

Strategic infarcts of the thalamus in vascular dementia

Imre Szirmai*, Ildikó Vastagh, Éva Szombathelyi, Anita Kamondi

Department of Neurology, Faculty of Medicine, Semmelweis University, Balassa u. 6., 1083 Budapest, Hungary

Abstract

Strategic infarcts or focal hemorrhages involving the paramedian nuclei of the thalamus may alter consciousness and produce complex neuropsychological symptoms such as impairment of memory, attention and motivation. Lesions disrupting the thalamo-prefrontal circuits lead to severe subcortical dementia.

We analysed here the clinical, neuropsychological and neuroimaging data of 19 patients with cerebrovascular lesions in the thalamus. In six patients with bilateral paramedian infarcts, and in two with anterior thalamic infarcts, vascular dementia and severe personality changes developed. SPECT findings did not correlate with the neuropsychological symptoms. Transcortical sensory and motor aphasia was observed in four patients with thalamic hemorrhages and infarcts. In these patients SPECT detected hypoperfusion in adjacent cortical areas. Clinical symptoms and outcome of four patients are reported in detail.

The clinico-morphological correlations of the thalamo-cortical circuits are reviewed and the possible causes of multiple cognitive and behavioural consequences of vascular thalamic lesions are discussed.

© 2002 Elsevier Science B.V. All rights reserved.

Keywords: Thalamus; Dementia; Infarct; Subcortical vascular dementia; Aphasia

1. Introduction

On the basis of clinico-pathological correlation strategic infarcts in the mesial temporal (hippocampal) region, caudate and thalamic nuclei, fronto-cingulate and anterior cerebral artery territory and in the angular gyrus are associated with vascular dementia (VaD) [1,2]. In the vast majority of cases, atherosclerotic occlusion or stenosis in the carotid and vertebral system causes subcortical infarcts [3]. Wetterling et al. [4] found 4.6% occurrence of circumscribed thalamic and basal ganglia infarcts in VaD. Thalamic infarcts develop with the highest prevalence in cases of vertebro-basilar ectasia [5] or basilar embolisation [6,7]. Thalamic dementia can be the consequence of well-defined strategic infarcts, which develop in the following four main arterial territories.

The tuberothalamic artery (tta) arises from the posterior communicating artery (pcoa) and supplies the rostral part of the ventral anterior (VA) nucleus, the reticular, the ventromedial (VM) nuclei, the anterior part of the ventro-lateral (VL), and the rostro-ventral part of the dorso-medial (DM)

nuclei. The mamillothalamic tract and the lateral aspect of the thalamic pole are also supplied by the tta. Ischemia of the tta territory causes anterolateral thalamic infarct. Clinical consequences of the left-sided lesions are the following: emotional facial paresis, deficits in language, temporal and spatial orientation, intellect, visual perception, visual and verbal memory and constructional apraxia [8]. Right-sided lesions cause disturbance in nonverbal intellect, visuo-perceptual, and constructional tasks and visual memory.

The paramedian (thalamoperforate) artery originates from the basilar communicating artery, and consists of anterior (thalamic) and posterior (mesencephalic) subdivisions. The thalamic branch supplies the ventral part of the DM, the intralaminar (IL) and parafascicular nuclei and the centrum medianum (CM) [9]. The mesencephalic part supplies the pretectal and rostromedial tegmentum [10]. The configuration of the vessels is variable. In type I. the arteries arise bilaterally. In type II. arteries arise unilaterally from a segment called basilar communicating artery and supply the right and left paramedian structures, or they form a common trunk which bifurcates at the thalamic level. Bilateral infarcts may develop when this common trunk occludes. Insufficient circulation in the single interpeduncular profunda artery causes vertical gaze paresis due to the damage of the rostral interstitial nuclei of the medial

* Corresponding author. Tel./fax: +36-1-210-0337.

E-mail address: szirmai@neur.sote.hu (I. Szirmai).

longitudinal fascicle. In the mesencephalon the fibers and nucleus of oculomotor nerve are affected in 70% of paramedian infarcts [11]. Simultaneously, lesions involving the DM-, CM-, ventro-oral, dorso-oral nuclei and the tract of Meynert may cause memory and behavioural disturbances. Paramedian infarcts in the acute stage usually cause unconsciousness [6,12], disturb the sleep regulation manifesting in hypersomnia or daylight sleepiness, and later complex neuro-psychological symptoms develop such as severe impairment of attention and motivation, anterograde and retrograde amnesia [13,14]. In case of unilateral left sided infarct inattention and mental slowness could be observed. Most of the patients with bilateral infarcts involving the paramedian nuclei or with an extension into the subthalamic and DM nuclei suffer profound personality changes [15].

The thalamogeniculate artery originates from the posterior cerebral artery (pca). It supplies partially the medial geniculate body, the ventral posterior (VP), lateral, medial and inferior subnuclei, the ventro-lateral posterior (VLp) nucleus, and partially the pulvinar. Ischemia in this territory

causes the classical Dejerine–Roussy syndrome (transient hemiparesis, hemihypesthesia, astereognosis, hemiataxia); in some cases, choreoathetosis, dystonia, or thalamic pain develops.

The posterior chorioideal artery (pcha) originates from the P2 segment of pca. It supplies the posterior and lateral part of the medial and lateral geniculate bodies, the dorsal part of the anterior thalamic nuclei, the dorso-lateral group, dorsal part of DM, the VLp, and most of the pulvinar. Occlusion of the pcha is rare [16].

2. Materials and methods

We included 21 patients in our study, who had vascular thalamic lesions. Clinical and topographical data were retrospectively analysed (see Tables 1 and 2). Topography and extension of vascular lesions were estimated by the help of CT and MRI. Four patients suffered left thalamic haemorrhage, one had occlusion of the internal cerebral veins,

Table 1
Summary of clinical data of patients with bilateral thalamus lesion

Name/age/gender	Site of lesion	SPECT hypoperfusion	Neurological signs	Dementia/psychological symptoms
(1) MZ/47/male	bilateral paramedian, tectal and peduncular infarcts	bilateral frontal	vertical gaze palsy, Horner-syndrome on the right, somnolence	MMSE 39/100; apathetic, irresponsible, profane, impaired verbal and visual memory paranoid and erotic thoughts
(2) PP/72/female	bilateral paramedian infarcts, leukoaraiosis	moderate right temporal	dyscalculia	MMSE 46/100; concretism, short term memory deficit, slowness, disorientation
(3) EGy/76/male	bilateral paramedian thalamus infarcts	right frontal	drowsiness, paresis of the left arm, ptosis on the left, skew deviation, dysarthria	MMSE 73/100; loss of abstraction, visuospatial and remote memory deficits
(4) KS/66/female	bilateral anterior thalamic and right caudatum, frontal leukoaraiosis	no SPECT	primitive reflexes, slight paresis on the right, decreased speech initiation	MMSE 34/100; moria, confabulation, severe disorientation, impaired short term memory
(5) TF/72/male	bilateral paramedian thalamus, multiplex lacunae	bilateral fronto-parietal	apathetic, unconcerned, impaired verbal and visual memory	MMSE 80/100; progressive severe dementia, logorrhoea, euphoria, perseveration, emotional outbursts, irritability, pathological self-estimation
(6) GHA/38/female	bilateral thalamic infarction due to thrombosis of the internal cerebral veins	right basal ganglia, temporal	drowsiness, vomiting, left arm dysmetria	no dementia, disinhibition, irritability, antisocial behaviour
(7) SZJ/73/male	ischemic foci within several thalamus nuclei, and in the mesencephalon and the fronto-central white matter	no SPECT	dysarthric slow speech, exaggerated deep reflexes on the right arm, akinesia, diplopia, upward gaze and adduction of the left bulb impaired primitive reflexes	MMSE 69/100; dysthymia, fatigability, depression (Beck-scale 23 points), verbal memory test 64%, slow mental activity, disorientation
(8) KP/77/male	bilateral paramedian thalamus with right dominance, multiplex lacinae bilaterally in the white matter, hydrocephalus	no SPECT	left Horner syndrome, bilateral vertical gaze palsy, dysarthry, left supranuclear facial palsy	MMSE 69/100; short term memory disturbance, decreased semantic and category specific verbal fluency, concretism
(9) JB/70/female	bilateral paramedian thalamus	no SPECT	somnolence, incontinence, primitive reflexes	MMSE 51/100; slow mental processing, concretism, impaired verbal and visual memory

Table 2
Summary of clinical data of patients with unilateral thalamus lesion

Name/age/gender	Site of lesion	SPECT hypoperfusion	Neurological signs/aphasia profile	Dementia/psychological symptoms
(1) JJ/54/female	left 2.5 × 2.5 cm thalamic bleeding	left fronto-temporal, thalamic and striatal	right hemiparesis, transcortical motor aphasia, dysarthria	expressive inertia
(2) KJ/59/male	left striato-capsular and thalamic bleeding	thalamic and deep temporal	global aphasia (mutism?)	impaired motivation, disorientation
(3) RL/65/female	left anterior thalamic and putamen	left basal ganglia and right cerebellum	nonfluent transient aphasia, disturbed repetition and comprehension, good naming	MMSE 74/100; euphoria, temporal disorientation, confabulation, inattention
(4) KJ/46/female	giant aneurysm on the left ICA—after surgical occlusion left anterior thalamic infarct	no SPECT	amaurosis on the left, transcortical sensory aphasia, perseveration	disturbed episodic memory of self, emotional lability
(5) SzL/75/male	left 2 × 2 cm posterior thalamic and capsular bleeding	fronto-temporal, insular and thalamic	transcortical sensory aphasia, good comprehension, dysarthria	apathy, slow mental processing, disorientation
(6) ÓGy/52/male	left dorsolateral (LP, CM, VP)infarct	left temporal and insular and crossed cerebellar	transient transcortical motor aphasia	DI: 14%, disturbed memory, apathy, disorientation, expressive inertia
(7) KA/63/female	left posterior thalamus and mesencephalon	normal	right hemiplegia, somnolent left ptosis, akinesis	akinetic mutism
(8) CsB/68/female	left paramedian thalamus and mesencephalon infarct	left fronto-temporal	skew deviation, vertical gaze palsy, right hemiparesis, speech disturbance	MMSE 66/100; verbal memory deficit, dysthymia, indifference, impaired visual orientation
(9) TI/63/male	right paramedian, and occipital border zone infarcts paramedian multiplex lacunae	right medial cerebral artery and posterior cerebral artery territory	dysarthric speech, vertical gaze palsy slight paresis of the left arm	MMSE 83/100; impaired memory, and spatial orientation
(10) UF/55/female	left thalamic bleeding	left cortical and basal ganglia	unconsciousness, right hemiparesis, skew deviation	spatial and temporal disorientation, disinhibition
(11) TA/64/male	left paramedian mesencephalon, thalamus, and cerebellum infarct	left temporal and thalamic	aphonia, skew deviation, right hemiparesis, right hemianopia, aware diplopia	post stroke depression, slow mental processing, verbal deficit
(12) OJ/45/male	right paramedian infarct	no SPECT		DI: 15%, slow mental processing, euthymia

and in 16 patients ischemic infarcts damaged the thalamus. Bilateral infarcts were found in 9, unilateral in 12 patients. In 2 out of 12 patients with unilateral infarcts the lesion was localised on the right side.

Fifteen patients were investigated by SPECT within the first week after stroke. Localisation and extension of cerebrovascular lesions and site of hypoperfusion were compared.

We used the Hungarian adaptation of the Mini Mental State Examination (MMSE, 80–100 points normal, 60–79 mild dementia, below 60 points severe dementia), the Benton Visual Retention Test (BVRT), the Rivermead Behavioural Memory Test (RBMT), the Hungarian adaptation of Wechsler Adult Intelligence Scale (WAIS). The dementia index (DI) was calculated based on the WAIS subtests. Patients were considered demented if DI was higher than 15%. Aphasia was investigated with the Hungarian adaptation of Western Aphasia Battery. In those cases where DI or MMSE data are not reported, aphasia or expressive inertia interfered with the examination.

The follow-up time varied from 2 months to 5 years. One patient remained akinetic and died within 3 months.

3. Case reports

3.1. Case 1

This 47 year old middle school history teacher developed mental confusion during classroom lecture. One day later he vomited several times and became drowsy for one week. Ten days later neurologist observed vertical gaze palsy, Horner syndrome on the right and somnolence. There was no motor or sensory impairment. Psychological examination revealed severe disorientation, inconsistency, explicit memory deficit and learning inability. MRI showed bilateral thalamic infarcts involving the DM-, IL-, CM-nuclei, and partially the left pulvinar (Fig. 1). Small ischemic foci were visualised in the left peduncle, within the periaqueductal grey and the mesencephalic tegmentum, and in the lower

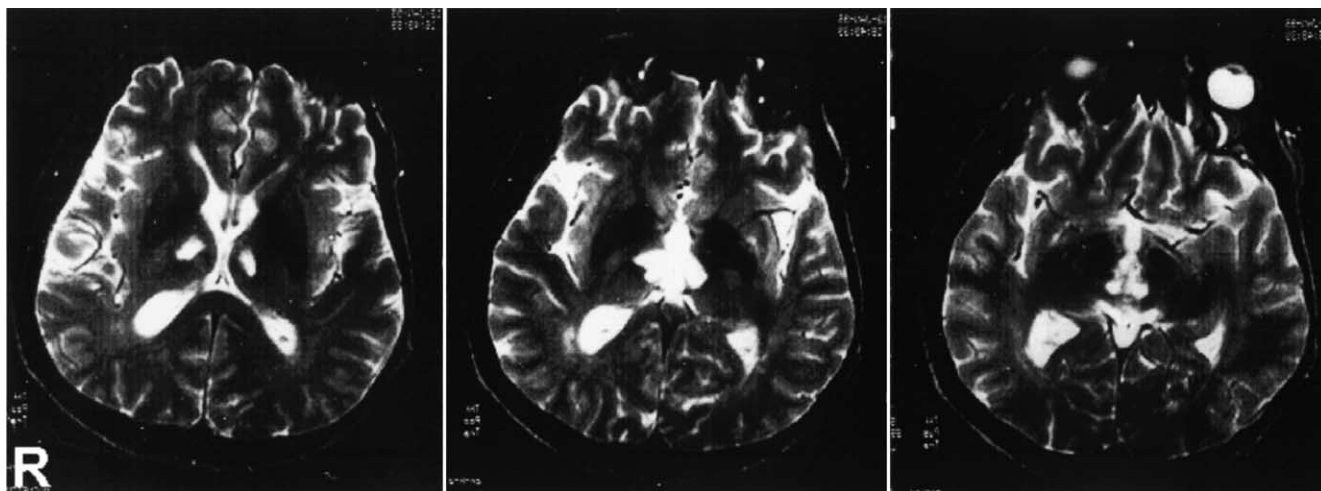


Fig. 1. T2 weighted MRI picture of Patient MZ.

aspect of the left cerebellar hemisphere. No evidence of vascular pathology including source of emboli was found by Doppler investigation. Intermittent theta-delta activity with rostral predominance was recorded during the first month on the EEG. Severe anterograde amnesia and hypersomnia of the patient persisted for 3 months after onset. SPECT showed hypoperfusion bilaterally in the thalamus with left dominance and minimal perfusion deficit in the frontal and temporo-parietal region. Modified MMSE indicated dementia (39/100) which improved gradually within 2 months to 55/100 and 64/100. WMS and BVRT indicated that verbal memory impairment was more severe than the visual. Verbal activity was poor. The patient answered only with single words when he was urged to speak. His dementia fitted the classical description of bilateral paramedian infarcts: indifference, passivity, and dullness. One year after the insult his episodic memory was severely affected but he could retrieve historical events. Irritability, aggression and disinhibited behaviour developed 3–4 years after the insult.

3.2. Case 2

This 72-year-old physicist had severe hypertension for years, and was treated medically. Relatives reported the change of his mood and behaviour some months earlier. He felt himself forgetful and drowsy. Neurological investigation did not reveal focal deficit. Psychologist found the patient to be apathetic and unconcerned. The Raven logical matrix was 77% corrected for his age; constructive visual memory test gave 66%. Retrograde verbal memory test was 70% on the day, and 44% on the second day of investigation. During verbal test, logorrhoea and perseveration was also observed. Later euphoria and lack of insight, emotional outbursts, irritability and pathologic self-estimation developed. The MRI visualised bilateral symmetric thalamic infarcts within the intralaminar and MD nuclei; additionally, multiple small lacunae were found within the basal ganglia and pons.

3.3. Case 3

A 72-year-old man had a 20-year history of hypertension and cardiac arrhythmia. Two years earlier he had gait imbalance and dizziness. Easy fatigability, slow speech, and impaired motivation had been observed by the family. Neurological findings included expressionless face, dysarthric speech, no paresis, exaggerated deep reflexes on the right arm, and loss of synkinetic movements of the arms when walking. Psychic life was characterised by dysthymia, slowness, and depression (Beck-scale: 23 points). BVRT was 90%, verbal memory test (paired association) was 80%. Three years later a new admission was necessary because of diplopia. The right eye was placed slightly laterally when looking straightforward. Upward gaze and adduction of the left eye was impaired. The pupils reacted to intention of convergence. There was no paresis. The patient was disoriented in time; sucking and grasping reflexes were observed. MMSE was 69%, Benton test 70%. Verbal memory test result decreased to 64%. His mental activity was slow. MRI found multiple ischemic foci within the thalamus bilaterally in several nuclei, some lacunae in the mesencephalon and in the border zone of the fronto-central white matter.

3.4. Case 4

A 64-year-old man developed sudden right hemiparesis and diplopia. Neurological examination found skew deviation (the left eye was adducted and placed downward). The left pupil was widened, and there was ptosis on the same side. The patient had severe hemiparesis, homonymous hemianopia, and supranuclear facial palsy on the right. His speech was dysarthric; later aphonia and dysphagia developed. One month later, severe depression, slow mental activity, and impaired motivation developed. MRI showed left paramedian mesencephalic and thalamus infarcts, and ischemic foci in the left cerebellum as well. SPECT local-

ised left temporal and thalamic hypoperfusion. Doppler ultrasound showed no flow in the left vertebral artery.

4. Results

4.1. Correlation between localisation of infarcts and clinical symptoms

Severe dementia with verbal and visual memory impairment and deficit in retrieving explicit memory contents was observed in 7/9 patients (78%) who suffered bilateral symmetric paramedian infarcts. Moderate dementia was found in two patients (RL/65, KJ/46) with left tuberothalamic infarct and in one patient (OJ/45) with right paramedian infarct. Neuropsychiatric symptoms such as slow mental processing, irritability, disorientation, or apathy were associated with speech disturbance or amnesia. Transient amnesia and spatial and temporal disorientation were observed in cases with anterior thalamic, mesial thalamic, and bilateral paramedian lesions in the acute stage. Lesions of the dominant anterior nuclei of the thalamus caused impaired attention in one patient (RL/65). In 9 out of 21 patients (43%) vertical gaze palsy and/or skew deviation and/or diplopia developed. This can be explained by the insufficient circulation in the mesencephalic branch of the thalamoperforate artery, which supplies the pretectal area and rostromedial tegmentum. In two patients (EGY/76, MZ/47) with bilateral thalamic infarcts and in one (TA/64) with left unilateral thalamic and mesencephalic (peduncular) infarcts, the localisation of the lesion could be explained by a variant unilateral trunk of pedunculothalamic artery.

4.2. Thalamic aphasia

It has previously been reported that 25% of patients with subcortical cerebrovascular lesion develop an aphasia syndrome [17]. We observed transcortical sensory aphasia in two patients (SZL/75, KJ/76) with capsular and thalamic bleeding. Two patients (OGY/52, JJ/54) with lesion of the medial and dorso-lateral part of the thalamus presented with transcortical motor aphasia. In one patient (KJ/59) thalamic bleeding extended to the striato-capsular territory causing global aphasia (mutism) (Table 3). In two patients (JJ/54, OGY/52) with subcortical aphasia, the signs of expressive inertia were observed. Patient RL (Table 2) who suffered anterior thalamus and lenticular infarcts had nonfluent

aphasia, and 2 weeks later became euphoric, disoriented, and confabulant. In one patient (KJ/46) with transcortical sensory aphasia, disturbances of episodic memory and emotional lability were observed after surgical occlusion of the left internal carotid artery because of a supraclinoid giant aneurysm. CT-scan showed left anterior thalamus infarct, suggesting ischemia within the anterior chorioid or tuberothalamic artery territory.

4.3. SPECT findings

Bleeding in the thalamus caused hypoperfusion in the adjacent ipsilateral fronto-temporal, deep temporal and insular cortex. In those five patients with bilateral paramedian thalamic infarcts who had SPECT, we found no characteristic cortical hypoperfusion area. In three patients hypoperfusion was localised in the right frontal and temporal lobe; in two patients it was found bilaterally in the frontal or fronto-parietal area. Anterior thalamic infarcts were associated with left fronto-temporal hypoperfusion.

5. Discussion

VaD in most of the cases is the consequence of multifocal vascular disease caused by atherosclerosis damaging the border zones of the brain, Binswanger's disease with multiple lacunae and degeneration of the white matter [18], or venous collagenosis [19]. The psychological symptoms of VaD appear as a composite of various particular syndromes which can be derived from the localization of focal or multifocal lesions. In VaD the following structures are frequently affected: caudate nucleus, globus pallidus, paramedian and anterior nuclei of the thalamus and connecting fibers of the frontal-subcortical circuits [1]. Analysing vascular and nonvascular demented groups, Esiri [20] concluded that microvascular deep white-and grey-matter lesions, but not macroscopic infarcts, were significant in vascular dementia. Selective inattention or executive disorder in VaD caused by strategic infarcts in the paramedian thalamic structures appears similar to the symptoms of patients with frontal damage. The cognitive and psychological alterations were suggested to be the consequences of the disconnection of executive frontal circuits. The symptoms were called "circuit specific behaviour," including lethargy, apathy, frontal behaviour, and memory loss [21].

Focal damage of the left MD generally causes anterograde amnesia. Remote memory loss develops if lesions extend into the proximal corresponding regions or systems [22]. The amnesia caused by thalamic infarcts appears mainly as learning deficit, rather than impaired retrieval. Ischemia in the nutritive territory of the tuberothalamic artery (anterior nuclei) with involvement of the mamillothalamic tract proved to be critical for learning and short time memory. Apathy and "abulia" is a frequent observation in cases with lesion of the anterior thalamic peduncle [23].

Table 3
Aphasia profiles according to the localisation of lesions

Localisation of lesion	Type of aphasia	Number of patients	Bleeding (b), infarct (i)
Thalamus	Transcortical motor	2	i, b
	Transcortical sensory	2	i, b
Striatum and thalamus	Global	1	b

Among the symptoms of subcortical infarcts, depression obtained special interest. This includes the slowness of mental labor, insufficiency of working memory, and attentive deficit [24].

Bilateral paramedian infarcts cause difficulty in acquiring new semantic information. Furthermore, autobiographical knowledge should be more severely affected than the knowledge of famous people and historical events. It is remarkable that in many patients from our group the cognitive decline is slowly progressing, caused presumably by Wallerian degeneration of the thalamo-cortical white matter, especially the inferior thalamic peduncle or the ansa peduncularis. Patients with subcortical dementia (most of the VaDs can be categorised like this) suffer impairment of working memory. In our patients, left-sided or bilateral thalamic infarcts reduced the speed of mental work and were associated with attention-, concentration-, verbal-, and visual memory deficit. These symptoms may be evoked by multiinfarct state as well [25].

Interruption of the limbic (cingular) connections in cases of anterior thalamic infarcts may explain the emotional reactions and prosopafactive agnosia as published by Vuilleumier et al. [26]. Clinical observation shows that the associating anxiety, depression, and severity of other neuropsychiatric symptoms in VaD are determined by the extent of white matter ischemia [27].

Paramedian lesions of the thalamus may cause naming defects and/or perseveration, but not cortical type aphasia [22]. Since the MD nucleus is connected both with Broca's and Wernicke's areas, its lesion may be responsible for different language problems. We experienced that semantic errors and verbal deficits were common if thalamic lesions were associated with striato-capsular infarcts. Mechanism of subcortical aphasia cannot be answered definitely. Unsolved question is, whether the dissolution of cortico-subcortical connections manifesting in metabolic derangement of the adjacent cortical regions, or the destruction of the underlying key structures causes the symptoms [23]. The associating memory, cognitive, and behavioural phenomena in cases with subcortical lesions indicate a complex vulnerability of the language system. Symptoms of "subcortical" speech disorder regularly associate with slowness of mental labor, insufficient working memory, and severe attentive deficit.

In eight patients of our cohort, imaging found lacunae additionally in brain area(s) outside the thalamus. In 5 out of 19 patients we found clinical and morphological evidences of the development of paramedian thalamopeduncular infarcts with involvement of the mesencephalic tegmentum. Consonantly with the classical observation of Castaigne et al. [11] and Kumral et al. [16], behavioral consequences of bilateral paramedian infarcts can exclusively be characterised among thalamic syndromes: "...loss of consciousness or somnolence at stroke onset, followed by concentration, orientation deficit and memory dysfunctions." Variability of the cognitive and behavioural consequences of other thala-

mic infarcts makes the relation between localisation and symptoms sometimes inconclusive. This can partially be explained by the overlapping nutritive arterial territories and the complexity of the corticothalamic circuitry.

The diagnosis of VaD is based mainly on clinical findings, which usually correlated with the results of neuroimaging. In many patients with strategic infarcts of the thalamus, there is no evidence of previous vascular events. Similarly, the correlation between multiple TIA and the presence of focal neurological symptoms proved to be statistically nonsignificant [4]. The NINCDS-ADRDA criteria with the modified Hachinski Ischemic Score lead to 80% diagnostic accuracy of dementia [28]. Using various classification criteria, high specificity and low sensitivity was found in NINDS-AIREN and the mixed pathology of dementias was 33.8% [29].

Acknowledgements

We are very grateful to M. Csüri for her invaluable assistance in the aphasia tests.

References

- [1] Cummings JL. Vascular subcortical dementias: clinical aspects. *Dementia* 1994;5:177–80.
- [2] Vinters HV, Ellis WG, Zarow C, Zaias BW, Jagust WJ, Mack WJ, et al. Neuropathologic substrates of ischemic vascular dementia. *J Neuropathol Exp Neurol* 2000;59:931–45.
- [3] Gandolfo C, Del Sette M, Finocchi C, Calautti C, Loeb C. Internal borderzone infarction in patients with ischemic stroke. *Cerebrovasc Dis* 1998;8:255–8.
- [4] Wetterling T, Kanitz RD, Borgis KJ. Comparison of different diagnostic criteria for vascular dementia (ADDTC, DSM-IV, ICD-10, NINDS-AIREN). *Stroke* 1996;27:30–6.
- [5] Passero S, Filosomi G. Posterior circulation infarcts in patients with vertebralbasilar dolichoectasia. *Arch Neurol* 1995;52:773–80.
- [6] Szirmai I, Guseo A, Molnár M. Bilateral symmetrical softening of the thalamus. *J Neurol* 1977;217:57–65.
- [7] Schwarz S, Egelhof T, Schwab S, Hacke W. Basilar artery embolism. Clinical syndrome and neuroradiologic patterns in patients without permanent occlusion of the basilar artery. *Neurology* 1997;49:1346–52.
- [8] Lisovoski F, Koskas P, Dubart T, Dessarts I, Dehen H, Cambier J. Left tuberothalamic artery territory infarction: neuropsychological and MRI features. *Eur Neurol* 1993;33:181–4.
- [9] Bogousslavsky J, Regli F, Uske A. Thalamic infarcts: clinical syndromes, etiology and prognosis. *Neurology* 1988;38:837–48.
- [10] Macchi G. Thalamic functions as interpreted from human lesions. In: Steriade M, Jones EG, McCormick DA, editors. *Thalamus*. Amsterdam: Elsevier; 1997. p. 546.
- [11] Castaigne P, Lhermitte F, Buge A, Escourolle R, Hauw JJ, Lyon-Caen D. Paramedian thalamic and midbrain infarcts: clinical and neuropathological study. *Ann Neurol* 1981;10:127–48.
- [12] Frey HR. Das bilaterale paramediane Thalamusinfarktsyndrom. Eine Differenzialdiagnose bei Störungen der Vigilanz und Kognition. *Schweiz Med Wochenschr* 1995;125:1294–8.
- [13] Hodges JR, McCarthy RA. Autobiographical amnesia resulting from bilateral paramedian thalamic infarction. A case study in cognitive neurobiology. *Brain* 1993;116:921–40.

- [14] Kalashnikova LA, Gulevskaya TS, Kashina EM. Disorders of higher mental function due to single infarctions in the thalamus and in the area of the thalamofrontal tracts. *Neurosci Behav Physiol* 1999;29: 397–403.
- [15] Gaff-Radford NR, Damasio H, Yamada T, Eslinger PJ, Damasio R. Nonhamorrhagic thalamic infarction. *Brain* 1985;108:485–516.
- [16] Kumral E, Evyapan D, Balkir K, Kutluhan S. Bilateral thalamic infarction. Clinical etiological and MRI correlates. *Acta Neurol Scand* 2001;103:35–42.
- [17] Szirmai I, Vadasdi K, Csüri M, Dabasi G, Kamondi A. Neurobehavioral symptoms in aphasic patients with subcortical vascular lesions. In: Szirmai I, Ertsey Cs, Arányi Zs, editors. *Proceedings of the Hungarian Society of Neurologists and Psychiatrists*. Budapest: T-MART Press; 2000. p. 78–85.
- [18] Caplan LR, Schoene WC. Clinical features of subcortical arteriosclerotic encephalopathy (Binswanger disease). *Neurology* 1978;28: 1206–15.
- [19] Moody DM, Brown WR, Challa VR, Anderson RL. Periventricular venous collagenosis. Association with leukoaraiosis. *Radiology* 1995; 194:469–76.
- [20] Esiri MM. Which vascular lesions are of importance in vascular dementia? *Ann NY Acad Sci* 2000;903:239–43.
- [21] Cummings JL. Frontal subcortical circuits and human behavior. *Arch Neurol* 1993;50:873–80.
- [22] Stuss DT, Guberman A, Nelson R, Larochelle S. The neuropsychology of paramedian thalamic infarction. *Brain Cogn* 1988;8:348–78.
- [23] Bhatia KP, Marsden CD. The behavioural and motor consequences of focal lesions of the basal ganglia in man. *Brain* 1994;117:859–76.
- [24] Robin DA, Schienberg S. Subcortical lesions and aphasia. *J Speech Hear Disord* 1990;55:90–100.
- [25] Tatemichi TK, Desmond DW, Prohovnik I, Cross DT, Groppen TI, Mohr JP, et al. Confusion and memory loss from capsular genu infarction: a thalamocortical disconnection syndrome? *Neurology* 1992;42: 1966–79.
- [26] Vuilleumier P, Ghika-Schmid F, Bogousslavsky J, Assal G, Regli F. Persistent recurrence of hypomania and prosopoaffective agnosia in a patient with right thalamic infarct. *Neuropsychiatry Neuropsychol Behav Neurol* 1998;11:40–4.
- [27] Sultzer DL, Mahler ME, Cummings JL, Van-Gorp WG, Hinkin CH, Brown C. Cortical abnormalities associated with subcortical lesions in vascular dementia. Clinical and positron emission tomographic findings. *Arch Neurol* 1995;52:773–80.
- [28] Loeb C, Meyer JS. Criteria for diagnosis of vascular dementia. *Arch Neurol* 2000;57:1382–3.
- [29] Holmes C, Cairns N, Lantos P, Mann A. Validity of current clinical criteria for Alzheimer's disease, vascular dementia and dementia with Lewy bodies. *Br J Psychiatry* 1999;174:45–50.