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Instruction To Authors

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Submission of a revised manuscript should include a Revision Letter or Cover Letter (with detailed responses to reviewers). Revised Manuscripts should have tracked or highlighted changes including also the revised Figures and/or Tables.

Management of Incidental Intracranial Meningiomas

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Meningiomas are one of the most frequent tumors of the central nervous system (CNS) in adults which are believed to originate from the arachnoid cap cells [1]. Most have a benign behavior and often discovered as incidental intracranial lesions. However, up to 10-15% of these tumors may exhibit malignant behavior and 1-2% may be extremely aggressive [2]. Meningiomas are usually diagnosed due to the neurological symptoms that they produce, which are related to their location [2]. The last years due to the technological progress and the high number of cranial imaging, incidental meningiomas are increasingly being detected [3,4].

An incidental meningioma is defined as a malignancy that is found on imaging of the CNS and is asymptomatic [4]. Most are small in size and generally do not require any surgical treatment. Thus, only regular monitoring is typically suggested [5]. However, many patients y choose to remove these tumors for personal reasons. However, currently, there are no specific guidelines concerning the frequency of follow-up imaging of incidental meningiomas neither is it determined when they should be removed.

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THE CLINICAL ASPECT OF INCIDENTAL MENINGIOMA

Meningiomas represent the most frequent primary tumor of the CNS in adults. According to the most recent WHO classification, they consist of 15 different histological subtypes which are classified based on their degree of malignancy into three grades (grade I, II and III) [1]. In recent years, an increase in the prevalence of the disease has been observed, particularly in middle-aged women, who are up to three times more at risk of developing meningiomas than men [4]. Heredity also seems to be involved in the development of these tumors since there is a higher prevalence among first-degree relatives and even some genes have been identified [6].

As for the incidental meningiomas, they seem to represent 15% of incidental Magnetic Resonance Imaging (MRI) findings. Further, due to the increasing age of the population this number tends to increase continuously. In some epidemiological studies in the United States, it has been shown that the number of asymptomatic meningiomas may exceed the 20% of all new diagnosed meningiomas [7]. Furthermore, some are eventually never confirmed on biopsy, leading to a situation of overtreatment and increased workload without showing whether there is any benefit for the patient [7]. The benign nature of these tumors and their asymptomatic appearance no consensus has been reached regarding their management.

FOLLOW-UP

Several researchers and some organizations believe that it is more reasonable to carefully follow-up these tumors and regularly re-evaluate them [4,8]. However, the frequency of follow-up suggested by the National Comprehensive Cancer Network (NCCN), the European Association of Neuro-Oncology (EANO) and the National Institute for Health and Care Excellence (NICE) vary since none have set a clear time frame for follow-up. In particular, the NCCN suggests for the first year after the diagnosis follow-up imaging every 3, 6 and 12 months, then for the next 4 years every 6-12 months, and next after the 5th year every 1-3 years [9]. On the contrary, the EANO suggests active monitoring every year and NICE the 1st and 5th year after the diagnosis, without specifying exactly the length of the follow-up [10,11]. Finally, Islim et al. [5], emphasize the need of active monitoring, by proposing individualized treatment and the application of certain prognostic models based on the imaging characteristics of each tumor.

SURGICAL INTERVENTION

Hanna et al., at their recent review, noted the absence of evidence-based guidelines for the management of incidental-asymptomatic meningiomas and they recommended that these tumors should be actively monitored initially within the first 3-4 months, and then every 2-3 years. However, they also highlight the need for immediate intervention in tumors showing significant growth or certain high-risk features (high proliferation index, rhabdoid, atypical or/and malignant meningiomas [12]. Näslund et al. [4], in their systematic review, reported that active monitoring versus immediate surgical or stereotactic radiotherapy can be initially followed. However, they pointed out that a proportion of these patients eventually needed surgical intervention and stated that those who receive active monitoring rather than direct intervention should be carefully evaluated. On the other hand, the International Stereotactic Radiosurgery Society (ISRS) seems to follow a more aggressive approach to these tumors. ISRS supports the surgical removal of asymptomatic meningiomas and additional stereotactic radiotherapy intervention in case their location excludes complete surgical removal [13].

CONCLUSION

Management of incidental meningiomas seems to be a matter of controversy in daily practice as simple active monitoring is opposed to direct surgical management. The high accuracy of neuroimaging has significantly increased the prevalence of incidental meningiomas which often leads to an increased number of imaging and workload for no significant reasons, as most of these tumors are benign with high 5-year survival rates. It is therefore obvious that the scientific community needs to establish clear guidelines on the surgical indications and on the timing of follow-up. Finally, well defined characteristics that will highlight the need for immediate intervention during the follow-up of this tumors have yet to be determined. This will prevent the need for unnecessary surgery, multiple imaging, and a high emotional burden for patients.

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TITLE

Intracranial meningiomas and risk for recurrence: A single institutional experience

Marios Lampros[1], Georgios Kafritsas[1], Nikolaos Konsolakis[1], Anna Goussia[2], Andreas Zigouris[1], Evangelos Michos[1], Dimitrios Pachatouridis[1], George A. Alexiou[1], Spyridon Voulgaris1

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Meningiomas, recurrence, risk factors

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ABSTRACT

Objective: Meningiomas are the most common primary central nervous system (CNS) neoplasms in adults, with surgical excision of symptomatic meningiomas being the treatment of choice. However, the risk of recurrence following excision of meningiomas is not negligible even in low grade tumors, while the risk factors associated with meningiomas recurrence have yet to be clarified entirely. In the present study, we set out to identify risk factors of recurrence in patients surgically treated for meningiomas.

Material and Methods: We retrospectively studied patients with intracranial meningiomas treated surgically in our institute during a period of 9 years. The patients were identified based on our institution's available medical records and data. The extent of resection was evaluated according to Simpson's grade. A univariate and multivariate analysis of the retrievable data was performed, aiming to identify potential risk factors of recurrence. Our hospital's Institutional Review Board (IRB) approved the study.

Results: A total of 134 patients were included in the present study. The cohort was comprised of 48 male and 86 female patients, and the mean follow-up period was 93 months. A statistically significant correlation was found between meningioma's recurrence with histological grade, Ki-67 index, and Simpson's extent of resection in univariate analysis. The recurrence-free survival was significantly higher in Grade I meningiomas compared to Grade 2 and Grade 3 meningiomas ($p<0.0001$). The mean Ki-67 proliferation index was 4.6 % (0.5-50 %). A Ki-67% > 5% was linked with a higher risk of recurrence (HR = 1,6, 95% CI =[0,5-2,1], p = 0,01). In multivariate analysis, only the WHO histological grade was found to be linked with meningioma's recurrence.

Conclusion: The results of the present single-institutional retrospective study support that the meningioma's histological grade, Ki-67 labeling index, and Simpson's excision grade can be used as potential markers to predict the risk of recurrence.

ΠΕΡΙΛΗΨΗ

Εισαγωγή: Τα μηνιγγιώματα είναι τα πιο συχνά πρωτοπαθή νεοπλάσματα του κεντρικού νευρικού συστήματος (ΚΝΣ) στους ενήλικες, με τη χειρουργική εκτομή των συμπτωματικών μηνιγγιωμάτων να είναι η θεραπεία εκλογής. Οι παράγοντες κινδύνου που σχετίζονται με την υποτροπή των μηνιγγιωμάτων δεν έχουν ακόμη διευκρινιστεί πλήρως. Στην παρούσα μελέτη, προσπαθήσαμε να εντοπίσουμε παραγόντες κινδύνου υποτροπής σε ασθενείς που υποβλήθηκαν σε χειρουργική εξαίρεση ενδοκράνιων μηνιγγιωμάτων.

Υλικό και Μέθοδος: Μελετήσαμε αναδρομικά ασθενείς με ενδοκρανιακά μηνιγγιώματα που αντιμετωπίστηκαν χειρουργικά για μια περίοδο 9 ετών. Η έκταση της εκτομής αξιολογήθηκε σύμφωνα με την κλίμακα Simpson. Πραγματοποιήθηκε μονοπαραγοντική και πολυπαραγοντική ανάλυση των ανακτήσιμων δεδομένων, με στόχο τον εντοπισμό πιθανών παραγόντων κινδύνου υποτροπής. Το επιστημονικό συμβούλιο (IRB) του νοσοκομείου ενέκρινε τη μελέτη.

Αποτελέσματα: Στην παρούσα μελέτη συμπεριλήφθηκαν συνολικά 134 ασθενείς. Η κοόρτη αποτελούνταν από 48 άνδρες και 86 γυναίκες ασθενείς και η μέση περίοδος παρακολούθησης ήταν 93 μήνες. Βρέθηκε μια στατιστικά σημαντική συσχέτιση μεταξύ της υποτροπής του μηνιγγίωμα με το βαθμό κακοήθειας, τον δείκτη Ki-67 και το βαθμό εκτομής κατά Simpson στην μονοπαραγοντική ανάλυση. Η επιβίωση χωρίς υποτροπή ήταν σημαντικά υψηλότερη στα μηνιγγιώματα βαθμού κακοήθειας I σε σύγκριση με τα μηνιγγιώματα βαθμού κακοήθειας 2 και 3 ($p<0,0001$). Ο μέσος δείκτης πολλαπλασιασμού Ki-67 ήταν 4,6 % (0,5-50 %). Ο δείκτης Ki-67% > 5% συνδέθηκε με υψηλότερο κίνδυνο υποτροπής (HR = 1,6, 95% CI =[0,5-2,1], p = 0,01). Στην πολυπαραγοντική ανάλυση, μόνο ο βαθμός κακοήθειας βρέθηκε να συνδέεται με την υποτροπή του μηνιγγιώματος.

Συμπεράσματα: Συμπερασματικά, τα αποτελέσματα της παρούσας αναδρομικής μελέτης υποστηρίζουν ότι ο βαθμός κακοήθειας του μηνιγγιώματος, ο δείκτης Ki-67 και ο βαθμός εκτομής κατά Simpson μπορούν να χρησιμοποιηθούν ως πιθανοί δείκτες για την πρόβλεψη του κινδύνου υποτροπής.

INTRODUCTION

Meningiomas are the most common primary central nervous system (CNS) neoplasms in adults [1]. They arise from the arachnoid cap cells of meninges and account for approximately one-third of primary CNS neoplasms [1,2]. All age groups can be affected by meningiomas. However, the incidence of meningiomas increases in older adults, with the mean age of patients with meningiomas being around 65 years [1]. Women are usually more frequently affected, with women being at greater risk at the age of forty years, indicating a potential role of female hormones in the pathogenesis of meningiomas [1,3]. Several genetic diseases have been linked with meningioma occurrence, including neurofibromatosis type (NF)-1, NF 2, and Von Hippel-Lindau (VHL) [4]. Exposure to ionized radiation is another potential risk factor associated with an increased risk of meningiomas [5]. The majority of meningiomas are primarily benign, about 80%, classified as Grade 1 by the World Health Organization (WHO) classification of CNS tumors. Grade 2 (WHO) meningiomas are atypical meningiomas with tumor cells having atypical features, while the malignant type 3 (WHO) meningiomas are malignant neoplasms with metastatic potential and tumor cells having histological features of prominent anaplasia and increased mitotic activity [2].

Meningiomas can be asymptomatic and diagnosed incidentally during brain imaging due to another medical reason or can be symptomatic and cause symptoms related to the meningioma's anatomical site on the CNS [6]. Magnetic resonance imaging (MRI) is the diagnostic modality of choice to display the features of CNS meningiomas. Meningiomas usually appear as well-circumscribed extra-axial lesions with a broad base to the dura [7]. Additional imaging features found in meningiomas include tumoral calcifications and hyperostosis of the surrounding bone, which are better displayed with a computed tomography (CT) scan [8].

The management of meningiomas is multifactorial and depends on several factors, including symptomatology, size and growth of the tumor, imaging features suggesting an atypical or malignant meningioma, and the patient's preference [9]. Typically, small meningiomas not causing significant symptoms can be treated conservatively, while larger meningiomas or having imaging features suggestive of atypia or anaplasia usually require surgical management with maximal safe resection [9,10]. However, meningiomas have a risk of recurrence depending on mainly on tumor grade [9]. Stereotactic radiosurgery is an alternative treatment for meningiomas, usually indicated for older patients with many risk factors for operative management or meningiomas in complex anatomical locations [11].

In the present study, we retrospectively studied patients with intracranial meningiomas surgically treated at our institution and examined potential risk factors associated with tumor recurrence.

MATERIALS AND METHODS

Patients' selection

We retrospectively studied patients with intracranial meningiomas treated surgically in our institute during a period of 9 years. The patients were identified based on our institution's available medical records and data. Our hospital's Institutional Review Board (IRB) approved the study.

Inclusion criteria

We included adult patients surgically treated at our Institution for intracranial meningiomas. The histological report set the diagnosis of meningiomas.

Exclusion criteria

We excluded patients younger than 18 years and patients with extracranial or spinal meningiomas.

Operation

A MRI scan was performed preoperative in all cases. The patients were treated under general anesthesia. The patient's operating position depended on the meningioma's location. The typical technique of meningioma resection was performed with devascularization of the tumor followed by detachment, debulking, and dissection. An attempt for maximal surgical resection under the surgical microscope was performed in each case. The extent of resection was evaluated according to Simpson's grade [12]. Depending on tumor location and if possible the pathological dura overlying the tumor was excised, with a 2cm free surgical margin, and meningoplasty was performed with a dural graft. A replacement with a bone graft was performed if the skull over the meningioma had imaging or gross evidence of infiltration or hyperostosis. A subcutaneous drain was placed for 24 hours following surgery. Finally, a post-operative CT scan was performed after 24 hours to assess the extent of surgical resection.

Data collection

In terms of demographics, patients' age and sex was recorded. Meningiomas' intracranial location, histological type, WHO Grade, and Ki-67 proliferation index were recorded. The degree of surgical resection, according to Simson's Grade, was also recorded. The patients were followed up for recurrence at regular time intervals.

Statistical analysis

Kaplan-Meier estimates were utilized to calculate survival curves, and the log-rank test was used to evaluate the differences between the survival curves. Factors that potentially affected the progression-free survival (PFS) of the patients, defined as recurrence-free survival, including WHO Grade and Ki-67 index, were investigated. Finally, a multivariate analysis was performed that included patient age (over or under 65), sex (male vs female), WHO grade (1 vs 2/3), Ki-67 (over vs under 5%), location, and Simpson's extent of resection. Differences were considered significant when $p \leq 0,05$.

RESULTS

A total of 134 patients were included in the present study. The cohort was comprised of 48 male and 86 female patients. The mean age of patients was 62.4 (CI 95%: 22-90) years. The female-to-male ratio was 1.79. The mean follow-up period was 93 months. Three patients died in the early postoperative period due to respiratory infection in two cases and myocardial infarction in one case. Twenty-two (16.4 %) patients were lost to follow-up. In the remaining 112 patients, 18 (16 %) cases of recurrence were recorded. The mean time to recurrence was 33.6 months. Adjuvant radiotherapy was performed in cases of anaplastic meningiomas.

Meningioma location

Convexity meningiomas were the most common, representing 47 (35 %) of the cases, followed by parasagittal 40 cases (29.8 %), sphenoidal ridge meningiomas 14 cases (10.4 %), olfactory groove 14 cases (8.2 %), posterior cranial fossa 11 cases (8.2 %), tuberculum sellae 6 cases (4.5 %), cavernous sinus 1 case and one intraventricular (0.7 % **Figure 1.**

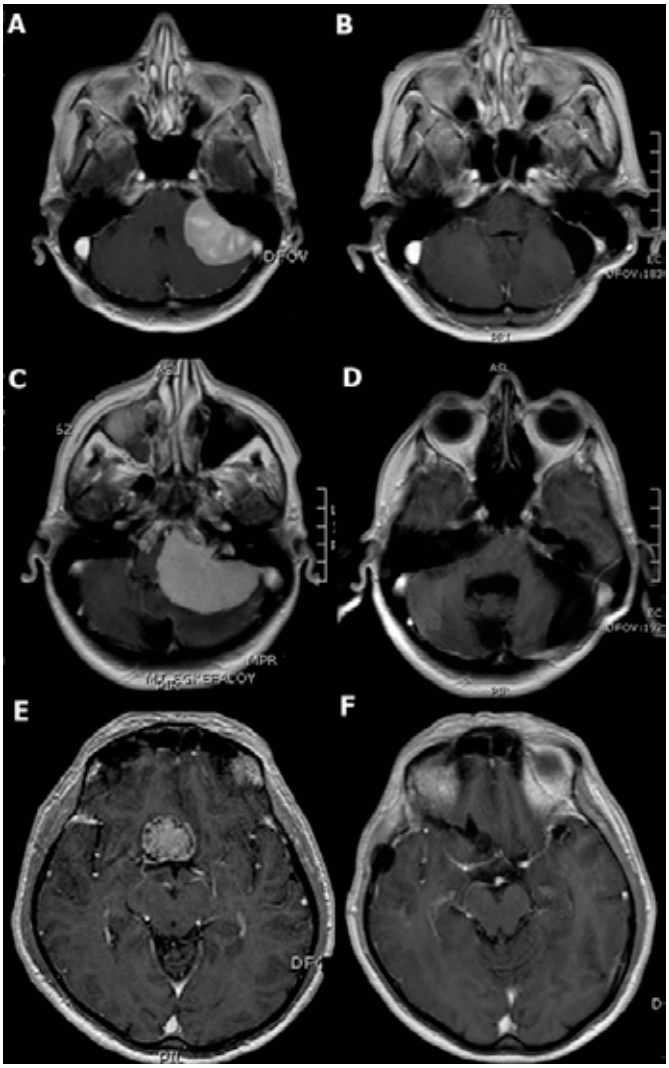


Figure 1.
Pre (A,C,E) and postoperative (B, D, F) gadolinium enhanced T1-weighted MR images of meningioma cases.

WHO Grade and histological features

Regarding the WHO Grade, Grade 1 meningiomas were the most common, representing 108 (80.5 %) of the cases, following by grade II 16 (12%) cases and grade III 10 (7.5%) cases. The meningiomas' histological type and their correlation with the WHO grade and recurrence rate are presented in Table 1. The recurrence rate for Grade I meningiomas was 7.1 %, for Grade II meningiomas was 29.1 %, for Grade III meningiomas was 51.5%.

Table 1. Demonstrates meningiomas' histological type and their correlation with the WHO grade and recurrence rate.

Grade	Histological type (frequency %)	Recurrence rate
I	Transitional (60 %)	7.1 %
	Meningothelial (25.7 %)	
	Psammomatous (13.3 %)	
	Angiomatous (1 %)	
II	Atypical (100 %)	29.1 %
III	Anaplastic (100 %)	51.5 %

Note: The percentages are calculated according to each WHO Grade separately.

Ki-67 proliferation index

The mean Ki-67 proliferation index was 4.6 % (0.5-50 %). A Ki-67% > 5% was linked with a higher risk of recurrence (HR = 1.6; 95% CI =[0.5-2.1]; p = 0.01).

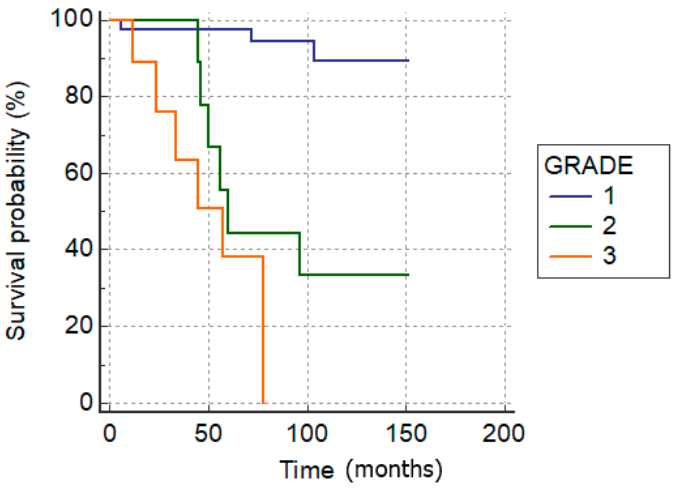
Extend of resection

Regarding the extent of resection, Simpson's Grade I excision was performed in 79 cases (58.9 %), followed by Grade II 37 cases (27.6%), Grade III 15 cases (11.2 %), Grade IV cases 2 (1.5%), Grade V 1 case (0.7 %). The Simpson's extent of resection was significantly correlated with the recurrence rate (p<0,05).

Overall survival

The overall survival was significantly higher in Grade I meningiomas compared to Grade II and Grade III meningiomas (p<0.0001). The overall survival in the different histological (WHO) grades of meningiomas is presented in **Figure 2**.

Figure 2. Survival in meningioma patients depending on WHO grade.



Multivariate analysis

In the multivariate analysis, only the WHO histological Grade was significantly linked with the recurrence rate (p=0.024). No significant association was observed for age, sex, location, and Ki-67.

DISCUSSION

Meningiomas are common, usually benign, CNS neoplasms with an increased recurrence rate following surgical resection in grade 2/3 tumors [6]. In the present study, we presented our institution's experience with patients operated for intracranial meningiomas, aiming to identify potential histological and operative risk factors associated with tumor recurrence. A statistically significant correlation was found between meningioma's recurrence with histological grade, Ki-67 index, and Simpson's extent of resectionin univariate analysis. In multivariate analysis, only the WHO histological grade was found to be linked with meningioma's recurrence.

Simpson grade of resection

The Simpson's Grading scale is a widely utilized classification system to define the extent of meningioma resection [12]. This system was introduced by Simpson et al. in 1957 and has five different macroscopic grades of resection according to the extent of the tumor, attached dura, and bone involvement. Currently, the Simpson scale is considered the gold standard for estimating the degree of meningioma resection. In our study, Simpon's extent of surgical resection was positively correlated with meningiomas recurrence. However, several authors suggest that the results of Simpson's original study were not reproduced from further studies published in the following years [13,14,15], while this scale is based on the surgeon's subjective intraoperative assessment. This assessment may be biased in deep-placed meningiomas, and in the era of high-quality imaging techniques, the extent of resection can be better assessed through a postoperative MRI or CT scan. The latter has been found to have a stronger correlation with the recurrence rate [13]. Hence, a suggestion for maximal safe resection toward an aggressive resection has been advocated. The use of stereotactic radiosurgery as a primary or adjuvant to surgical treatment in patients with partially resected meningiomas placed in "difficult" surgical positions further supports the maximal safe resection approach for meningiomas treatment [13, 16].

WHO Grade and Ki-67

In the most recent (2021) WHO classification of CNS tumors, similar to the previous WHO 2016 classification, meningiomas are classified into three different malignancy Grades (1,2,3) [17]. Meningioma's histological grade is positively correlated with brain invasiveness and recurrence, with histological subtypes of rhabdoid, papillary, and anaplastic being the most aggressive [17,18]. The present study's multivariate analysis yielded a significant correlation between the recurrence rate and WHO histological grade. Moreover, the recurrence rate was positively correlated with the Ki-67 index, and a Ki-67 index over 5% being positively associated with a higher risk of recurrence. However, in multivariate analysis, the Ki-67 was not linked with the recurrence. Several studies have investigated the role of Ki-67 as a potential marker of recurrence of meningiomas [19, 20, 21, 22, 23]. The Ki-67 has been found to be an independent factor of meningioma recurrence, especially for the recurrence of atypical or anaplastic meningiomas [22]. Similar to the results of our study, Nowak-Choi et al. reported a high risk of recurrence for Grade 1 meningiomas with a Ki-67 index over 5% [23]. Moreover, in another study, the combined positivity of Ki-67 with p53 status was linked to an increased risk of recurrence [21]. In a recent study by Mirian et al., the Ki-67 index was found to be correlated with the time to recurrence rather than the recurrence [20]. Finally, a meta-analysis on the role of Ki-67 in meningioma recurrence reported that the Ki-67 index was a marker of recurrence and poor prognosis. Further research into the molecular features of meningiomas may reveal more surrogate histological or genetic markers of recurrence. Chen et al. discovered 36-gene signatures of meningiomas recurrence with prognostic significance similar to or higher than the WHO histological grade [25].

Limitations

The present study is retrospective and subjective to several limitations. The sample size is relatively small, and the data was derived from a single institution. The study's retrospective nature also introduces potential biases and limitations inherent to this study design, such as missing data and reliance on medical records for information.

CONCLUSION

In conclusion, the results of the present single-institutional retrospective study support that the meningioma's histological grade, Ki-67 labeling index, and Simpson's excision grade can be used as potential markers to predict the risk of recurrence. Further studies with more patients that include potential genetic risk factors should be performed to discover more surrogate and reproducible biomarkers of recurrence.

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TITLE

Lumbar Microdiscectomy for Lumbar Disc Herniation: A Single Institution Experience at the Ten Years Follow-up

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CONFLICT OF INTEREST

None

KEYWORDS

Lumbar microdiscectomy, lumbar disc herniation, Visual analogue scale, Oswestry disability Index

ABSTRACT

Objective: We retrospectively studied the long-term (10 year) outcomes of patients operated with lumbar microdiscectomy at our institution.

Material and Methods: In our study we included patients that operated for lumbar microdiscectomy at our institution before 10 years and their outcome was assessed with the Oswestry Disability Index (ODI) and the Visual Analogue Scale (VSA).

Results: At the ten-year follow-up, 33 men and 18 women (mean age 44,5±12,8 years) were included. Most patients were operated on at level L4-L5 (28 patients – 54,9%), level L5-S1 (21 patients – 41,1 %) and 2 (3,9 %) patients at level L3-L4. The disc was considered extruded in 28 patients, protruded in 6 and sequestrated in 17 patients based on MRI findings. The median length of symptoms before surgery was around ten months. A clinically and statistically significant reduction in the median VAS scale was observed after operation (8,5 vs 4, p<0,01), and at the ten year follow up (8,5 vs 2, p<0,01). A significant improvement was also observed at the ten years follow up with a median value of 2. A significant reduction at the median ODI scale was also noted at the ten years follow up (24,1 vs 4,7, p<0.01).

Conclusions: In conclusion, this retrospective study provides valuable insights into the long-term outcomes of lumbar microdiscectomy in patients with herniated discs. The findings demonstrate that the surgical intervention is associated with significant pain relief and functional improvement, as evidenced by the reduction in VAS scores and ODI scores both immediately after surgery and at the ten-year follow-up.

ΠΕΡΙΛΗΨΗ

Σκοπός: Μελετήσαμε αναδρομικά τα μακροπρόθεσμα (10ετή) αποτελέσματα ασθενών που χειρουργήθηκαν με οσφυϊκή μικροδισκεκτομή στο ίδρυμά μας.

Υλικό και Μέθοδος: Στη μελέτη μας συμπεριλάβαμε ασθενείς που χειρουργήθηκαν για οσφυϊκή μικροδισκεκτομή στο ίδρυμά μας πριν από τουλάχιστον 10 χρόνια και η έκβασή τους αξιολογήθηκε με το Oswestry Disability Index (ODI) και την Visual Analogue Scale (VSA).

Αποτελέσματα: Στη δεκαετή παρακολούθηση συμπεριλήφθηκαν 33 άνδρες και 18 γυναίκες (μέση ηλικία 44,5±12,8 έτη). Οι περισσότεροι ασθενείς χειρουργήθηκαν στο επίπεδο L4-L5 (28 ασθενείς – 54,9%), 21 ασθενείς (41.1 %) στο επίπεδο L5-S1 και σε 2 (3,9 %) ασθενείς στο επίπεδο L3-L4. Η διάμεση διάρκεια των συμπτωμάτων πριν από την επέμβαση ήταν περίπου δέκα μήνες. Μια κλινικά και στατιστικά σημαντική μείωση στη διάμεση κλίμακα VAS παρατηρήθηκε μετά την επέμβαση (8,5 έναντι 4, p<0,01) και στη δεκαετή παρακολούθηση (8,5 έναντι 2, p<0,01). Σημαντική βελτίωση παρατηρήθηκε επίσης στη δεκαετή παρακολούθηση με διάμεση τιμή 2. Σημαντική μείωση στη διάμεση κλίμακα ODI σημειώθηκε επίσης στη δεκαετή παρακολούθηση (24,1 έναντι 4,7, p<0,01).

Συμπεράσματα: Συμπερασματικά, αυτή η αναδρομική μελέτη παρέχει πληροφορίες για τα μακροπρόθεσμα αποτελέσματα της οσφυϊκής μικροδισκεκτομής σε ασθενείς με συμπτωματική δισκοπάθεια. Τα παραπάνω ευρήματα υποστηρίζουν ότι η χειρουργική παρέμβαση σχετίζεται με σημαντική ανακούφιση από τον πόνο καθώς και με λειτουργική βελτίωση των ασθενών, όπως αυτή αποδεικνύεται από τη μείωση των βαθμολογιών VAS και βαθμολογίας ODI τόσο αμέσως μετά την επέμβαση όσο και στη δεκαετή παρακολούθηση.

INTRODUCTION

Approximately 80% of individuals experience at least one episode of low back pain (LBP) in their lifetime [1]. LBP is a prevalent condition that contributes significantly to disability, resulting in an annual cost exceeding $100 billion in the USA [1, 2]. Among the various causes of LBP, intervertebral degeneration, which leads to degenerative disc disease and lumbar disc herniation (LDH), is the most common [2].

The initial treatment of patients with LDH is conservative with activity modification, physiotherapy, and short-term (2-3 weeks) treatment with anti-inflammatory drugs (e.g., ibuprofen, diclofenac), muscle relaxants, paracetamol, and short-term treatment with opioid medications can be administered in acute pain crisis [7]. However, if the radical and low back pain symptoms persist for more than four weeks, more interventional treatment methods may be considered, including epidural corticosteroid injections and neuromodulator drugs. However, if the pain persists for more than six weeks or focal neurological deficits are present, then an operative treatment of lumbar disc herniation should be considered.

Currently, several operating techniques have been utilized in treating LDH, including open discectomy, microdiscectomy, and the most recent endoscopic microdiscectomy [8]. Microdiscectomy was first described by Yasargil and Caspar independently back in 1977 and is a variation of the traditional open discectomy in which the operating surgeon utilizes a microscope and principles of microsurgery to remove the herniated disk material [9]. Compared to the traditional discectomy, in microdiscectomy, a smaller incision line is performed, and the use of microscopy allows better visualization of the herniated disc and of the neural components, including the dura and nerve roots, theoretically minimizing the risk of recurrent disc herniation, dural tears, and of soft tissue damage [8,10,11]. Both discectomy and microdiscectomy are considered acceptable and highly efficient techniques for treating symptomatic LDH [11].

However, despite the broad use of microdiscectomy for treating LDH, only a few studies have been performed to assess the long-term outcome of patients treated for microdiscectomy based on quantified validated outcome indexes [12, 13, 14, 15]. In our study, we included patients who were operated for LDH at our institution ten years ago, and their outcome was assessed with the Oswestry Disability Index (ODI) and the Visual Analogue Scale (VSA). By utilizing these established outcome measures, we aimed to gain insights into lumbar microdiscectomy's long-term effectiveness and impact on patient outcomes

MATERIALS AND METHODS

Patients selection and identification

In this retrospective study, we focused on evaluating the long-term outcomes of lumbar microdiscectomy. Our study cohort consisted of patients who underwent a typical lumbar microdiscectomy a decade ago, in 2013. The patients were identified based on our institution's available medical records. A follow-up assessment for the identified patients was scheduled via telephone calls. Informed consent was given by all the patients participating in the present study. The study was approved from the institutional review board.

Inclusion criteria

We included adult patients who underwent an elective microdiscectomy for symptomatic lumbar disc herniation. The indications for operation were patients with focal neurological deficits or sciatic pain refractory to conservative treatment for a duration over three weeks. An MRI prior to the operation was performed in all the included patients to establish the diagnosis of lumbar disc herniation for pre-operative planning and to exclude alternative diagnoses such as inflammatory discitis, spinal neoplasms, vertebral fractures, and abdominal aortic aneurysms. All types of lumbar disc herniation were included.

Exclusion criteria

We excluded cases of patients who were operated on in an emergency setting for cauda equina and conus medullaris syndrome. Moreover, we excluded cases of patients with lumbar herniation associated with congenital spinal anomalies, spinal neoplasms, severe spinal trauma, spondylolisthesis, and inflammatory diseases of the spine. Finally, we did not include cases of patients in which the pre-operative VAS and ODI scores were not retrievable or were not performed.

Patients assessment

To assess the outcomes of the surgical intervention, we employed two widely used measures in spinal surgery research: the Oswestry Disability Index (ODI) and the Visual Analogue Scale (VAS) [16,17]. These validated assessment tools allowed us to measure the impact of lumbar microdiscectomy on patients' functional disability and pain levels. The assessment involved administering the ODI questionnaire, which evaluates various aspects of daily activities and provides a comprehensive understanding of functional disability. Additionally, the VAS was used to measure the intensity of pain experienced by the patients, allowing us to gauge their subjective perception of pain severity.

Data collection

Patients' demographic information and several other factors that could be linked with the patient's outcome, including pre-operative BMI, history of smoking, comorbidities, and educational level, were recorded. Moreover, spinal level and type (protruded, extruded, sequestrated) of LDH, pre-operative clinical manifestations, and duration from symptoms onset to operation were included. Pre-operative, one-month post-operative, and 10-year post-operative follow-up VAS and ODI scores were collected. An attempt was made to limit the recalling bias by correlating the clinical information given by the patients in the 10-year follow-up with the information given by the patient preoperatively.

Statistical analysis

The Mann-Whitney was used to compare the means between two groups. The level of significance, p-value, was set at 0.05.

RESULTS

Demographic features

The study cohort comprised 51 patients, including 33 men and 18 women, with a mean age of 44.5 (±12.8 SD) years. Among the patients, 26 (50%) individuals were identified as smokers. A significant history of alcohol drinking, defined as over two alcohol units per day, was present in 7 (13.7%) patients. The mean BMI among the patients was 26.1 Kg/m2. Occupational history linked with heavy lifting was present among five patients (9.8%). A summary of patients' demographic features is presented in Table 1.

Table 1. Table 1 demonstrating the patients' baseline demographic and clinical features.

Baseline Patient Features	
Mean Age (years)	*44.5*
Male to Female Ratio	*1.83*
Mean BMI (Kg/m^2)	*26.1*
*Smokers (%)**	*50*
*Significant alcohol consumption (%)***	*13.7*
Significant Occupational History (%)	*9.8*
Spinal Level:	
L5-S1 (%)	*41.1*
L4-L5 (%)	*53.9*
L3-L4 (%)	*3.9*
Type of degeneration:	
Protruted (%)	*33.3*
Extruded (%)	*54.9*
Sequestrated (%)	*11.8*

**Self-identified, ** Defined as consumption of over 2 units of alcohol per day*

Clinical manifestations of LDH

Sciatica was the primary clinical manifestation presented in 42 patients (82.3%). Isolated lower back pain was present in 5 patients (9.8%). Isolated lower limb pain was present in 4 patients (7.9 %). The Laseque sign was present in 37 patients (72.5%). Focal motor deficits were present in 27 patients (52.9%), while focal sensor deficits were present in 15 patients (29.4%). Patients' symptom duration over three weeks was present in 41 patients (80.3%), while the median duration of symptoms before surgery was ten months. Diminished patellar or Achilles reflexes were present in 1 (2 %) and 17 (33.3 %) patients, respectively.

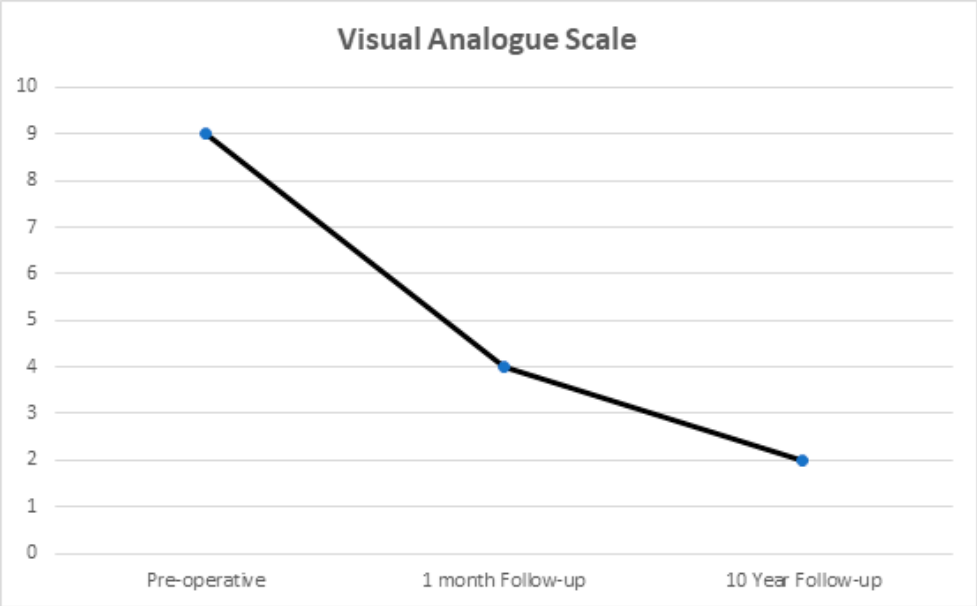
Microdiscectomy

Most patients underwent lumbar microdiscectomy at the L4-L5 level (28 patients, 54.9 %), followed by the L5-S1 level (21 patients, 41.1%). Only two patients (3.9%) underwent surgery at the L3-L4 level. Regarding the characteristics of the herniated discs, the analysis revealed that 28 (54.9 %) patients had an extruded disc, six (11.8 %) patients had a protruded disc, and 17 (33.3%) patients had a sequestrated disc. In two cases (3.9%), the dura was accidentally lacerated. No new post-operative neurological deficits were reported. A summary of the level of microdiscectomy and types of discs degenerative features observed in the present study is presented in Table 1.

Visual Analogue Scale (VAS)

To evaluate pain severity, the Visual Analogue Scale was employed. The median VAS score before surgery was 9 (±1.54 SD), indicating a high level of pain experienced by the patients. However, after the surgical intervention, there was a significant improvement ($p<0.0001$) in pain levels, with a median score of 4 (±1.78 SD) at the one-month post-operative follow-up assessment. This significant improvement ($p<0.01$) compared to the preoperative VAS score was sustained even at the ten-year follow-up, as evidenced by a median VAS score of 2 (±1.84 SD). Patients' median VAS pain scores preoperative, 1-month post-operative follow-up, and the final ten-year follow-up are presented as a graph in **Figure 1**.

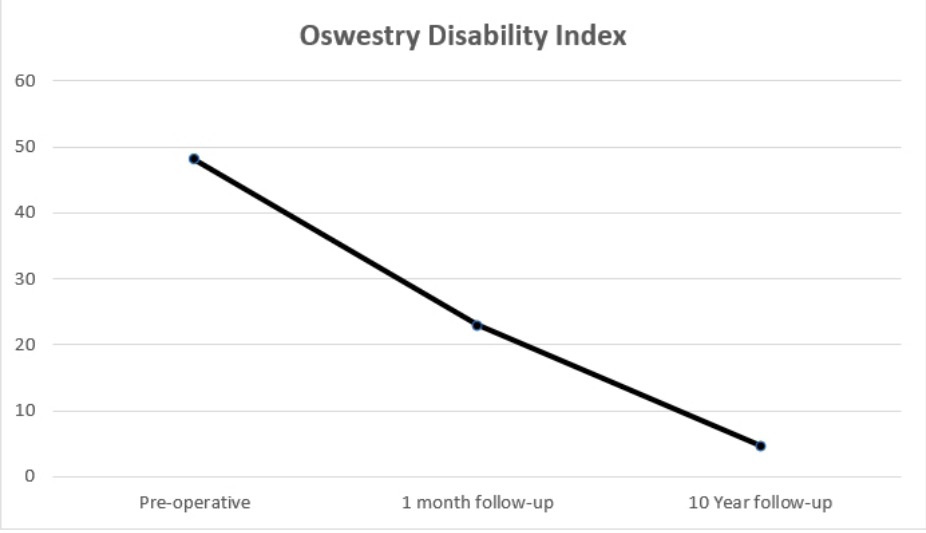
Figure 1. Demonstrating patient's median Visual Analogue Scale (VAS) pain scores pre-operative, at 1 month post operative follow up, and at the ten-year follow-up.



3.5 Oswestry Disability Index (ODI)

Functional disability was assessed using the Oswestry Disability Index (ODI). The median ODI score before surgery was 48 (±21.33), indicating a considerable degree of functional impairment among the patients. The median ODI score was significantly ($p<0.01$) decreased to 23(±10.66 SD) at the one-month post-operative follow-up assessment. Ten years after the surgery, there was a further substantial decrease ($p<0.01$) in the median ODI score to 4.7 (±6.14) compared to the preoperative ODI score. Patients' median ODI scores preoperative, at one-month post-operative follow-up, and the final ten-year follow-up are presented as a graph in **Figure 2**.

Figure2. Patients' median Oswestry Disability Index (ODI) pain scores pre-operative, at 1 month post operative follow up, and at the ten-year follow-up



DISCUSSION

In the present study, we aimed to study the long-term outcome of elective microdiscectomy in the treatment of symptomatic LDH. The findings of this retrospective study shed light on the long-term outcomes of lumbar microdiscectomy in a cohort of 51 patients. The analysis revealed that most patients underwent surgery at the L4-L5 and L5-S1 levels, with various types of disc pathology observed, including extruded, protruded, and sequestrated discs. The significant reduction in pain levels, as measured by the VAS, both immediately after surgery and at the ten-year follow-up, indicates the efficacy of lumbar microdiscectomy in alleviating pain. Similarly, the substantial decrease in functional disability, as measured by the ODI, underscores the long-term benefits of surgical intervention in improving patients' daily functioning. These findings align with previous studies and contribute to the growing body of evidence supporting the effectiveness of lumbar microdiscectomy as a treatment option for herniated discs [15].

The study also considered additional factors that could influence surgical outcomes. The median duration of symptoms before surgery was ten months, emphasizing the chronic nature of the conditions that necessitated surgical intervention and highlighting the importance of timely diagnosis and intervention to prevent prolonged suffering and functional limitations. Although the impact of BMI, smoking status, and alcohol consumption are well-known risk factors for LDH [18], their inclusion in the study provides valuable insights into potential considerations for patient selection and pre-operative counseling.

Except for the traditional open discectomy and microdiscectomy, the endoscopic microdiscectomy is an alternative, less invasive technique for the treatment of LDH [19]. In endoscopic microdiscectomy, an endoscope is utilized to remove the herniated disk material. Endoscopic microdiscectomy is the most recently introduced and the least invasive technique, with some studies reporting comparable efficacy and adverse effect rates with the classic discectomy and microdiscectomy [19, 20]. However, these results are from small cohorts, and further studies should be performed to assess its efficacy and safety [19].

Study limitations

It is important to acknowledge the limitations of this retrospective study. The sample size was relatively small, and the data was derived from a single institution, which may limit the generalizability of the findings. Additionally, the study's retrospective nature introduces potential biases and limitations inherent to this study design, such as missing data and reliance on medical records for information. Future prospective studies with larger sample sizes and multi-center collaborations would provide a more comprehensive understanding of the long-term outcomes of lumbar microdiscectomy

CONCLUSIONS

In conclusion, this retrospective study provides valuable insights into the long-term outcomes of lumbar microdiscectomy in patients with herniated discs. The findings demonstrate that the surgical intervention is associated with significant pain relief and functional improvement, as evidenced by the reduction in VAS and ODI scores immediately after surgery and at the ten-year follow-up. These outcomes support the efficacy of lumbar microdiscectomy as a treatment option for selected patients with herniated discs. However, further research with larger sample sizes and prospective study designs is warranted to confirm these findings and address the limitations of this study. The results of this study contribute to the existing body of knowledge in spinal surgery and have implications for clinical decision-making and patient management strategies.

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CASE REPORT

A girl with multiple congenital spinal anomalies

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KEYWORDS
Congenital spinal anomalies, diastematomyelia, spina bifida, syringomyelia, tethered cord syndrome

CONFLICT OF INTEREST
None declared

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ABSTRACT
The presence of multiple spinal defects at birth is rare and usually makes the management of such patients complicated and challenging. The purpose of this article is to report a female pediatric patient with four different congenital malformations affecting the thoracolumbar area of her spine. A 6-year-old girl suffered from low back pain and incontinence was born with diastematomyelia, syringomyelia, tethered cord syndrome, and a lumbar cutaneous hemangioma. Such cases (with at least four different congenital spinal anomalies) are rare in the literature. These patients seem to have diastematomyelia, syringomyelia, and tethered cord syndrome as common findings, followed by spina bifida.

ΠΕΡΙΛΗΨΗ
Η παρουσία πολλαπλών συγγενών ανωμαλιών της σπονδυλικής στήλης είναι σπάνια και η αντιμετώπιση αυτών των ασθενών είναι συνήθως πολύπλοκη αποτελώντας ιατρική πρόκληση. Σκοπός αυτού του άρθρου είναι η αναφορά ενός θήλεος παιδιατρικού ασθενούς με τέσσερις διαφορετικές συγγενείς ανωμαλίες στη θωρακοοσφυϊκή περιοχή της σπονδυλικής της στήλης. Ένα κορίτσι 6 ετών που έπασχε από χαμηλή οσφυαλγία και ακράτεια γεννήθηκε με διαστηματομυελία, συριγγομυελία, σύνδρομο καθηλωμένου μυελού και ένα δερματικό οσφυϊκό αιμαγγείωμα. Παρόμοιες περιπτώσεις (με τουλάχιστον τέσσερις διαφορετικές συγγενείς ανωμαλίες της σπονδυλικής στήλης) είναι σπάνιες στη βιβλιογραφία. Αυτοί οι ασθενείς φαίνεται να έχουν τη διαστηματομυελία, τη συριγγομυελία και το σύνδρομο καθηλωμένου μυελού ως κοινά χαρακτηριστικά, ακολουθούμενα από τη δισχιδή ράχη.

INTRODUCTION

Neural tube defects (NTDs) affect the development of the central nervous system (CNS) and are among the most common congenital anomalies in humans. Quite frequent in the NTDs spectrum, spina bifida results from failure of fusion of the caudal neural tube. It is a term that is used to describe a range of malformations such as spina bifida occulta (bony defect in the vertebral arch with intact dura), meningocele (dural herniation through an opening in the vertebral arch) and myelomeningocele (dural and neural tissue herniation through an opening in the vertebral arch)1. Spina bifida occulta is often associated with cutaneous stigmata. Tethered cord syndrome (TCS) is defined as an abnormal attachment of the spinal cord to its surrounding tissues and is often associated with other congenital disorders2. Apart from TCS, diastematomyelia is also associated with congenital malformations and is described as an incomplete or partial splitting of the spinal cord into two hemicords, each with its own central canal and pia matter3. Furthermore, syringomyelia, which is often associated with numerous CNS pathologies, both acquired and congenital, can be described as a fluid-filled, gliosis-lined cavity within the spinal cord parenchyma4.

Although some congenital spinal anomalies may occasionally coexist, the presence of multiple spinal defects at birth is rare and thus the management of such patients is complicated and challenging. The purpose of this article is to report a female pediatric patient with four distinct congenital malformations at the thoracolumbar area.

CASE REPORT

A 6-year-old girl was brought in our Pediatric Neurosurgery Outpatient Clinic by her parents because of low back pain. She had history of multiple congenital spinal anomalies, namely lower thoracic (T11-T12) syringomyelia (14 X 5 mm), type II diastematomyelia (single dural sac with two hemicords), TCS (with low lying conus medullaris), and a lumbar (L2-L3) cutaneous hemangioma (18 X 25 mm). Notably, the syrinx bifurcated to extend caudally in the two hemicords for approximately 7 mm (**Fig. 1**). She underwent surgical treatment of the tethered cord, diastematomyelia and cutaneous hemangioma as a neonate, in another hospital.

Regarding her current clinical findings, she had no motor or sensory lower limb deficits but the parents reported primarily nocturnal urinary incontinence. Her recent magnetic resonance imaging (MRI) scan revealed persisting lower thoracic (T11-T12) syringomyelia (25 X 8 mm) extending caudally in the two hemicords and recurrent TCS (with low lying conus medullaris at the same level as shown preoperatively). The patient was referred for urodynamic testing, review by a rehabilitation medicine specialist and reevaluation by our clinic with the results in order to discuss potential treatment options.

DISCUSSION

Reviewing the literature, we found five other cases with multiple spinal defects of similar nature with our case's. More specifically, Dutta et al.5 reported a case of a 1-year-old male patient with myelomeningocele, diastematomyelia (with a dorsal bony spur at the same level, i.e. L1-L2), TCS, syringomyelia, and a lumbar lipoma at a lower level. Shashank et al.6 reported another case of coexisting meningocele, diplomyelia (with a dorsal bony spur) with limited dorsal myeloschisis, TCS, and syringomyelia, along with a ventricular septal defect and bilateral rocker-bottom feet malformation.

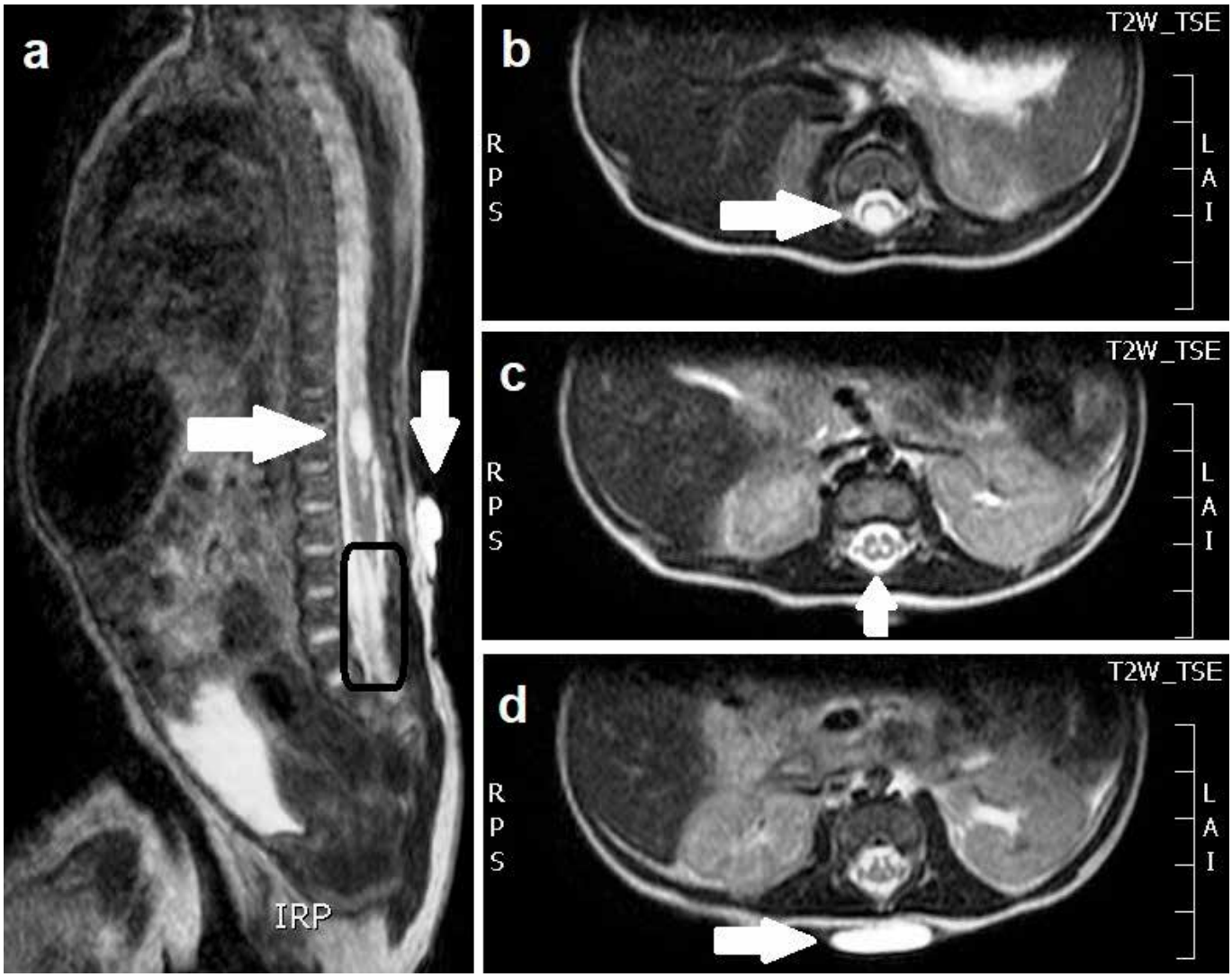

Figure1. T2-weighted spinal magnetic resonance imaging of our patient as a neonate (2 days old). a) Midsagittal section showing lower thoracic syringomyelia (horizontal arrow), tethered cord (frame) and a lumbar cutaneous hemangioma (vertical arrow); b) Transverse section at the T12 level showing syringomyelia (horizontal arrow); c) Transverse section at the L1 level showing diastematomyelia with extension of the syrinx into the two hemicords (vertical arrow); d) Transverse section at the L2 level showing the lumbar cutaneous hemangioma (horizontal arrow).

Avcu et al.[7] reported a case of a 5-year-old boy that was referred to their hospital with complaints of full inability to walk and incontinence. After MRI and computed tomography (CT) examination, he was diagnosed with a tethered cord at the S1 level, along with an intradural lipoma and a dorsal dermal sinus tract at the same level. He also had syringomyelia all along the spinal cord and diastematomyelia at the lower thoracic levels. They also found spina bifida occulta and an epidermoid cyst at the S1 level. According to the authors' hypothesis, epidermoid cysts appear to be one of the very rare causes of TCS[7].

Furthermore, Pettorini et al.[8] reported a case of a 2-year-old boy that presented to their hospital with a skin-covered protrusion at the thoracic region of his spine ("human tail"). The spinal MRI, showed a lipomeningocele was identified at the T6-T7 level along with diastematomyelia at the T1-T5 area. Above the split, there was a large syrinx that extended from C6 to T1. The cord was interestingly tethered due to a fibrous tract connecting the dorsal surface of the spinal cord to the lipomeningocele sac. Additionally, the patient underwent brain MRI showing hydrocephalus, a finding which was not expected according to the authors[8].

Finally, Kramer et al.[9] reported a case of an older patient, a 54-year-old female suffering from thoracic disc herniation, who also had history of multiple congenital abnormalities, including spina bifida occulta, TCS, lumbar syringomyelia, and lumbar diastematomyelia. In agreement with these authors, neuroimaging and electrophysiology investiga-

tions are of paramount importance for best clinical evaluation and treatment decision-making[9].

As extracted from the aforementioned cases, summarized in Table 1, common malformations among the reported patients with multiple congenital spinal anomalies are diastematomyelia, syringomyelia, and TCS. It is quite interesting the observation that classic forms of spina bifida (occulta or aperta), which is the most common isolated congenital spinal malformation and frequently coexists with TCS[10,11], were not present in our case, as opposed to the other cases of **Table 1**.

Table 1. Reported cases with multiple congenital spinal anomalies

AUTHORS	CONGENITAL SPINAL FINDINGS	OTHER FINDINGS
Dutta et al.[5]	Myelomeningocele, diastematomyelia, syringomyelia, tethered cord, lipoma	
Shashank et al.[6]	Meningocele, diplomyelia, myeloschisis, syringomyelia, tethered cord	Ventricular septal defect, rocker-bottom feet
Avcu et al.[7]	Spina bifida occulta, diastematomyelia, syringomyelia, tethered cord, lipoma, epidermoid cyst, dermal sinus tract	
Pettorini et al.[8]	Lipomeningocele, diastematomyelia, syringomyelia, tethered cord	Hydrocephalus
Kramer et al.[9]	Spina bifida occulta, diastematomyelia, syringomyelia, tethered cord	Thoracic disc herniation (in adulthood)
Komiotis et al. (present case)	Diastematomyelia, syringomyelia, tethered cord, lumbar cutaneous hemangioma	

CONCLUSION

To conclude, the presence of multiple spinal defects at birth is rare and usually makes the management strategy of these patients complicated. The coexistence of at least four different congenital spinal anomalies, as in our case, is very rare. Such patients seem to have diastematomyelia, syringomyelia, and TCS as common findings, followed by spina bifida (occulta or aperta).

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CASE REPORT

Coiling of a recurrent anterior choroidal artery aneurysm using the double catheter technique

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KEYWORDS
Aneurysm, Coiling, Coil Compaction, Embolizationa

CONFLICT OF INTEREST
None

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ABSTRACT
During the past couple of decades, and largely due to the ISAT results, first line treatment for cerebral aneurysms has been coil embolization. A number of different techniques, in combination with growing experience, allow us today to deal endovascularly with increasingly demanding lesions. We present the case of a 39-year-old female who initially underwent coil embolization of a ruptured anterior choroidal artery (AChA) aneurysm. Unfortunately, follow-up imaging revealed coil compaction and aneurysm regrowth. Due to the relatively wide neck and low aspect ratio of the lesion, retreatment was performed using a double catheter technique. Technical details of the case, aneurysm recurrence rates after coiling as well as different endovascular approaches applicable in cases of unfavorably configurated lesions are discussed. In an ever-changing field, new technologies are constantly introduced in everyday endovascular practice. Neurosurgeons need to be aware of them in order to make informed decisions dealing with such cases.

ΠΕΡΙΛΗΨΗ
Κατά την διάρκεια των δύο τελευταίων δεκαετιών, και κυρίως μετά την δημοσιοποίηση των αποτελεσμάτων της ISAT, θεραπεία εκλογής των εγκεφαλικών ανευρυσμάτων έχει καταστεί ο εμβολισμός αυτών με την χρήση σπειραμάτων (coils). Η ανάπτυξη των ενδαγγειακών τεχνικών σε συνδυασμό με την συνεχώς αυξανόμενη εμπειρία σε αυτές μας επιτρέπουν σήμερα την αντιμετώπιση ανευρυσμάτων με ολοένα μεγαλύτερη δυσκολία. Στο παρόν άρθρο παρουσιάζεται η περίπτωση γυναίκας ασθενούς 39 ετών η οποία υπεβλήθη σε εμβολισμό ραγέντος ανευρύσματος της πρόσθιας χοριοειδικής αρτηρίας. Κατά την διάρκεια του τακτικού follow-up αναδείχθηκε επαναναγγοποίηση της βλάβης και ακολούθησε δεύτερος εμβολισμός με την χρήση διπλού μικροκαθετήρα (double catheter technique). Στο άρθρο συζητούνται οι τεχνικές λεπτομέρειες του περιστατικού, οι γενικότερες πιθανότητες επαναναγγοποίησης ενός ανευρύσματος μετά από εμβολισμό αυτού καθώς και κάποιες από τις ενδαγγειακές εναλλακτικές που μας προσφέρονται σήμερα σε περιπτώσεις ανευρυσμάτων με σύμπλοκη ανατομία. Σε ένα δυναμικά αναπτυσσόμενο πεδίο, οι εξελίξεις στην ενδαγγειακή είναι καθημερινές και οι νευροχειρουργοί οφείλουν να τις παρακολουθούν στενά προκειμένου να είναι σε θέση να προσφέρουν στους ασθενείς την βέλτιστη και ασφαλέστερη κάθε φορά θεραπεία.

INTRODUCTION

During the past decade, and largely due to the ISAT results, first line treatment for aneurysms has been, in most European countries at least, coil embolization. A number of different techniques, in combination with growing experience, allow us today to deal with increasingly demanding cases such as wide necked or other unfavorably configurated lesions. Despite all these advances, an overall recurrence rate of 20% makes follow-up of coiled aneurysms essential in order to ensure that a stable over time result has been achieved.

CASE DESCRIPTION

Our case is that of a 39-year-old female who initially presented 51/2 years ago with a WHO grade II subarachnoid haemorrhage (**Fig. 1**).

The cause of the bleeding was identified as a left anterior choroidal artery (AChA) aneurysm which was subsequently treated by coil embolization **(Fig. 2 & 3)**. No complications were reported during the procedure while it's end result was classified as an OG II (neck remnant).

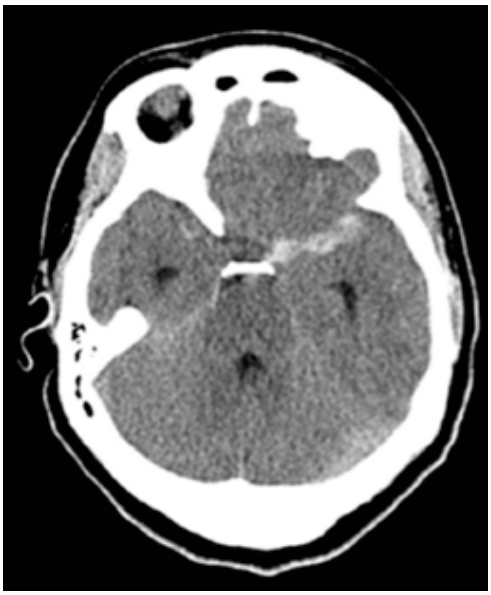


Figure 1. Unenhanced axial CT scan showing evidence of a Fisher grade III subarachnoid haemorrhage. Blood distribution was compatible with rupture of the subsequently revealed left AChA aneurysm.

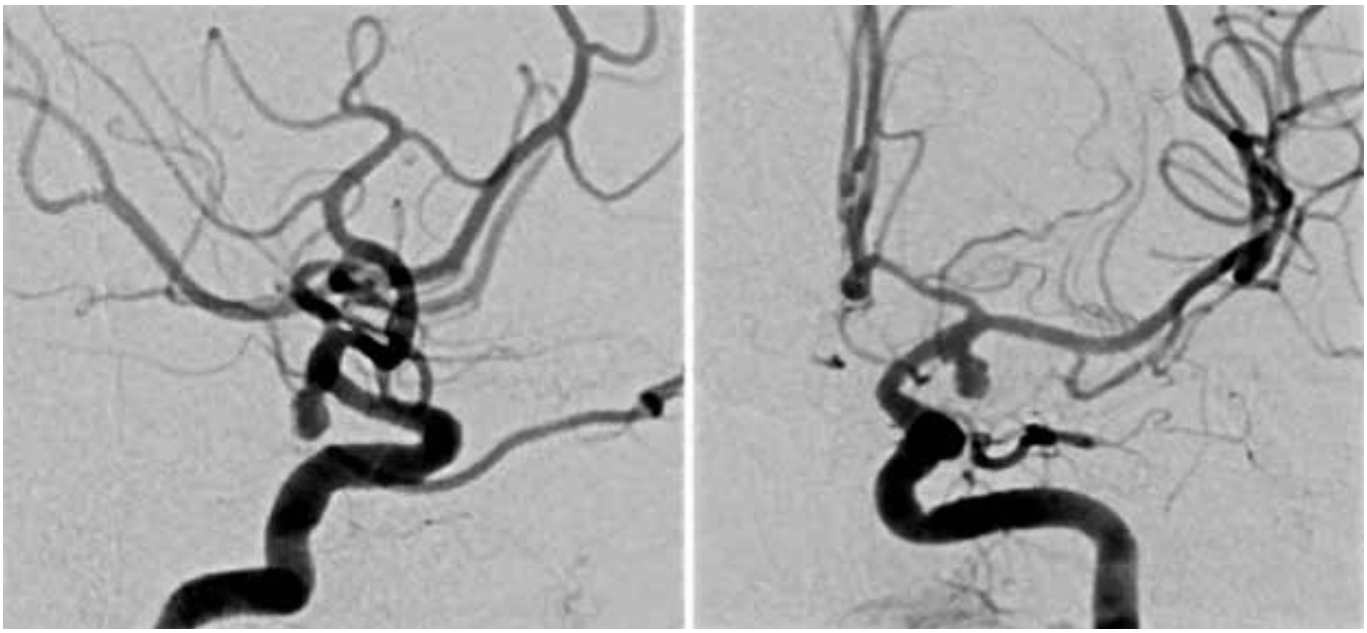


Figure 2. DSA, lateral (Left) and AP (Right) views. Left internal carotid injection and identification of an AChA aneurysm.

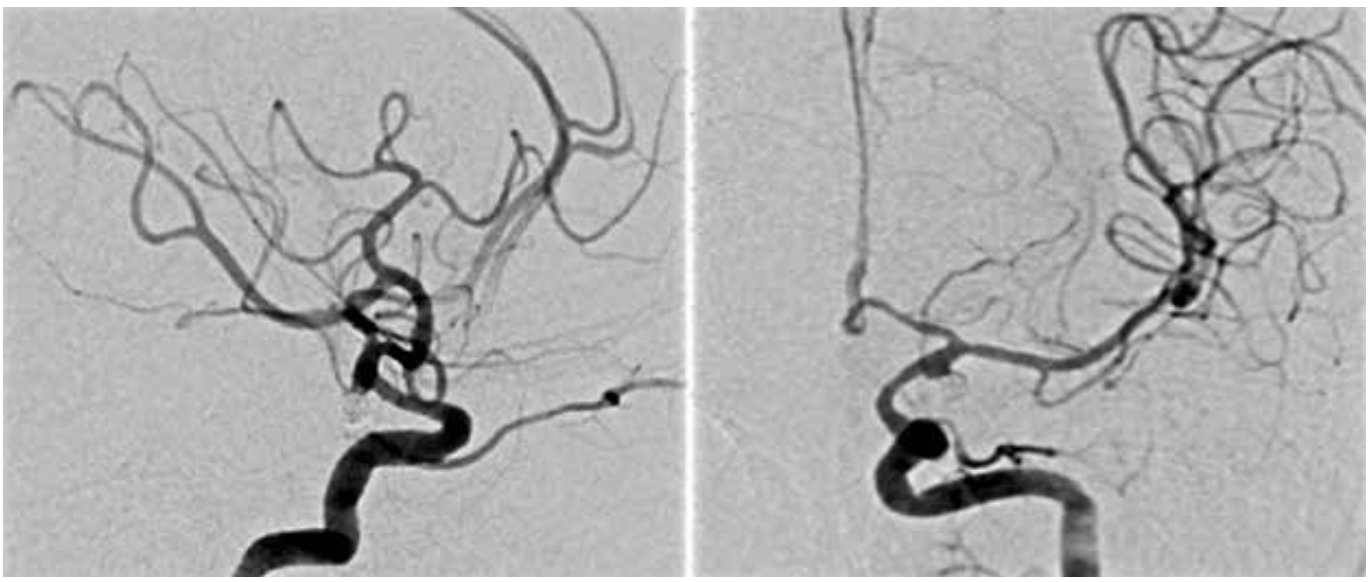


Figure 3. Post-embolization angiogram. The aneurysm is readily occluded but preservation of the AChA required for a neck remnant to be left in place (OG II).

Unfortunately, and despite her good recovery (mRS 1), follow-up imaging of the patient revealed increasing coil compaction which progressively came to such a degree that retreatment was deemed in fact necessary (**Fig. 4**).

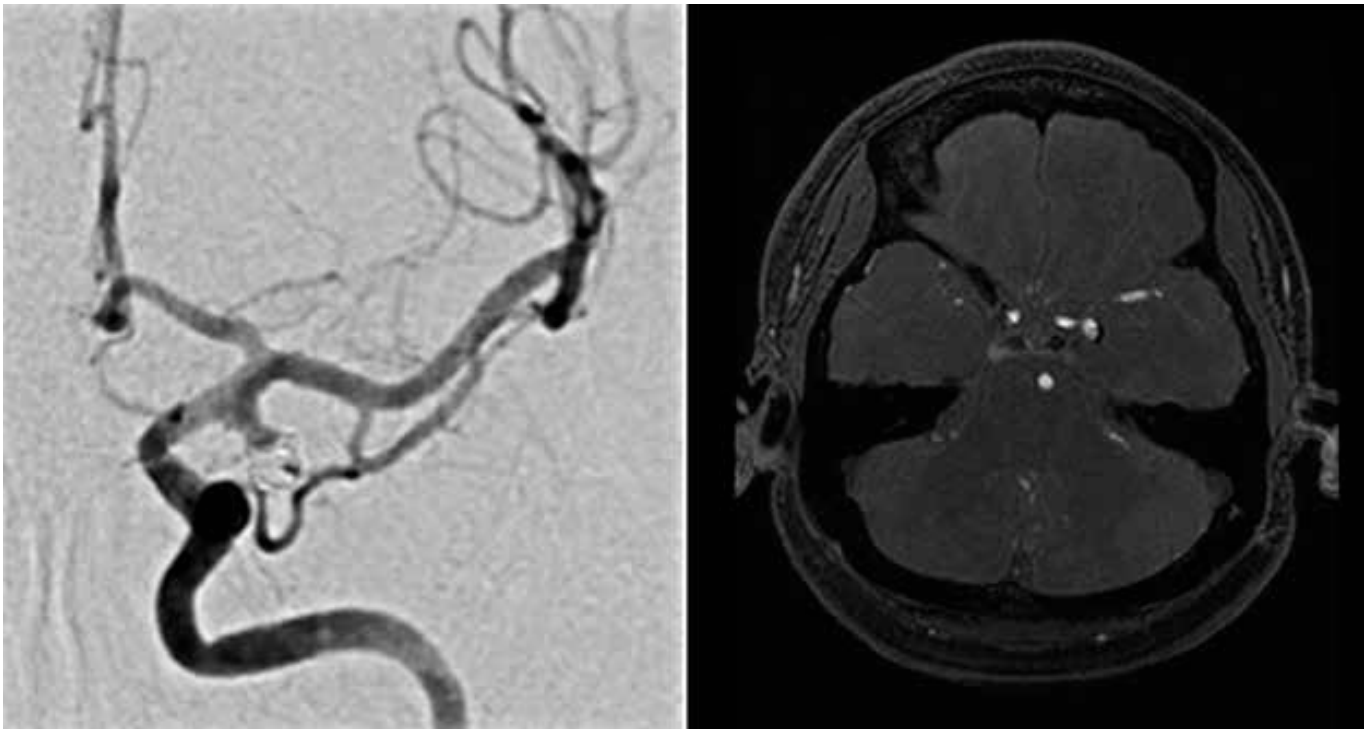
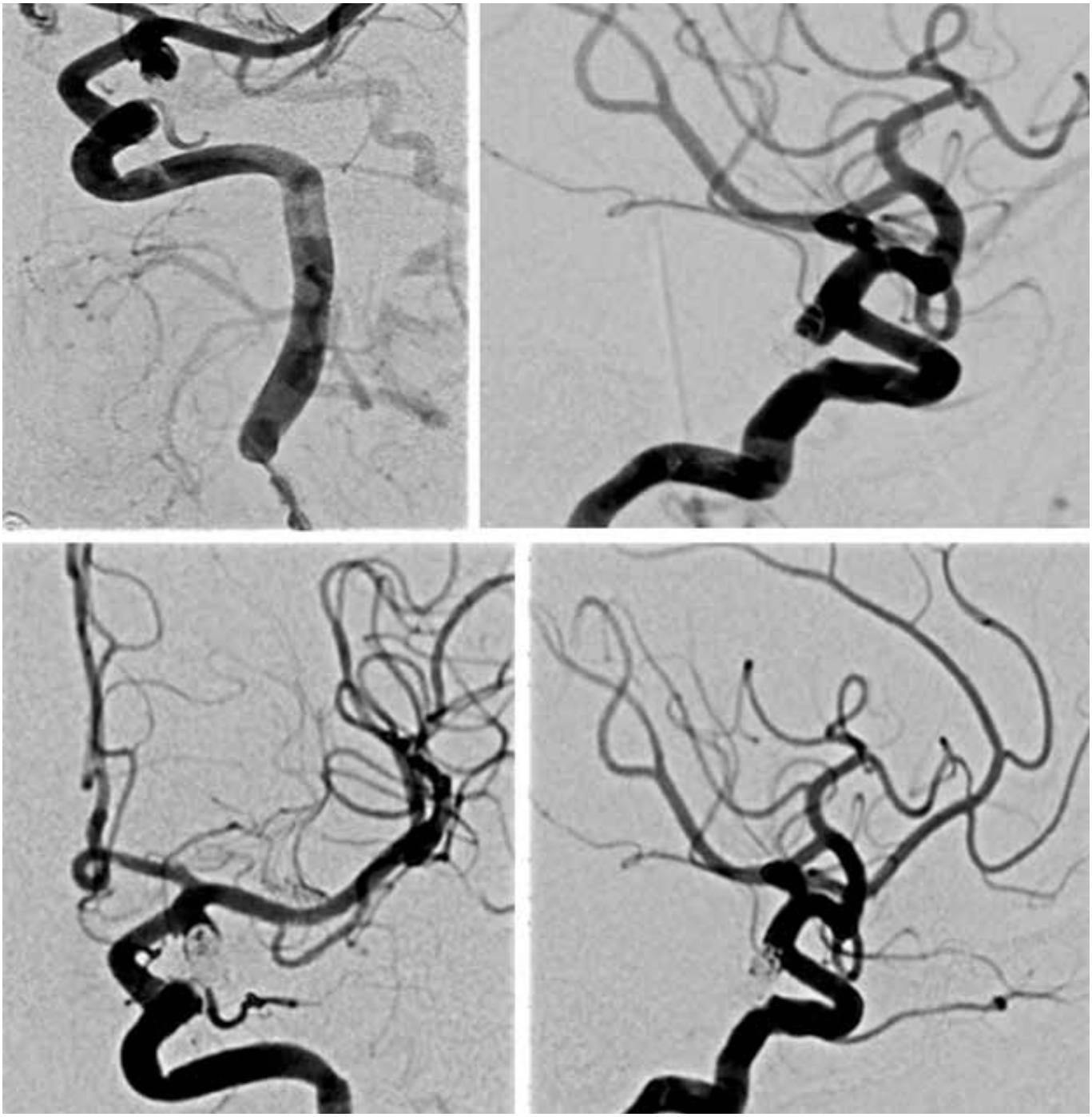


Figure 4. Follow up imaging DSA (Left) and MRA (Right). Aneurysm recurrence.

As for most elective procedures, and in case stenting was to be needed, the patient was prescribed double antiplatelets for a week prior to retreatment (75mg aspirin and 75mg clopidogrel daily). The procedure was performed under general anaesthesia, full heparinization (5,000 IU of heparin IV) and continuous ACT monitoring. A 6F sheath was placed in the right common femoral artery and a 6F Envoy guide catheter was used to selectively catheterize the left internal carotid artery. A diagnostic angiogram performed at this stage confirmed our previous findings and the recurrent lesion was measured at 4X4X5 mm. Due to the relatively wide neck and low aspect ratio of the lesion, a double catheter technique was to be used. Under roadmap and over a Transend EX platinum hydrophilic guide wire, two microcatheters, an Echelon -10 90o and an SL-10 900, were navigated inside the aneurysmal sac. Through the Echelon microcatheter, a 4mm X 7cm GDC-10 bare platinum 3D coil was deployed, creating a rigid frame within the lesion's dome. Prior to detachment, and through the SL-10 microcatheter, 3 more coils (Micrusphere 10 3.5mm X 6.6cm, Ultipaq 10 2.5mm X 6cm, Ultipaq 10 2mm X 4cm) were placed in the aneurysm, intermingling with each other and finally forming a solid metal mesh locked within the sac. The procedure was at this point terminated and the GDC coil was detached. A final angiogram confirmed occlusion of the recurrent aneurysm (OG II) and patency of both the internal carotid and the anterior choroidal arteries (Fig. 5). Haemostasis was achieved with the aid of a vascular closure device (6F Angioseal).

Figure 5. Embolization procedure. Working projections. Catheter induced ICA spasm. (Top). Final coiling result. Occlusion of the aneurysm but with a neck remnant (OG II). Patent AChA (Bottom).



The patient awoke in the angio room with no neurological deficits and the whole procedure was reported as uneventful. Given that eventually no stenting was needed, antiplatelets were discontinued immediately after coiling and the patient was instead placed on a heparin infusion for 24h as per standard protocol for wide necked lesions. No complications were noted during her post-procedural recovery and she was discharged home 2 days later. Follow-up was arranged for 6 months.

DISCUSSION

Aneurysm recurrence after coiling

When it comes to aneurysm coiling, a major concern has always been the durability of the achieved results. Although there is no agreed definition of what constitutes a recurrence of a coiled aneurysm, this is generally taken to mean an increase in the size of patent sac compared to a baseline post-treatment angiogram. In a recent meta-analysis, the overall risk of recurrence of coiled aneurysms has been calculated close to 30% [1]. Factors associated with increased recanalization risk include low packing density (<25%), neck width >4mm, overall sac size (small<large<giant) and presence of intrasaccular thrombus. On the contrary, use of balloons, stents and 3D coils have all been shown to reduce recurrence rates [2].

Management of recurrent aneurysms after coil embolization is controversial and there are no defined criteria to guide everyday clinical practice. In general, retreatment is offered when the degree of recurrence is of sufficient concern. It should be noted here that, despite the high recanalization rates reported in the literature, only 9% of coiled lesions will need retreatment [3].

Given the above stated figures, it is obvious that careful follow-up imaging after coiling of an aneurysm is essential. Up to recently, digital substraction angiography (DSA) has been considered to be the gold standard but nowadays most centers use time-of-flight magnetic resonance angiography (TOF-MRA). Although platinum coils do alter the MR signal, they do not produce artifacts that could interfere with the evaluation of aneurysm obliteration [4]. In our department in Oxford, surveillance imaging is performed at 6 months and 2 years after coil embolization. At this point, patients are discharged if no concerns have been raised. The only exception is young patients who are usually followed for longer periods.

Wide necked aneurysms

Wide necked lesions are generally considered to be technically challenging and a number of different techniques have been developed around them:

- Balloon remodeling

First introduced by Jacques Moret in 1997, this technique involves temporary inflation of a non detachable balloon during coil placement [5]. The balloon is centered over the aneurysm neck and with its help coil prolapses or protrusions are avoided.

- Stent assisted coiling

The key concept behind this technique is that the stent acts within the parent artery as a scaffold to hold coils in place. It also stimulates and promotes endothelialization while at the same time it alters regional haemodynamics. The overall result is, as previously mentioned, a reduction in recurrence rate. Different options that the interventionist has when using stents include either trans-stent coiling or a jailing technique. Recently, balloon assisted coiling followed by stenting has also been advocated for unfavorably configurated lesions [6].

- The double catheter technique

In this technique, two 3D coils are simultaneously deployed within the aneurysm through separate microcatheters. The key concept is for those coils to intermingle with each other, forming a stable metal mesh locked within the lesion [7].

- The catheter assisted technique

In the catheter assisted technique, a first microcatheter, used for coil deployment, is placed in the sac of the aneurysm while a second one is deployed across the orifice of the aneurysm to prevent coil herniation within the parent artery. An aneurysm neck that opens to the outer curve side of the patent artery is the morphological prerequisite that guarantees success of this method [8].

CONCLUSION

Endovascular treatment of intracranial aneurysms is an ever-changing field. New technologies are constantly introduced in everyday practice and the array of available adjuncts, especially stents, has grown substantially during the past few years. Today, interventionists are able to safely treat the vast majority and even the most difficult of aneurysms but whether all these will also result at a lower recurrence rate remains only to be proven.

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CASE REPORT

Delayed post-traumatic tension pneumocephalus: An unexpected "Bubble in the head"

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Tension pneumocephalus, craniotomy, antibiotics, intracranial air

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ABBREVIATIONS DTP: delayed tension pneumocephalus, CT: computed tomography

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ABSTRACT
Intracranial air accumulation accompanied by neurological deterioration is called tension pneumocephalus. We present a 51-year-old male who was operated on 11 years ago for the evacuation of an acute subdural hematoma followed by cranioplasty with xenograft. Additionally, he had fractures in the ethmoid, sphenoid and facial bones. He was admitted to our Department after several days of headache, with GCS: 14/15 and seizures. At his CT scan a high amount of air was detected over the right frontal lobe at the site of the past surgery. Revision of craniotomy and reconstruction of skull base were performed. Postoperative CT scan revealed an extended resolution of pneumocephalus. The patient returned to his activities a month later with total recovery. A more than 10 years delayed case of tension pneumocephalus is very rare and surgical treatment remains the gold standard.

ΠΕΡΙΛΗΨΗ
Η ενδοκρανιακή συσσώρευση αέρα με συνοδό νευρολογική σημειολογία ονομάζεται πνευμεγκέφαλος υπό τάση. Παρουσιάζουμε έναν άνδρα 51 ετών που χειρουργήθηκε πριν από 11 χρόνια για οξύ υποσκληρίδιο αιμάτωμα και μετά από ένα χρόνο έγινε κρανιοπλαστική με ξενομόσχευμα. Επιπλέον, είχε κατάγματα στο ηθμοειδές, στο σφηνοειδές οστό και το προσωπικό κρανίο. Εισήχθη στο νοσοκομείο μετά από αρκετές ημέρες πονοκεφάλου, σε GCS: 14/15 και επιληπτικές κρίσεις. Από την αξονική τομογραφία ανεδείχθη μεγάλη ποσότητα αέρα δεξιά μετωπιαία στο σημείο της προηγούμενης επέμβασης. Έγινε αναθεώρηση της κρανιοτομής και ανακατασκευή της βάσης του κρανίου. Η μετεγχειρητική αξονική τομογραφία ανέδειξε σημαντική υποχώρηση του πνευμεγκεφάλου. Ο ασθενής επέστρεψε στις δραστηριότητές του μετά από ένα μήνα. Είναι πολύ σπάνια μετά από περισσότερα από 10 χρόνια η εμφάνιση πνευμεγκεφάλου υπό τάση. Η χειρουργική παρέμβαση παραμένει θεραπεία εκλογής.

INTRODUCTION

Pneumocephalus is caused usually by head injury in about 4-10% of cases, can be acute (<72 h) or delayed (≥72 h) and follows a benign course [1]. When intracranial air leads to intracranial hypertension and consecutive mass effect is called tension pneumocephalus and is characterized always by variable neurological deterioration [1]. Head trauma with skull base, paranasal cavities or/and skull convexity fractures with dural laceration is the major cause of tension pneumocephalus. Common symptoms include headache, altered level of consciousness and seizures [1-6]. A computed tomography (CT) scan reveals accumulation of air in the subdural space. The appearance of bilateral subdural hypodense collections, which compress and separate frontal lobes, is called "Mount Fuji" sign. In some cases this trapped intracranial air is called pneumatocele [4]. Herewith, we present a case of a delayed post-traumatic tension pneumocephalus.

CASE REPORT

We present a case of a 51-year old male who was operated on 11 years ago because of a traumatic acute subdural hematoma and bifrontal contusions followed by cranioplasty with xenograft after 12 months. There were also fractures in the ethmoid, sphenoid and facial bones. The patient was admitted because of headache for several days, with GCS: 14/15, recurrent seizures and a recent history of upper respiratory tract infection with coughing, sneezing and congestion. A CT scan was performed and revealed a pneumatocele, which displaced the right frontal lobe at the site of previous surgery. Additionally, an anterior cranial fossa

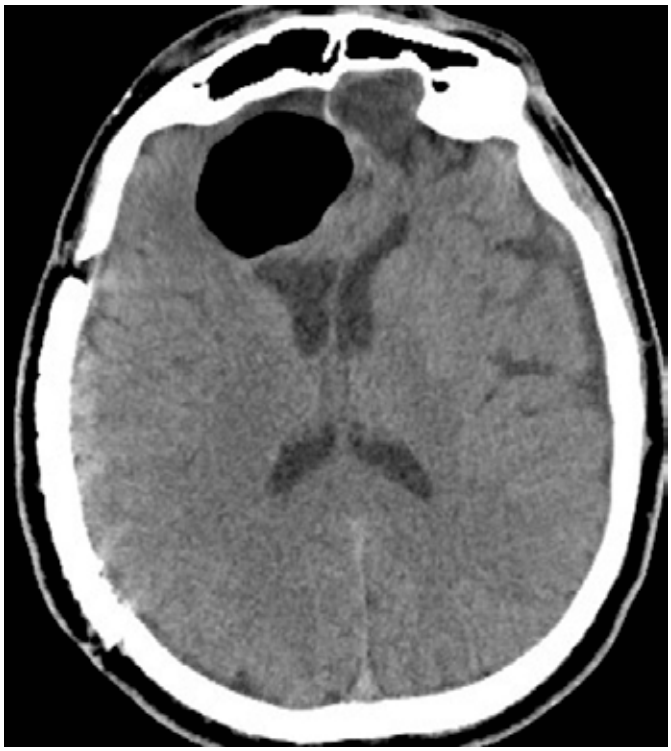

Figure 1.
Air bubble in the right frontal region, CT scan brain parenchyma window.

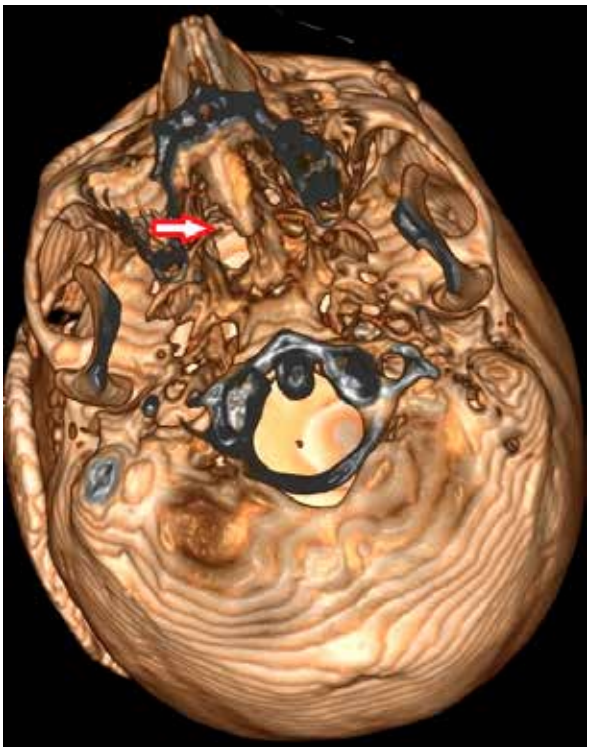

Figure 2.
Anterior cranial fossa defect depicted with the red arrow.

defect was revealed [Figures 1-3].

We revised the right craniotomy in order to succeed an effective reconstruction of the anterior skull base. Postoperative CT scan revealed an extended resolution of intracranial air. Patient returned to his activities after a month with total clinical and radiological recovery. At 6-month follow up no neurological deficits or signs of infection were reported.

DISCUSSION

Intracranial acculmulation of air was first described in 1741 by Lecat et al. The term "pneumocephalus" was invented by Wolff in 1914 and "tension pneumocephalus" was first described in 1962 by Ectors, Kessler, and Stern [2,3,5]. The term delayed tension pneumocephalus (DTP) is used when intracranial air is accumulated after 72 hours of the initial event (trauma, surgery, shunting) followed by neurological deterioration. Intracerebral pneumatocele is reported in 24.9% of cases of pneumocephalus [4].

The formation of pneumocephalus is primarily explained by two theories: the "ball valve" idea and the "inverted soda bottle effect" theory. According to the first, air enters the cerebral cavity unidirectionally and becomes trapped there. According to the second explanation, there is excessive CSF loss that results in a negative intracranial pressure [7]. In our case a supposed mechanism of valve in the site of skull base defect would be an appropriate opening allowing air movement and intracranial entrapment. Further on, the development of pneumatocele could be explained from liquefaction of a contused frontal lobe in the anterior cranial fossa as it was described by Mendelsohn et al [8].

In the past 40 years, 21 cases of DTP were described; 19 of them needed surgery [Table 1]. A delayed symptomatic

Figure 3.
A 3D CT scan revealing the air in the right frontal region.

case of intracranial air accumulation especially after more than 10 years is very rare; to our knowledge, our case is the second described in the literature [7, 9-24]. In our patient intracranial air was accumulated like a bubble in the head (pneumatocele) displacing significantly the right frontal lobe with concomitant neurological symptoms [Figure 3]. We hypothesized that a basal defect caused tension pneumocephalus after many years because he had a recent nasal infection with sneezing and congestion, a condition that might had triggered a reopening of this defect. All patients in such studies achieved complete recovery of symptoms, as in our case.

Surgical reconstruction of skull base included an implementation of a multi-layered repair of the anterior cranial fossa with dural graft and surgical glue. Cunqeiro et al and Eftekhar et al reported that more than 10 ml of intracranial air could contribute to the development of meningitis [25,26]. With a previous nasal infection and a reopened cranial defect, our case was probably at high risk of ascending infection from bacteria or viruses, so we preferred a 4-week antibiotic administration. However, the effectiveness of antibiotics in patients with basal fractures and intracranial air cannot be determined because studies published to date are flawed by biases from large randomized control trials [27].

CONCLUSION

In cases of DTP, a CT scan is the gold standard for diagnosis and should be proposed in cases of previous head trauma and new neurological findings. Early surgery is the treatment of choice in the majority of cases. In general, surgery provides excellent outcome.

Table 1. Review of literature for delayed tension pneumocephalus

Author	Year	Sex/Age	Cause of DTP	Management
Ruge et al	1985	M/28 M/7	Shunt	Surgery
Satapathy and Dash	2000	M/10	Craniopharyngioma	Surgery
Kon et al	2003	M/46	Trauma (7y)	Surgery
Sankhala et al	2004	M/19	Shunt	Surgery
Kuncz et al	2004	F/8	Trauma	Surgery
Cho et al	2004	Adult	Craniopharyngioma	Surgery
Hong et al	2005	M/64 F/38	Shunt Trauma (12y)	Surgery
Kiymaz et al	2005	M/63	Trauma (11d)	Surgery
Chandran et al	2007	M/18	Spontaneous	Surgery
Leong et al	2008	M/42 M/71	Trauma Trauma	Conservative Conservative
Lee et al	2009	M/45	Trauma	Surgery
Shaikh et al	2010	M/70	Trauma	Surgery
Rathore et al	2011	M/30	Trauma (2w)	Surgery
Prüss et al	2011	M/58	Trauma	Surgery
Solomiichuk et al	2013	M/75	Trauma	Surgery
Wang et al	2016	M/25	Trauma (16w)	Surgery
Kankane et al	2016	M/30	Trauma (30d)	Surgery
Chen et al	2018	F/27	Trauma (9y)	Surgery

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