Original article

Folia Neuropathologica

Secretory meningiomas: immunohistochemical pattern of lectins and ultrastructure of pseudopsammoma bodies

Anna Taraszewska, Ewa Matyja

Department of Experimental and Clinical Neuropathology, Mossakowski Medical Research Centre, Polish Academy of Sciences, Warsaw, Poland

Folia Neuropathol 2014; 52 (2): 141-150 DOI: 10.5114/fn.2014.43785

Abstract

Secretory meningioma is an infrequent histological subtype of benign, WHO grade I meningioma, that is characterized by focal epithelial and secretory transformation of meningothelial cells. The leading histopathological feature of neoplastic tissue is the presence of eosinophilic hyaline inclusions, defined as "pseudopsammoma bodies". These inclusions are mostly intracytoplasmic, different in size and often multiple. They are stained with periodic acid-Schiff (PAS) and are immunopositive for epithelial and secretory markers.

The aim of this study was to determine the pattern of lectin bindings and ultrastructural features of secretory meningiomas. The examination was performed on 8 cases of secretory meningiomas that occurred in women and were mostly associated with prominent peritumoural oedema. Histologically, the tumours exhibited numerous eosinophilic, PAS positive pseudopsammoma bodies. Immunohistochemical studies revealed a strong, ring-like cytokeratin expression around the pseudopsammoma bodies. The inclusions were CEA and EMA positive but negative for vimentin. The immunolabeling with four lectins (PNA, SBA, Con A and DBA) was studied. The majority of pseudopsammoma bodies and surrounding tumour cells were strongly labelled with PNA and SBA. Immunolabelling with Con A showed irregular staining with high intensity in small inclusions. Immunostaining with DBA was seldom positive in inclusions and negative in the tumour cell cytoplasm. Ultrastructure of pseudopsammoma bodies exhibited advanced heterogeneity. The size of inclusions and the content of intracytoplasmic lumina varied greatly. Some pseudopsammoma bodies seemed to be located extracellularly and lacked the obvious lumina.

Our ultrastructural study and lectin binding pattern support the unique epithelial and secretory transformation of neoplastic cells connected with their altered glycosylation.

Key words: *secretory meningioma, pseudopsammoma bodies, lectins, ultrastructure, immunohistochemistry.*

Introduction

Secretory meningioma is an unusual histological subtype of meningiomas, characterized by focal epithelial and secretory transformation of meningothelial cells. It is a benign, slowly growing lesion, referred to as grade I tumour, according to the 2007 World Health Organization (WHO) classification of tumours of the central nervous system [24]. The incidence of this specific variant, reported in various studies, ranged from 1.1% to 4.4% of all meningiomas [7,12,

Communicating author:

Anna Taraszewska, MD, Department of Clinical and Experimental Neuropathology, Mossakowski Medical Research Centre, Polish Academy of Sciences, 5 Pawinskiego St., 02-106 Warsaw, Poland, e-mail: ataraszewska@imdik.pan.pl

22,25,34,38]. Only one study documented a high incidence, accounting for 9.3% [1].

Secretory meningiomas are characterized by the presence of eosinophilic inclusions [20], which were originally described as hyaline bodies by Cushing and Eisenhart in 1938 (2nd edition 1962) [8] and later defined as "pseudopsammoma bodies" by Kepes in 1961 [14]. These inclusions are strongly stained with periodic acid-Schiff (PAS) and were immunopositive for some epithelial antigens, including cytokeratins (CKs), epithelial membrane antigens (EMA) and carcinoembryonic antigen (CEA) [2,5,7,25]. Moreover, pseudopsammoma bodies exhibit positivity for various secretory components, as immunoglobulins [4], α-1-antitripsin (AT) and α-1-antichymotrypsin (ACT) [7]. Ultrastructural features of secretory properties of the neoplastic cells were primarily demonstrated by Kepes [13] and confirmed by other electron microscopic findings [3,9,15-17,22]. Subsequently, the tumour was defined as "secretory meningioma" in 1986 by Alguacil-Garcia *et al*. [1]. From a clinical point of view, secretory meningiomas appear predominantly in women, with the most frequent location at the sphenoid ridge and frontal region. In comparison with other ordinary meningiomas, they are often associated with significant peritumoral oedema [5,12,25,26,36,38,40]. It has been speculated that some products of pseudopsammoma bodies might be involved in the development of cerebral oedema [23,26,36].

The aim of this report was to evaluate the clinico-pathological and ultrastructural features in the series of secretory meningiomas, including the immunohistochemical pattern of the lectin binding sites in tumour cells and pseudopsammoma bodies.

Material and methods

The study was performed on the surgical archival material from eight patients with postoperative diagnosis of secretory meningioma. Clinico-pathological characteristics of the patients are summarized in Table I.

All tumour specimens were fixed in 10% buffered formalin and routinely embedded in paraffin blocks. Sections were stained with haematoxylin and eosin (H&E) and periodic acid-Schiff (PAS).

Immunohistochemistry was performed on paraffin-embedded specimens; labelling was carried out by the avidin-biotin complex (ABC) method, with 3,3'-diaminobenzidine (DAB) as a chromogen. The following primary antibodies were used: anti-epithelial membrane antigen (EMA), anti-cytokeratin AE1/AE3 (CK), anti-CD34, anti-vimentin (vim) and anti-carcinoembryonic antigen (CEA); all reagents were obtained from Dako. Immunohistochemical staining of the lectin glycoconjugates was performed with 4 biotinylated lectins, as summarized in Table II: Peanut agglutinin (PNA), Soybean agglutinin (SBA), Dolichos biflorus agglutinin (DBA), Concanavalin A (Con A) (obtained from Vector Laboratories, Burlingame, CA, USA). Briefly, the deparaffinized sections were incubated with lectins in concentration of 10 µg/ml for 1 h, and then with the avidin-biotin peroxidase complex (ABC Kit) and 3'3'diaminobenzidine (DAB, Dako) reagents and counterstained with haematoxylin; details of the used method are presented in our previous report [33].

For electron microscopy, the small fragments of paraffin embedded specimens were selected, then deparaffinized, rinsed in 0.1 phosphate buffer, post-

Table I. Clinico-pathologic data

No.	Gender/Age	Tumour localization	Diameter of tumour (cm)	Peritumoural oedema	Basic histopathological pattern of meningioma
1	Female/51	Frontal convexity	5.0	No data	Meningothelial
2	Female/58	No data	2.5	Yes	Transitional
3	Female/73	Sphenoid ridge	No data	No data	Meningothelial
4	Female/50	Petrous apex	2.0	Yes	Angiomatous
5	Female/67	Sphenoid ridge	3.5	Yes	Fibroblastic
6	Female/55	Sphenoid ridge	2.5	Yes	Angiomatous
7	Female/58	Temporal basis	3.3	Yes	Meningothelial
8	Female/55	Temporal basis	4.0	No data	Meningothelial

Table II. Characteristics of lectins used for the study

Lectin names	Abbreviations	Sugar specificities
Peanut agglutinin	PNA	β-D-galactose (1-3)N-acetylgalactosamine/Gal(β1-3)GalNAc/
Soybean agglutinin	SBA	N-acetylgalactosamine (α1-3)galactose/GalNAc (α1-3)Gal/
Dolichos biflorus agglutinin	DBA	α-N-acetylgalactosamine/α-GalNAc/
Concanavalin A	Con A	α-D-mannose and β-D-glucose

fixed in solutions of 2% glutaraldehyde and 1% osmium tetroxide in the same buffer, dehydrated in graded alcohols and embedded in Epon 812. Ultrathin sections stained with uranyl acetate and lead citrate were examined with a JEM-1010 electron microscope (JEOL, Japan).

Results

Histopathological findings

All meningiomas were characterized by the presence of eosinophilic and PAS-positive pseudopsammoma bodies (Fig. 1A, B) that occurred on the background of various basic histopathological growth patterns, assessed as meningothelial, transitional, fibroblastic or angiomatous type (Table I). Pseudopsammoma bodies exhibited a wide spectrum of morphology, regarding their size and shape. The number and distribution of inclusions greatly varied within the same tumour. The bodies were loosely scattered or collected in groups and exhibited diverse forms, ranging from minute homogenous and brightly eosinophilic spheres to huge heterogeneous, weakly eosinophilic deposits, surrounded by clear "halo" (Fig. 1A).

Immunohistochemistry

Immunohistochemical studies revealed a strong immunoreactivity for CK, limited to the part of the cytoplasm of tumour cell that bordered the pseudopsammoma bodies. This CK expression usually displayed the form of a strong ring-like pattern around pseudopsammoma bodies (Fig. 2A). Immunoreactivity for CEA, of varying intensity, was evidenced both in the pseudopsammoma bodies and in the surrounding cytoplasm of neoplastic cells (Fig. 2B). Pseudopsammoma bodies were also immunopositive for EMA (Fig. 2C) but they were negative for vimentin, what was in contrast to overall positivity of tumour cells (Fig. 2D).

Immunohistochemical staining with the lectins showed that the majority of pseudopsammoma bodies and surrounding neoplastic cell cytoplasm were strongly labelled with PNA (Fig. 3A) and SBA (Fig. 3B), although the individual bodies remained unstained or were only weakly stained with the both lectins. Immunolabelling with Con A showed irregular staining of pseudopsammoma bodies. It was intense mainly in small bodies and weak in larger ones, whereas several bodies and the cytoplasm of

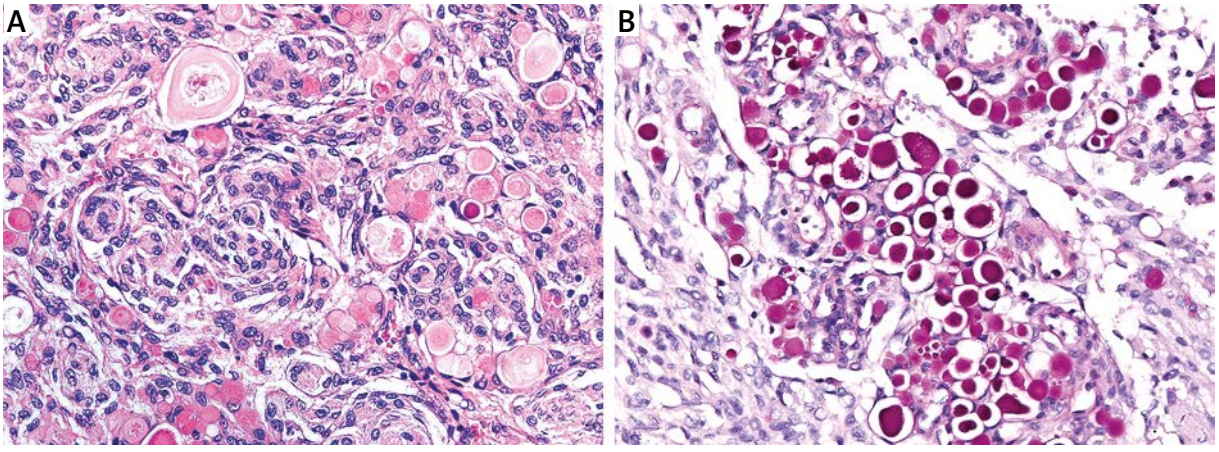

Fig. 1. A) Secretory meningioma with multiple, hyaline, eosinophilic cytoplasmic inclusion. **B)** PAS positive pseudopsammoma bodies. Original magnification **(A, B)** ×200.

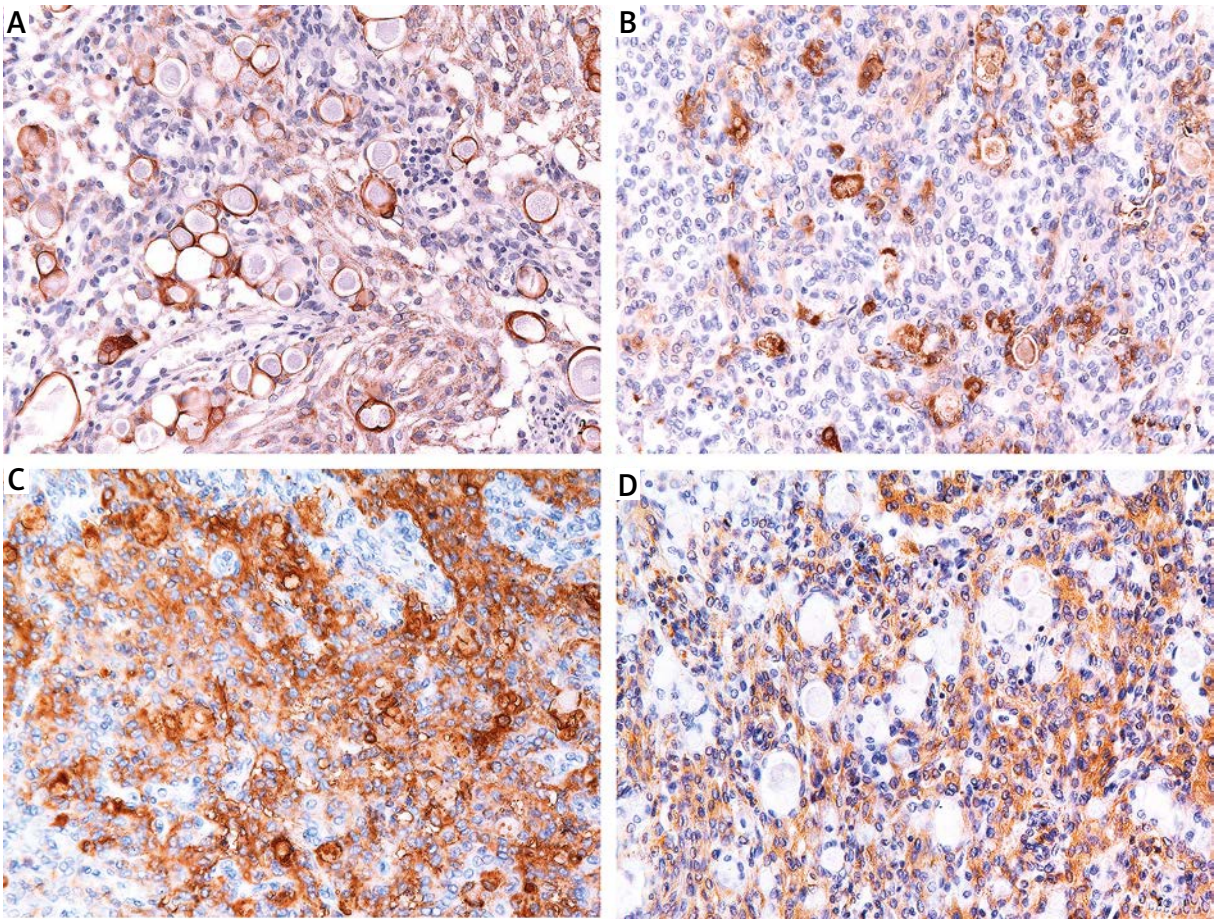

Fig. 2. Immunohistochemistry of secretory meningioma. **A)** CK expression with a distinct ring-like pattern around pseudopsammoma bodies. **B)** Immunoreactivity for CEA in the pseudopsammoma bodies and in the cytoplasm of surrounding tumour cells. **C)** Diffuse EMA immunoexpression in the pseudopsammoma bodies and in the tumour cells. **D)** Negative immunostaining for vimentin in the psammoma bodies and positive in the tumour cells. Original magnification **(A-D)** ×200.

neoplastic cells were unlabelled (Fig. 3C). Immunostaining with DBA was rarely positive in pseudopsammoma bodies and was negative in the tumour cells cytoplasm, however, the slight reactivity for DBA was seen in the nuclei of neoplastic cells (Fig. 3D).

Electron microscopy

Electron microscopic examination revealed the presence of numerous neoplastic cells, exhibiting intracytoplasmic lumina filled with microvilli and aggregations of homogenous or heterogeneous material, corresponding to pseudopsammoma bodies (Fig. 4A, B). The cytoplasm of these cells was characterized by increased electron-density, rich endoplasmic reticulum and Golgi complex vesicles and conspicuous bundles of tonofilaments, often in the close connection with intracytoplasmic lumina and microvilli (Fig. 4A, B). Furthermore, distinct interdigitations of cell processes with desmosomes and numerous microvilli, projecting from the plasmalemma to the extracellular space, were seen (Fig. 4C, D). The size of the pseudopsammoma bodies and content of intracytoplasmic lumina greatly varied. Small lumina usually contained moderately electron dense, fine filamentous and rather homogenous substance, similar to those covering the surface of microvilli (Fig. 4B). Enlarged lumina were filled with polymorphic, filamentous or granular electron dense material, either homogenous or exhibiting a mixture of heterogeneous vesicles, membranaceous structures and dense bodies (Fig. 5A, B). Numerous lumina of dif-

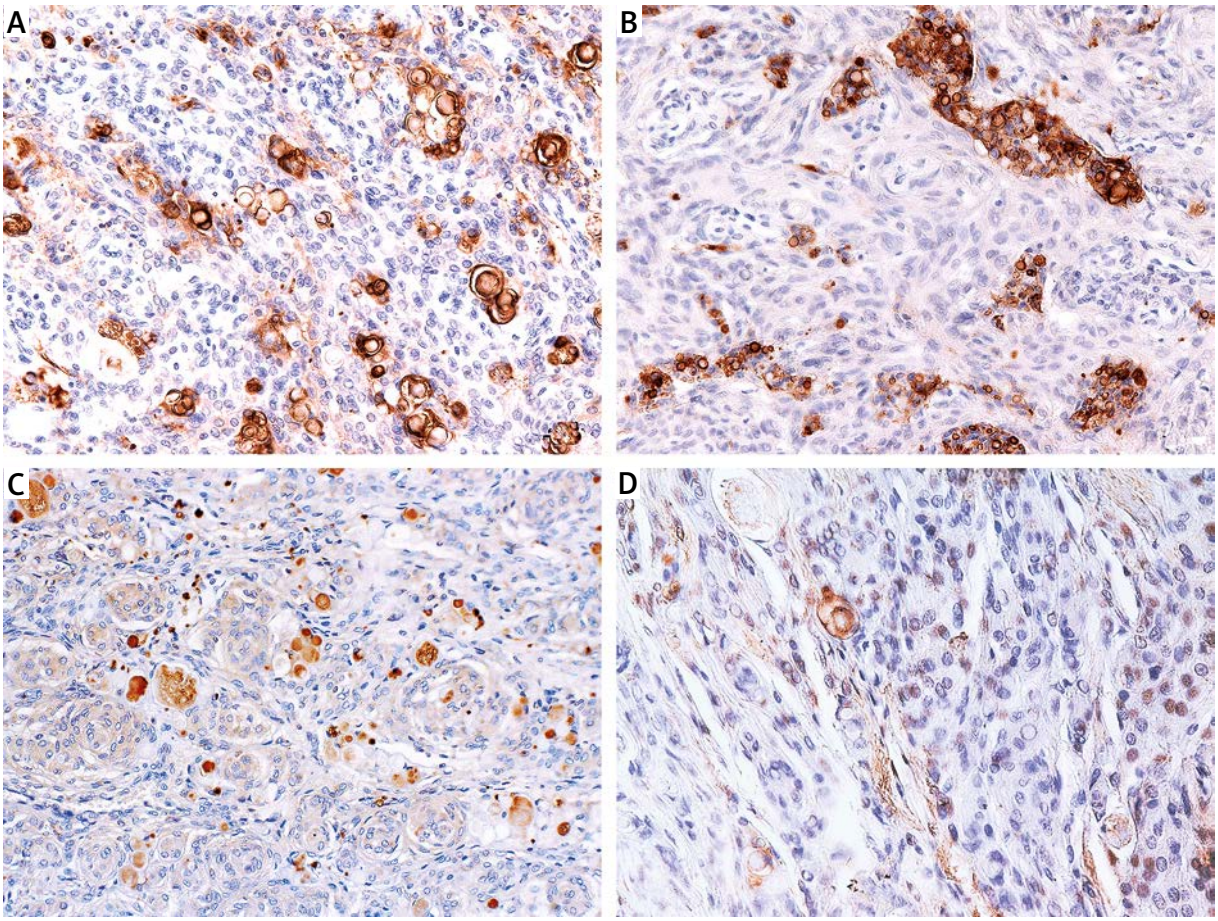

Fig. 3. Immunohistochemical staining with lectins. **A)** Strong PNA immunolabelling in the majority of pseudopsammoma bodies and the cytoplasm of surrounding tumour cells. **B)** Strong labelling with SBA of pseudopsammoma bodies and the cytoplasm of surrounding cells. **C)** Irregular staining of pseudopsammoma bodies with Con A with high intensity in small inclusions. **D)** Labelling with DBA in some pseudopsammoma bodies. Slight reactivity in the nuclei of tumour cells. Original magnification **(A-B)** ×200.

ferent size, filled with polymorphic pseudopsammoma bodies, were often seen in the cytoplasm of the same cell. Some pseudopsammoma bodies seemed to be located extracellularly and lacked the obvious lumina. They were associated with numerous microvilli, extending into intercellular space (Fig. 5C). Pseudopsammoma bodies were frequently surrounded by numerous fascicles of tonofilaments (Fig. 5D).

Discussion

All secretory meningiomas in our series showed focal epithelial and secretory transformation with accumulation of pseudopsammoma bodies. The same features have been previously demonstrated in other reports [13,22,29,35,38]. Pseudopsammoma bodies are most frequently associated with the meningothelial pattern of the tumour, however they might occur also in other histological subtypes of benign meningiomas, including lipomatous or vacuolated component [18,20,21,39]. The secretory meningiomas of the present study, comprised tumours with the basic growth pattern of the meningothelial type (4 cases), angiomatous type (2 cases), transitional type (1 case) and fibroblastic type (1 case). The mechanism, by which the individual neoplastic cells of any subtype of meningioma might be transformed into the secretory cells, is unknown. The most characteristic cellular abnormalities, corresponding to the epithelial and secretory features, consist of the presence of intracytoplasmic lumina with accumulation of secretory products [6,7,11,19]. Epithelial and

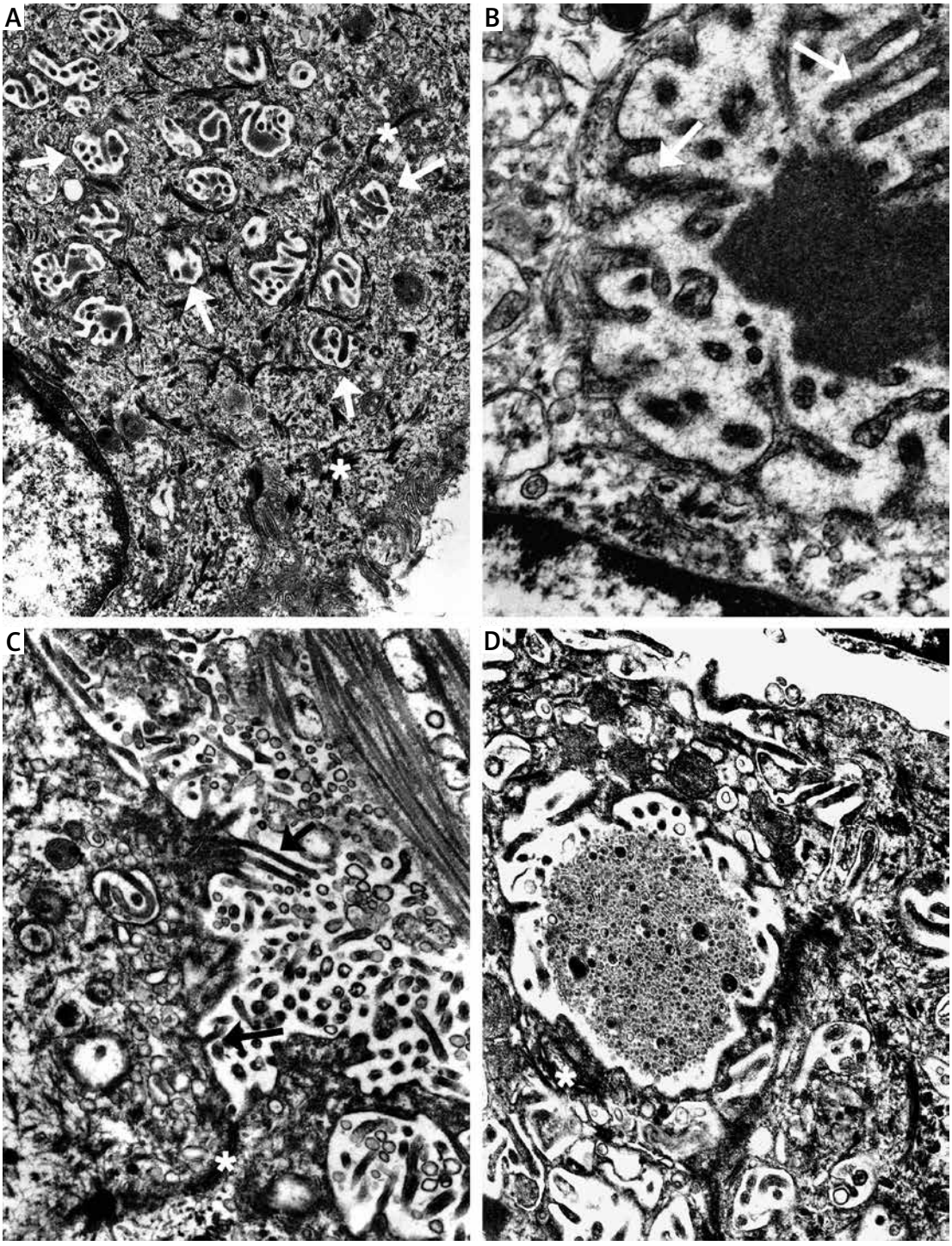

Fig. 4. Ultrastructural features. **A)** Tumour cell exhibiting numerous small intracytoplasmic cavities filled with microvilli (arrows). The cytoplasm of tumour displays increased electron-density, abundant vesicles and conspicuous bundles of tonofilaments (asterisk). **B)** Intracytoplasmic lumina containing microvilli (arrows) and homogenous or fine filamentous material. **C)** Distinct interdigitation of cell processes with desmosomes (asterisk) and numerous microvilli (arrows), projecting from the plasmalemma to the extracellular space. **D)** Multiple intercytoplasmic lumina of different size filled by microvilli and microvesicles and surrounded by tonofibrils (arrows). Original magnification: **A** ×7500; **B** ×15 000; **C–D** ×12 000.

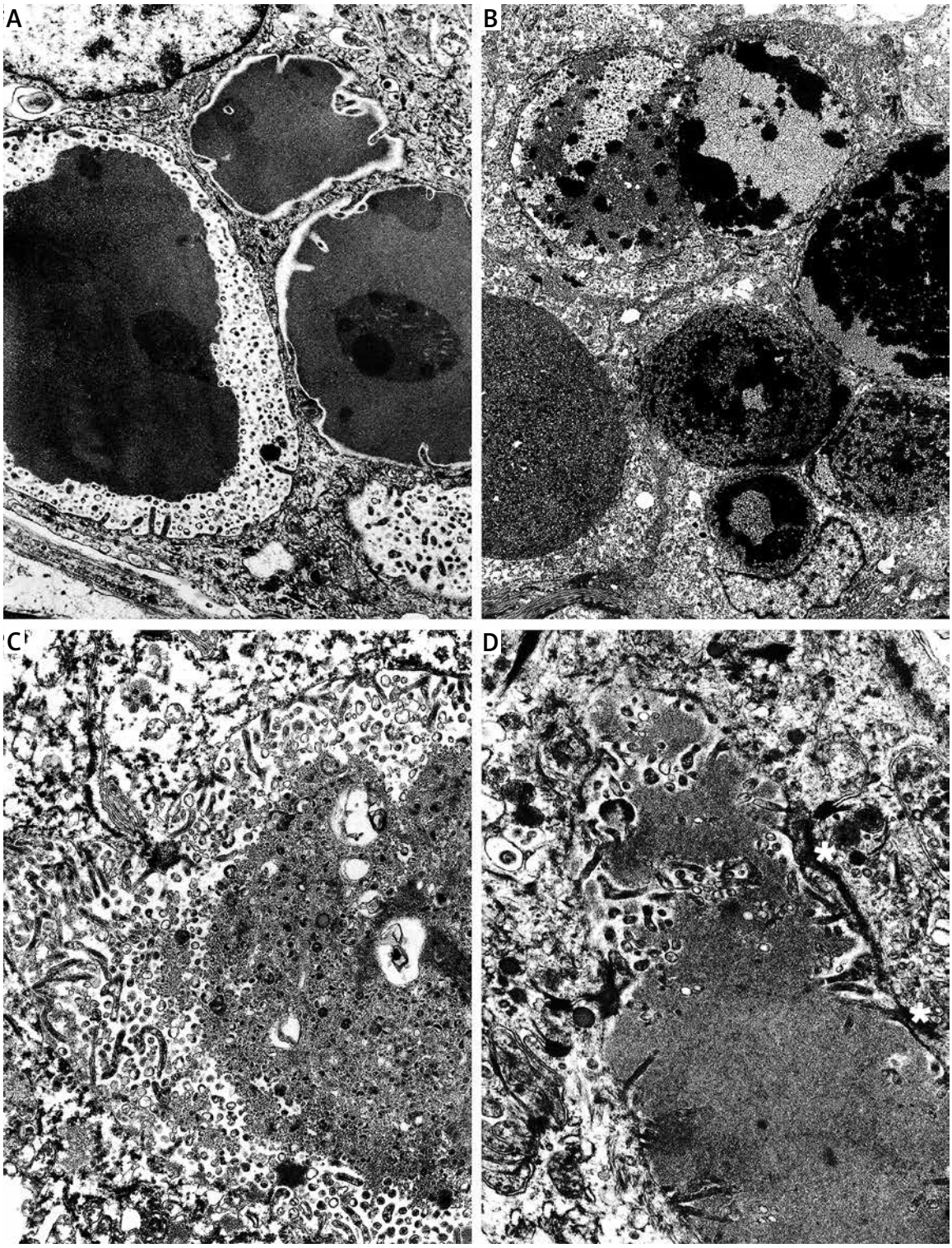

Fig. 5. Ultrastructural features. **A)** Enlarged lumina filled with homogenous, electron dense material and mixture of microvesicles. **B)** Multiple, enlarged pseudopsammoma bodies exhibiting high heterogeneity of their structure. **C)** Extracellularly located pseudopsammoma bodies associated with numerous microvilli and lacking the obvious lumen. **D)** Pseudopsammoma body surrounded by numerous fascicles of tonofilaments (asterisk). Original magnification: **A** ×6000; **B** ×2500; **C–D** ×75 000.

glandular-like differentiation of the cells has been also indicated with CK, EMA and CEA immunoreactivity in many studies [1,2,25,32,35]. Moreover, our present study demonstrated the abnormal glycosylation pattern of secretory meningioma cells.

Considering the morphology of pseudopsammoma bodies, it ought to be noted that histochemical and ultrastructural patterns of pseudopsammoma bodies exhibit the striking resemblance to the inclusions, observed within intracellular lumina in some epithelial neoplasms, especially in mammary and gastro-intestinal carcinoma or mesothelioma [4,13,16]. In epithelial cancer cells, the intracytoplasmic lumina appears as spherical cavities with microvilli and accumulation of secretion products, and they are usually surrounded by a filamentous network [27,28]. Various types of intracytoplasmic lumina have been demonstrated in electron microscopic study of breast carcinoma: type A with many microvilli on the luminal surface and abundant secretion within the lumen; type B with fewer microvilli and little or abundant secretion, and a third type of large intracytoplasmic lumina with abundant secretion and compression of the nucleus [30,31].

The present ultrastructural investigations of secretory meningiomas documented that the pseudopsammoma bodies were predominately located within large intracytoplasmic lumina, lined by microvilli. The same ultrastructural features of pseudopsammoma bodies were also demonstrated in other studies [3,9,13,16,37]. Less frequently the pseudopsammoma bodies were observed within extracellular space, filling by numerous projecting microvilli [13,15]. Both intracellular and extracellular secretory material might exhibit various forms of homogenous deposits of moderately electron-dense fine filamentous and granular substances or polymorphic large inclusions with a mixture of microvesicles, lamellar structures and electron dense clumps. These findings indicated that ultrastructural features of the secretory type of meningioma differ from the fine structure of other types of meningothelial tumours [10].

We found also some cells with predominance of small intracytoplasmic cavities, accompanied by intraluminal protrusions of microvilli and scanty secretory material. These features probably represent an initial stage of secretory activity. Sometimes, the small lumina coexisted with larger and polymorphic pseudopsammoma bodies. These observations indicate the dynamic secretory process and support the suggestion that formation of the large polymorphic bodies represent the final stage of accumulation and degradation of secretory products [3,15-17,22].

The previous histochemical reports showed that the products of secretion are composed mainly of conjugated glycoproteins [9,13,17] and are reminiscent to the glycoproteinaceous coating seen on the surface of intestinal and respiratory epithelia [16]. Immunohistochemical characteristics of pseudopsammoma bodies with one lectin were given by Kuratsu *et al*. [17]. The authors used only Concanavalin A staining and postulated that secretory bodies in meningiomas belong to mucosubstances of class II and III.

In the present study we demonstrated the reaction of the pseudopsammoma bodies and the tumour cells with four lectins, including glucose and mannose binding Con A and three lectins specific to galactose/N-acetylgalactosamine (GalNAc) glycoconjugates with differential binding sites, i.e. PNA, SBA and DBA. Our results showed that pseudopsammoma bodies and surrounding cells presented a large range of glycan structures. Pseudopsammoma bodies were stained more intensely with PNA and SBA, moderately with Con A and weakly with DBA, whereas the cytoplasm of the surrounding neoplastic cells was labelled mostly with PNA and SBA. Very small secretory granules, probably corresponding to small intracytoplasmic lumina, were also labelled with the lectins and visualized especially with Con A. These findings and our previous study of the lectin binding in various subtypes of meningioma indicated that the pattern of lectin glycoconjugates in secretory meningioma differs from other variants of meningothelial tumours [33]. Moreover, the variations in lectin bindings were demonstrated between the secretory cells and other neoplastic cells within the same tumour. Enhanced expression of the lectin glycoconjugates in the meningioma secretory cells probably reflects the selective changes in tumour cell glycosylation, that may be important for their phenotypic heterogeneity. Expression of CEA, which is a highly N-glycosylated glycoprotein, is also the characteristic finding in secretory meningiomas [1,5,22,36,37]. We demonstrated a similar pattern of the immunoreactivity for CEA and the binding sites for PNA in the pseudopsammoma bodies and the cells surrounding them.

Concluding, the present study documented the heterogenous ultrastructural and lectin binding pat-

tern of pseudopsammoma bodies and illustrated the status of altered glycosylation in the neoplastic cells of secretory meningiomas.

Disclosure

Authors report no conflict of interest.

References

1. Alguacil-Garcia A, Pettigrew NM, Sima AA. Secretory meningioma. A distinct subtype of meningioma. Am J Surg Pathol 1986; 10: 102-111.
2. Assi A, Declich P, Iacobellis M, Cozzi L, Tonnarelli G. Secretory meningioma, a rare meningioma subtype with characteristic glandular differentation: an histological and immunohistochemical study of 9 cases. Adv Clin Path 1999; 3: 47-53.
3. Berard M, Tripier MF, Choux R, Chrestian MA, Hassoun J, Toga M. Ultrastructural study of meningiothelial meningioma with 'hyaline inclusions' (author's transl). Acta Neuropathol 1978; 42:59-62 [in French].
4. Budka H. Hyaline inclusions (Pseudopsammoma bodies) in meningiomas: immunocytochemical demonstration of epithel-like secretion of secretory component and immunoglobulins A and M. Acta Neuropathol 1982; 56: 294-298.
5. Buhl R, Hugo HH, Mihajlovic Z, Mehdorn HM. Secretory meningiomas: clinical and immunohistochemical observations. Neurosurgery 2001; 48: 297-301; discussion 301-292.
6. Cenacchi G, Ferri GG, Salfi N, Tarantino L, Modugno GC, Ceroni AR, Martinelli GN. Secretory meningioma of the middle ear: a light microscopic, immunohistochemical and ultrastructural study of one case. Neuropathology 2008; 28: 69-73.
7. Colakoglu N, Demirtas E, Oktar N, Yuntem N, Islekel S, Ozdamar N. Secretory meningiomas. J Neurooncol 2003; 62: 233-241.
8. Cushing H, L E. The meningiomas: their classification, regional behavior, life history and surgical end results. Hafner Publishing Company, New York 1962; 175.
9. Font RL, Croxatto JO. Intracellular inclusions in meningothelial meningioma. A histochemical and ultrastructural study. J Neuropathol Exp Neurol 1980; 39: 575-583.
10. Jaskolski D, Papierz T, Liberski PP, Sikorska B. Ultrastructure of meningiomas: autophagy is involved in the pathogenesis of "intranuclear vacuoles". Folia Neuropathol 2012; 50: 187-193.
11. Jeong HS, Lee GK. Secretory meningioma – a case report with histopathological, immunohistochemical and ultrastructural analysis. J Korean Med Sci 1996; 11: 369-372.
12. Kamp MA, Beseoglu K, Eicker S, Steiger HJ, Hanggi D. Secretory meningiomas: systematic analysis of epidemiological, clinical, and radiological features. Acta Neurochir (Wien) 2011; 153: 457-465.
13. Kepes J. The fine structure of hyaline inclusions (pseudopsammoma bodies) in meningiomas. J Neuropathol Exp Neurol 1975; 34: 282-294.
14. Kepes J. Observations on the formation of psammoma bodies and pseudopsammoma bodies in meningiomas. J Neuropathol Exp Neurol 1961; 20: 255-262.
15. Kock KF, Teglbjaerg PS. Meningiomas with a non-meningotheliomatous component. A new type of tumour? Acta Neuropathol 1981; 55: 199-203.
16. Kubota T, Hirano A, Yamamoto S. The fine structure of hyaline inclusions in meningioma. J Neuropathol Exp Neurol 1982; 41: 81-86.
17. Kuratsu J, Matsukado Y, Sonoda H. Pseudopsammoma bodies in meningotheliomatous meningioma. A histochemical and ultrastructural study. Acta Neurochir (Wien) 1983; 68: 55-62.
18. Liebig T, Hoffmann T, Hosten N, Sander B, van Landeghem F, Stoltenburg-Didinger G, Lanksch WR. Lipomatous secretory meningioma: case report and review of the literature. Neuroradiology 1998; 40: 656-658.
19. Louis DN, Hamilton AJ, Sobel RA, Ojemann RG. Pseudopsammomatous meningioma with elevated serum carcinoembryonic antigen: a true secretory meningioma. Case report. J Neurosurg 1991; 74: 129-132.
20. Matyja E, Naganska E. History and nature of pseudopsammoma bodies. Clin Neuropathol 2006; 25: 204.
21. Nakamura N, Nojima T, Inoue K, Terasaka S, Aida T, Abe H. Vacuolated meningioma with secretory features: a case report. Noshuyo Byori 1993; 10: 99-101.
22. Nishio S, Morioka T, Suzuki S, Hirano K, Fukui M. Secretory meningioma: clinicopathologic features of eight cases. J Clin Neurosci 2001; 8: 335-339.
23. Osawa T, Tosaka M, Nagaishi M, Yoshimoto Y. Factors affecting peritumoral brain edema in meningioma: special histological subtypes with prominently extensive edema. J Neurooncol 2013; 111: 49-57.
24. Perry A, Louis DN, Scheithauer BW, Budka H, A. VD. Meningiomas. In: Louis DN, Oghaki H, Wiesttler D, Cavenee WK (eds.). WHO Classification of Tumors of the Central Nervous System, 4th edn. IARC Press, Lyon 2007, pp. 164-172.
25. Probst-Cousin S, Villagran-Lillo R, Lahl R, Bergmann M, Schmid KW, Gullotta F. Secretory meningioma: clinical, histologic, and immunohistochemical findings in 31 cases. Cancer 1997; 79: 2003-2015.
26. Regelsberger J, Hagel C, Emami P, Ries T, Heese O, Westphal M. Secretory meningiomas: a benign subgroup causing life-threatening complications. Neuro Oncol 2009; 11: 819-824.
27. Remy L. The intracellular lumen: origin, role and implications of a cytoplasmic neostructure. Biol Cell 1986; 56: 97-105.
28. Remy L, Marvaldi J. Origin of intracellular lumina in HT 29 colonic adenocarcinoma cell line. An ultrastructural study. Virchows Arch B Cell Pathol Incl Mol Pathol 1985; 48: 145-153.
29. Slowinski J, Kaluza J, Sabat D, Mrowka R, Lange D, Adamek D, Betlej M. Secretory meningioma of the brain. Report of two cases. Folia Neuropathol 1999; 37: 87-92.
30. Sun YK, Bi XL. Secretory carcinoma of the breast as a separate entity – histological, histochemical and ultrastructural study. Zhonghua Zhong Liu Za Zhi 1988; 10: 177-179.
31. Suzuki F, Saito A, Ishi K, Okazaki T, Kina K, Koyatsu J, Sugiyama K. Secretory carcinoma of the breast: an immunohistochemical and ultrastructural study. Med Electron Microsc 1999; 32: 50-56.
32. Tada T, Ishii K, Oshima S, Hara H, Kobayashi S. Secretory meningioma associated with numerous meningothelial rosettes. Acta Neuropathol 1992; 84: 342-345.

33. Taraszewska A, Matyja E. Lectin binding pattern in meningiomas of various histological subtypes. Folia Neuropathol 2007; 45: 9-18.
34. Tirakotai W, Mennel HD, Celik I, Hellwig D, Bertalanffy H, Riegel T. Secretory meningioma: immunohistochemical findings and evaluation of mast cell infiltration. Neurosurg Rev 2006; 29: 41-48.
35. Tsunoda S, Takeshima T, Sakaki T, Morimoto T, Hoshida T, Watabe Y, Goda K. Secretory meningioma with elevated serum carcinoembryonic antigen level. Surg Neurol 1992; 37: 415-418.
36. Tsuzuki N, Nakau H, Sugaya M, Hashizume K, Matsukuma S, Wada R, Kuwabara N. Secretory meningioma with severe perifocal edema - case report. Neurol Med Chir (Tokyo) 1997; 37: 620-623.
37. Vakili ST, Muller J. Intracytoplasmic lumina in meningioma: an ultrastructural and immunohistological study. Neurosurgery 1988; 23: 180-184.
38. Wang DJ, Xie Q, Gong Y, Wang Y, Cheng HX, Mao Y, Zhong P, Huang FP, Zheng K, Wang YF, Bao WM, Yang BJ, Chen H, Xie LQ, Zheng MZ, Tang HL, Zhu HD, Chen XC, Zhou LF. Secretory meningiomas: clinical, radiological and pathological findings in 70 consecutive cases at one institution. Int J Clin Exp Pathol 2013; 6: 358-374.
39. Yamada H, Hanada T, Okuda S, Yokota A, Haratake J. Secretory meningioma with lipomatous component: case report. Brain Tumor Pathol 1999; 16: 77-80.
40. Zielinski G, Grala B, Koziarski A, Kozlowski W. Skull base secretory meningioma. Value of histological and immunohistochemical findings for peritumoral brain edema formation. Neuro Endocrinol Lett 2013; 34: 111-117.