderate correlation between age and annual growth rates, with younger patients showing a higher growth rate and shorter doubling time. Other important predictive factors included the presence of calcifications and hypointense or isointense tumor signal on T2-weighted MR imaging, which were associated with statistically significantly lower growth rates. Although annual growth rates appear to be higher in men than in women, the difference did not reach statistical significance.

In several studies that investigated the growth pattern of incidental meningiomas, annual growth rates were calculated by determining the initial and final volumes during the follow-up period based on the assumption that these tumors grow exponentially.<sup>8,19</sup> Hashiba et al.<sup>11</sup> performed serial monitoring of tumor volumes in 70 patients and used regression analysis to analyze tumor growth. In each case, the tumor volume was calculated at follow-up and plotted on time-to-volume coordinates. Patients were then divided into 2 groups: a growth group and a no-growth group. Growth curves in the first group were examined to determine whether they followed a linear or an exponential model. Twenty-six patients (37%) showed essentially no growth of their tumor. Among 44 patients with tumor growth, 16 followed an exponential growth pattern, 15 followed a linear pattern, and 13 did not fit either pattern. The presence of calcification was the only radiological characteristic predicting a no-growth pattern. Of note, there was no significant difference between

growth/no-growth or between different growth patterns with regard to tumor location; however, the authors of the study admitted that tumor cell kinetics are complex and their relationship to tumor volume is still poorly understood. Fitting the growth curves to either linear or exponential patterns may be too simplistic, and meningiomas may actually exhibit various patterns of growth over multiple phases.

In the largest and most recent study on the topic published to date, Oya et al.<sup>22</sup> reported their results in 244 patients who harbored 273 incidental meningiomas. A 2-mm or greater increase in maximum diameter was observed in 120 tumors (44% of the cases), with a mean follow-up period of 3.8 years. Predictive factors of tumor growth in this study were younger age, absence of calcifications, T2 signal hyperintensity, and peritumoral edema. Tumor location was not found to be a significant predictive factor (Table 1). Nakasu et al.<sup>20</sup> suggested that atypical meningiomas grow exponentially, while benign meningiomas exhibit exponential, linear, or no growth. Exponential growth essentially means that the tumor grows with a constant growth fraction. Linear growth entails a gradual decrease in the tumor growth speed (decrease of the cell proliferation rate and/or increase of the cell death rate). Meningiomas may initially grow exponentially but then slow their growth, possibly in relationship to the availability of blood supply and progression of calcifications; the opposite may also happen, possibly through acquisition of new mutations resulting in an increase in growth rate.

### Lesions Mimicking Meningiomas

Incidental meningiomas are, by definition, diagnosed on brain imaging, typically an MR image of the brain, with no histopathological confirmation. Although radiological findings are usually fairly characteristic, many lesions can mimic the appearance of meningiomas on imaging (Figs. 1 and 2). This possibility underscores the importance of an initial close follow-up evaluation if a conservative approach is chosen. The two classical differential diagnoses for meningioma are hemangiopericytoma and meningeal metastasis. Hemangiopericytoma is a rare intracranial malignancy believed to represent 2%–3% of all primary meningeal tumors.<sup>24</sup> Hemangiopericytomas were initially considered a subgroup of meningioma (angioblastic variant),<sup>1</sup> but since 1993 the WHO has classified them as a distinct entity.<sup>27</sup> Hemangiopericytomas are known for their aggressive behavior, high recurrence rate, and potential for metastasis. The median survival from the time of diagnosis is approximately 13 years.<sup>24</sup>

Dural metastasis can also look like meningiomas, with a similar enhancing pattern and dural tail. It is estimated that dural metastases are found in 8%–9% of patients with advanced systemic cancer at autopsy.<sup>18</sup> The clinical incidence is lower because many of these lesions are asymptomatic. The most commonly reported primary tumors that undergo meningeal metastases are prostate, lung, and breast cancer.<sup>16,18</sup> Numerous other diseases can also mimic meningiomas, including lymphoma,<sup>9,23</sup> ependymoma,<sup>25</sup> sarcoma,<sup>3</sup> periosteal osteoblastoma,<sup>30</sup> inflammatory pseudotumor,<sup>14</sup> and Rosai-Dorfman disease.<sup>10</sup>

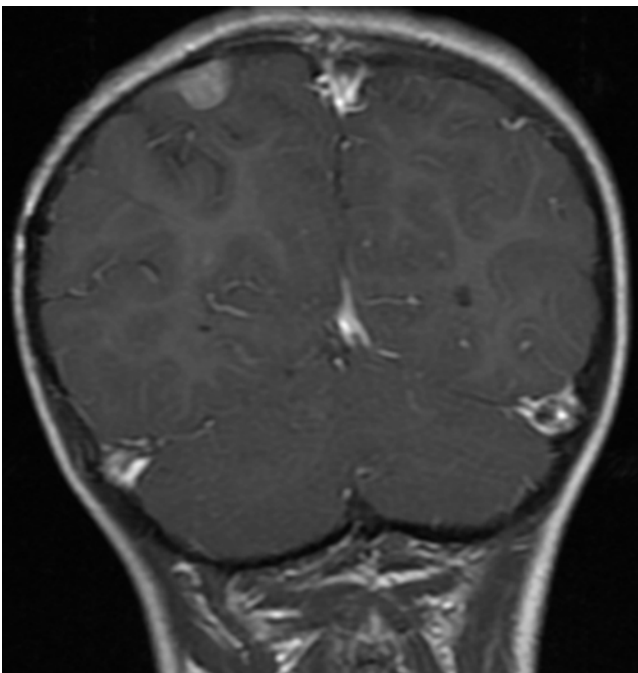
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**TABLE 1: Summary of studies on natural history of incidental meningiomas published from 2000 through 2011\***

Authors & Year	No. of Patients	Mean FU (mos)	No. (%) Showing Growth	Average Growth Rate Per Year	Factors Favoring Growth	Factors Favoring No Growth
Kuratsu et al., 2000	63	27.8	20 (31.7)	not available	T2 hyperintensity	calcification
Niuro et al., 2000	40	41.8	14 (35)	not available	larger size, T2 hyperintensity, male sex	calcification
Yoneoka et al., 2000	37	50.4	9 (24.3)	>1 cm <sup>3</sup>	younger age	smaller tumors
Nakamura et al., 2003	41	43	(33% grew >1 cm <sup>3</sup> /yr)	0.796 cm <sup>3</sup>	younger age, T2 hyperintensity	calcification
Herscovici et al., 2004	43	67	16 (37.2)	>0.2 cm <sup>3</sup>	younger age, sphenoid ridge	calcification, smaller tumors
Yano & Kuratsu, 2006	67	>60	25 (37.3)	1.9 mm	T2 hyperintensity	calcification
Hashiba et al., 2009	70	39.3	40 (57.1)	exponential growth in 16, linear in 15	none	calcification
Oya et al., 2011	244	45.6	120 (49.2)	0.54 cm <sup>3</sup> (patients <60 yrs), 0.83 cm <sup>3</sup> (patients >60 yrs)	younger age, T2 hyperintensity, peritumoral edema	calcification

\* FU = follow-up.

Regular radiological and clinical monitoring can help ascertain the behavior of the lesion and can potentially raise uncertainties regarding the presumed diagnosis of a benign meningioma. Table 2 provides a summary of the main lesions that are usually considered in the differential diagnosis, although it is not an exhaustive list of all of the possibilities. In addition, depending on the anatomical location, other diagnoses should be considered. For instance, schwannomas may be included in the differential diagnosis for a cerebellopontine angle tumor and pituitary adenomas and craniopharyngiomas should be added for a sellar tumor.



**Fig. 1.** Coronal T1-weighted MR imaging with contrast enhancement showing an extraaxial ependymoma that mimicked meningioma on imaging.

## Complications of Surgery

Despite major advances in modern therapies, including state-of-the-art medical care and up-to-date surgical technologies, the risk of complications from a surgical intervention cannot be overlooked. Meningioma surgery as a



**Fig. 2.** Axial T1-weighted MR imaging with contrast enhancement showing a solid enhancing extraaxial mass with evidence of focal bone involvement of the temporal bone (arrow). This lesion was an osteoblastoma that mimicked meningioma on imaging. Reprinted from **Pathol Res Pract 204**: Tawil A, Comair Y, Nasser H, et al. Periosteal osteoblastoma of the calvaria mimicking a meningioma, 413–422, Copyright (2008), with permission from Elsevier.

**TABLE 2: Differential diagnosis for meningiomas**

glial & mesenchymal neoplasms
hemangiopericytoma
solitary fibrous tumor
sarcoma (leiomyosarcoma, gliosarcoma)
ependymoma
osteoblastoma
dural metastatic tumors
prostate cancer, lung cancer, breast cancer, & others
hematopoietic neoplasms
Hodgkin disease
Non-Hodgkin lymphoma
plasmacytoma
inflammatory/infectious lesions
Rosai-Dorfman disease
sarcoidosis
granuloma
tuberculoma

whole constitutes a very heterogeneous group, and the risk of complications varies greatly within this group. The resection of a meningioma can vary from a technically simple procedure to a formidably challenging endeavor associated with a high risk of injury to critical structures. When recommending surgery, the clinician should be mindful of the risks involved and should balance them against the potential benefits of surgical intervention. Sanai et al.<sup>26</sup> reported a series of 141 consecutive patients who underwent resection for a supratentorial convexity meningioma. Their objective was to report the outcome of this kind of surgery in the modern neurosurgical era. They found an overall complication rate of 10%, including hematoma, infection, CSF leak, and pulmonary embolus. Unsurprisingly, the complication rate is significantly higher when more complex types of meningiomas are considered. In a series of 81 patients with tentorial meningiomas treated microsurgically, the permanent surgical morbidity rate was 19.8%, while the mortality rate was 2.5%.<sup>2</sup> Such a high rate of complications has also been reported with many skull base tumors such as petroclival meningiomas. In a surgical series of 109 consecutive patients, for instance, Couldwell et al.<sup>6</sup> reported a perioperative mortality rate of 3.7%; in addition, 56 significant complications occurred in 35 other patients.

Complications of meningioma surgery, however, are not solely related to tumor location and the technical aspects of surgery. Many patients that present are elderly individuals with comorbidities that put them at risk for serious medical complications that may be unrelated to their disease. In a review of 834 patients who underwent surgery for meningiomas in a large tertiary care center, 33% of the patients were older than 60 years of age.<sup>29</sup> Overall, 57 patients (6.8%) experienced serious medical complications, and 4 patients died. The most common complication was pneumonia, followed by renal dysfunction, arrhythmia, and deep venous thrombosis and/or pulmonary embolus. The risk factors for serious medical complications included

a new or worsened neurological deficit, age greater than 65 years, hypertension, and currently taking more than 2 cardiac medications.

### Indications for Surgery

The treatment strategy for an incidentally diagnosed meningioma should be formulated after a careful and thorough evaluation. Unfortunately, no Class I or Class II evidence is available to support the standard of care or practice guidelines. All recommendations are based on Class III evidence related to expert opinions and retrospective case series. Pertinent questions that should be addressed include the following. Is the lesion symptomatic? What is the size of the lesion? Does the patient have previous imaging? How old is the patient? What is the patient's medical condition? A number of arguments can be made in favor of resection of incidental meningiomas: 1) a certain percentage of these tumors can be atypical or malignant; 2) numerous more aggressive lesions can mimic meningiomas on imaging; 3) an untreated tumor can be the source of anxiety to the patient; and 4) resection would reduce the need for careful initial follow-up. Although these arguments support resection for some incidental meningiomas, we believe that the vast majority of asymptomatic incidental meningiomas should be treated conservatively. In our practice, surgery is recommended if 1) the tumor is large with obvious mass effect accompanied by neurological symptoms; 2) there is a documented increase in size on serial imaging; 3) there is a reasonable suspicion for malignancy based on tumor appearance or behavior; and 4) if the patient is medically fit for surgery.

The decision to use conservative management is supported by several factors. Although the differential diagnosis is vast and although some meningiomas may prove to be malignant, benign meningiomas remain by far the most common lesion when the MR imaging is characteristic for this tumor. Furthermore, a close initial radiographic and clinical monitoring can detect rapid growth, change in imaging characteristics, or unexpected worsening in the neurological examination, leading to an adjustment in the management plan. A reasonable approach would be to start with a first follow-up in 3–4 months from the time of diagnosis to rule out growth of an aggressive lesion. The time frame can then be further increased to 6–9 months and thereafter to 1 year. Furthermore, the vast majority of asymptomatic meningiomas either remain stable or grow slowly. In a large clinical series of 603 asymptomatic meningiomas,<sup>33</sup> 63% did not increase in size, and only 6% of patients eventually experienced symptoms (mean follow-up of 3.9 years). In light of these data, and because the risk of serious complications can clearly outweigh any potential benefit in the elderly and patients with significant comorbidities, a conservative approach is often sufficient. Finally, patient education on the nature of these lesions and their natural history would alleviate anxiety in most cases. The senior author (W.T.C.) specifically removes incidental tumors that are of significant size in young individuals, those tumors that are associated with significant edema, or those found in younger individuals in locations in which further growth might limit the ability to remove the lesion with

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**TABLE 3: General criteria for treatment selection in patients with intracranial meningioma\***

Patient Age (yrs)	Type of Intracranial Meningioma	Treatment
≤65	asymptomatic	observation: serial imaging and clinical FU; surgery recommended for growing lesions or stereotactic radiosurgery can be considered for some tumor locations associated w/ high surgical morbidity (such as cavernous sinus)
	symptomatic	primary treatment is surgery; stereotactic radiosurgery considered adjunctively when complete resection is not possible; adjuvant radiotherapy considered for atypical & anaplastic tumors
>65 (or poor surgical candidate)	asymptomatic	observation: serial imaging & clinical FU; stereotactic radiosurgery considered for growing lesions; surgery considered for further progression & neurological deterioration
	symptomatic (tumor <3 cm)	stereotactic radiosurgery is considered; surgery considered for further progression & neurological deterioration
	symptomatic (tumor ≥3 cm)	close monitoring if minimally symptomatic; surgery considered for further progression &/or significant impact on quality of life

\* From Couldwell 2011.<sup>5</sup>

the lowest possible Simpson grade. Stereotactic radiosurgery is usually considered for lesions showing documented growth on serial imaging in older patients, those with comorbidities, and for lesions in locations associated with a high surgical morbidity. Table 3 illustrates the general criteria that we use when deciding which treatment option is best for the individual patient.<sup>5</sup>

### Case Illustrations

#### Case 1

This patient was a 79-year-old woman who complained of swelling of the throat. On physical examination, she was found to have bruit over the left internal carotid artery. As part of her evaluation, she underwent MR angiography of the neck that showed the presence of asymptomatic stenosis of the internal carotid artery. Magnetic resonance imaging of the brain showed the presence of an incidental tuberculum sella meningioma (Fig. 3). The patient did not have visual symptoms and was neurologically intact on examination. Her endocrinological workup was normal as well. In view of her age and the size of the lesion, the decision was made to proceed with serial imaging for follow-up. She has since been followed-up for more than 5 years without tumor growth or visual symptoms.

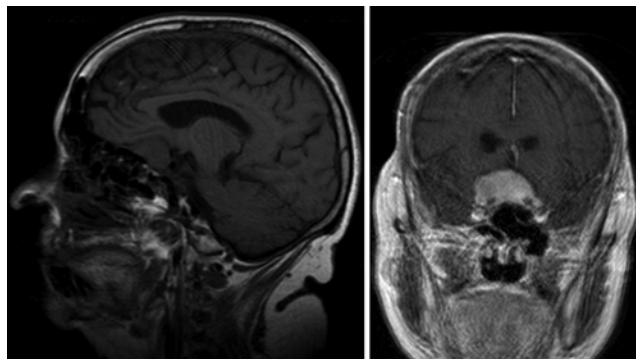
#### Case 2

This patient was a 27-year-old woman with longstanding nonspecific headaches and a normal neurological examination. Magnetic resonance imaging of the brain showed the presence of a large lateral sphenoid wing meningioma (Fig. 4). The mass had a maximum diameter of 4.5 cm and was associated with significant brain edema and mass effect. The decision to operate was made because of the large size of the tumor, the peritumoral edema, and the young age of the patient.

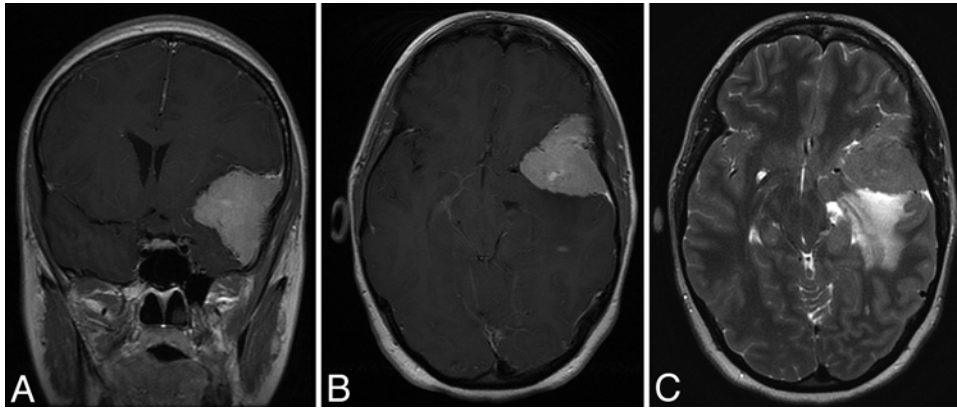
### Conclusions

In recent years, physicians have increasingly been

faced with an aging population in a technologically advanced world of preventative medicine that affords more screening modalities performed over a longer time period. This ultimately results in the identification of a number of patients with asymptomatic meningiomas. While these lesions can be the source of anxiety for the patient, a thorough discussion with the physician and an education on the nature of incidental meningioma can help the patient to better understand the condition and participate in the decision-making. The available data on the natural history of incidental meningioma suggest that most of these lesions either remain stable in size or grow very slowly over time. In light of this, physicians should try to be conservative in their approach for treating incidentally found meningiomas, keeping in mind, however, that some of these lesions can grow significantly and become symptomatic. The possibility of a malignant meningioma or other kinds of malignancies mimicking meningiomas should also be kept in mind. A prudent approach would be a close initial radiographic and clinical follow-up to detect unexpected tumor behavior. The follow-up period



**FIG. 3.** Case 1. Sagittal T1-weighted MR imaging without contrast enhancement (left) and coronal T1-weighted MR imaging with contrast enhancement (right) showing a tuberculum sella extraaxial lesion consistent with meningioma. The lesion measured 2.5 × 1.7 cm. No treatment was offered, and the tumor has been monitored for more than 5 years with no changes in size or symptoms.



**FIG. 4.** Case 2. Coronal (A) and axial (B) T1-weighted MR imaging with contrast enhancement and axial T2-weighted MR imaging (C) showing the presence of a large, left, lateral sphenoid wing meningioma. The lesion was 4.5 × 3.0 cm. The T2-weighted image demonstrates significant peritumoral edema. The large lesion (WHO Grade I meningioma) was surgically resected; 2 smaller contralateral lesions are being monitored with serial imaging.

can then be increased gradually once the tumor is found to be stable. In addition, the possibility of complications in a population of older patients who may harbor comorbidities that puts them at higher risk for serious complications from surgery argues for a conservative management approach. We prefer to reserve surgical interventions for large symptomatic lesions and those with a documented potential for growth. A high index of suspicion for malignancy based on imaging characteristics and/or patient's medical history would also favor resection.

#### Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Couldwell. Acquisition of data: Chamoun, Krisht. Analysis and interpretation of data: Chamoun. Drafting the article: Chamoun, Krisht. Critically revising the article: Couldwell, Chamoun. Reviewed submitted version of manuscript: Couldwell, Chamoun. Approved the final version of the manuscript on behalf of all authors: Couldwell. Study supervision: Couldwell.

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