

# Clinical study on cognitive dysfunction after spontaneous subarachnoid haemorrhage: patient profiles and relationship to cholinergic dysfunction

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## Abstract

**Purpose** We aimed to explore the cognitive profiles of subarachnoid haemorrhage patients who returned to the community, along with the associated risk factors.

**Methods** We recruited 40 Chinese patients with spontaneous subarachnoid haemorrhage 7–27 months after the initial presentation. They had all been discharged to their homes or to care homes for the elderly. For cognitive assessment, we employed the Cognitive Subscale of the Alzheimer Disease Assessment Scale (ADAS-cog) for global cognitive function,

the Frontal Assessment Battery (FAB) for frontal lobe function, and the Rivermead Behavioural Memory Test (RBMT) for everyday memory function.

**Results** An ADAS-cog of more than 21/85 (poor global cognitive function) was noted in 14 (35%) patients. A FAB of less than 12/18 (poor frontal lobe function) was noted in 13 (27.5%) patients. An RBMT score of less than 15/26 (poor everyday memory function) was noted in 17 (43.6%) patients. Poor cognitive function was found to be associated with chronic hydrocephalus (in terms of FAB), with clinical vasospasm (in terms of RBMT), and with cerebral infarction (in terms of RBMT).

**Conclusions** Poor cognitive function was common and occurred in up to 43.6% of the patients, with the verbal and behavioural memory aspects predominantly affected. We did not find a significant association between cholinergic dysfunction and cognitive dysfunction. Organization of future drug trials and cognitive rehabilitation should take into account the association between frontal lobe dysfunction and chronic hydrocephalus.

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## Introduction

Despite advances in intensive care and vascular neurosurgery, up to 60% of survivors of aneurysmal subarachnoid haemorrhage, including patients discharged back to the community, still suffer from different degrees of disability, of which a large proportion is related to cognitive dysfunction [9]. Data exist in the literature on cognitive outcomes (especially in the case of ruptured anterior communicating artery aneurysms), but these studies are

mainly descriptive and concerned either with comparison of microsurgical clipping and endovascular embolization or time course [1, 2, 6–9, 12, 14, 19, 25]. Data that relate the anatomical domains of cognitive deficits to clinical factors, such as the sites of aneurysms, have not been previously analysed. There was a previous report, employing the Mini Mental State Examination, of cholinergic dysfunction (with pupillometry) associated with cognitive dysfunction following aneurysmal subarachnoid haemorrhages [23]. Results suggested an association and presented the possibility for drug treatment. However, the necessary detailed cognitive assessment was lacking. Rivastigmine might also have beneficial effects in patients with traumatic brain injury and moderate to severe cognitive memory deficits [21]. We aimed to delineate firstly the cognitive anatomical profile (in terms of global cognition, frontal lobe function, and everyday memory function) of Chinese patients who had returned to the community following aneurysmal subarachnoid haemorrhage, and secondly the associated clinical factors and possible cholinergic dysfunctions.

## Subjects and methods

Approval was obtained from the local ethics committee for recruiting patients into the current study. Treatment strategy of aneurysmal subarachnoid haemorrhage in our institution was described previously [27]. We did not administer hypothermic treatment for aneurysmal subarachnoid haemorrhage in our institute. All patients were put on sodium valproate as anticonvulsant prophylaxis unless contraindicated, to cover for 2 weeks for embolization cases and to cover for 3–6 months for clipping cases. Criteria for inclusion in the study included: (1) a history of spontaneous subarachnoid haemorrhage; (2) the initial ictus was at least 6 months apart from the assessment, ranging from 7 to 27 months after ictus; (3) the patient was aged between 18 and 80 years; (4) the patient would be cooperative for the cognitive assessment; (5) the patient had been discharged to his or her home or a care home for the elderly with a neurological status of good recovery, moderate disability, or severe disability. Patients with a known history of other neurological disease, such as dementia, or known cognitive impairment before subarachnoid haemorrhage were excluded. Eligible patients or their next of kin were approached by one of the investigators for their consent to participate in the study. The study conformed to the declaration of Helsinki. Demographic data, clinical data, and outcome measures, as GOSE (Glasgow Outcome Scale Extended), were recorded.

Cognitive assessment was performed to delineate patterns of cognitive function with the Cognitive Subscale of Alzheimer Disease Assessment Scale (ADAS-cog) for

global function, the Frontal Assessment Battery (FAB) for frontal lobe function, and the Rivermead Behavioural Memory Test (RBMT) for everyday memory function [3–5, 10, 15, 17, 18, 26]. In addition, ADAS-cog is an established measure for dementia patients and allows comparisons with dementia patients of other etiologies. There were three main domains in the ADAS-cog, which include memory (word recall, word recognition task, remembering test instruction on word recognition, and orientation), language (naming objects and fingers, commands, receptive language, word-finding difficulty, and comprehension of spoken language) and praxis (constructional praxis and ideational praxis). The FAB consisted of six subtests exploring different functions related to the frontal lobes, and included conceptualization and abstract reasoning (similarity test), mental flexibility (verbal fluency test), motor programming and executive control of action (Luria motor sequence), resistance to interference (conflicting instructions), inhibitory control (go-no go test), and environmental autonomy (prehension behaviour). The RBMT was developed to assess the real-life memory capacities (including verbal and visual aspects) of individuals who had sustained brain damage. It included 12 subtests as analogues to everyday memory situations. The Chinese versions of ADAS-cog, FAB and RBMT had been previously validated and an ADAS-cog of more than 21/85, a FAB of less than 12/18, and an RBMT of less than 15/26 were taken as the cut-off for poor cognitive performance [4, 15, 17, 26].

The pupillary response to tropicamide was performed according to the methods of Takao et al. [23]. The baseline resting pupil diameter of each eye (R1, right pupil size; L1, left pupil size) was measured by the Pupillometer P2000 SA (Procyon Instruments, UK, 2003), with three illumination levels for each measurement (scotopic at 0.03 lux, mesopic low at 0.82 lux, and mesopic high at 6.4 lux) [13]. One drop of 0.01% tropicamide was then applied to the right eye. The left eye served as a control, with one drop of physiological saline solution applied. The pupil diameter of each eye (R2, right pupil size; L2, left pupil size) was measured 30 min later. The pupil diameter data were represented as the dilation ratio of the right eye (R2/R1) and the relative dilation ratio of the right pupil to that of the left pupil (R2/R1 divided by L2/L1, or R2L1/R1L2).

Data analysis was carried out with the aid of SPSS for Windows Version 14.0. Statistical significance was taken to be a two-tailed *p* value of less than 0.05. To compare patients with or without cognitive dysfunction, categorical data were analysed with Pearson's chi-squared test or Fisher's exact test, and interval data were analysed with the unpaired Student's *t*-test. Data were presented in the form of mean  $\pm$  standard deviation (SD) as appropriate. The

strength of the relationships between the cognitive assessment scores was analysed by product-moment correlation coefficient, and the strength of the relationships between the clinical outcome (GOSE) and the scores of cognitive assessment was analysed using Kendall's rank correlation. Comparison of pupil diameter data with poor cognitive function (in terms of the cut-off scores) was analysed using an unpaired Student's *t*-test.

## Results

A total of 74 consecutive Chinese patients with aneurysmal subarachnoid haemorrhage admitted to our unit within 48 h after ictus were prospectively followed-up. Fifty-five patients were at home or at a care home for the elderly at the last follow-up visit. The median duration to the last follow-up visit was 17 months, ranging from 7 to 27 months. Forty (73%) patients consented for cognitive assessment and their data are summarised in Table 1. The mean age (mean  $\pm$  SD) was  $55 \pm 12$  years. The female to male ratio was 2.3:1. The median presentation WFNS (World Federation of Neurological Surgeons) grade was 2, and ranged from 1 to 5. Twenty-one (52.5%) patients were of good grade (WFNS 1–2), and 19 (47.5%) were of poor grade (WFNS 3–5). Twelve (30%) patients had ruptured internal carotid artery aneurysms; 12 (30%) had ruptured anterior communicating artery aneurysms; eight (20%) had ruptured middle cerebral artery aneurysms; and five (12.5%) had ruptured posterior circulation aneurysms. Overall, one-third of the aneurysms were clipped, and two-thirds of the aneurysms were coiled. Complications arising from aneurysm treatment happened in six (15%) patients, which included infection in three patients and neurological deficits (which improved over a period of 1–6 months) in three patients. Nine (22.5%) patients had clinical vasospasm and five (12.5%) patients had vasospasm-induced cerebral infarct. Fourteen (35%) patients had ventriculo-peritoneal shunt inserted for treatment of chronic hydrocephalus.

Forty patients completed the ADAS-cog and FAB. Thirty-nine patients completed the RBMT. An ADAS-cog of more than 21/85 (poor global cognition) was noted in 14 (35%) patients, and the score (mean  $\pm$  SD) was  $20.8 \pm 13.0$ . A FAB of less than 12/18 (poor frontal lobe function) was noted in 13 (27.5%) patients, and the score (mean  $\pm$  SD) was  $13.6 \pm 4.2$ . An RBMT of less than 15/26 (poor everyday memory function) was noted in 17 (43.6%) patients, and the score (mean  $\pm$  SD) was  $13.9 \pm 6.8$ . The median GOSE at the time of assessment was 7. The GOSE was 7–8 (good recovery) in 25 (62.5%) patients, 5–6 (moderate disability) in nine (22.5%) patients, and 3–4 (severe disability) in six (15%) patients. Patients with

moderate or severe disability had poorer cognitive performance in terms of ADAS-cog ( $25.1 \pm 14.2$  vs  $18.2 \pm 11.8$ ,  $p = 0.122$ ), FAB ( $12.2 \pm 4.7$  vs  $14.4$ ,  $p = 0.142$ ), and RBMT ( $11.6 \pm 6.5$  vs  $15.2 \pm 6.7$ ,  $p = 0.110$ ), though not reaching statistical significance.

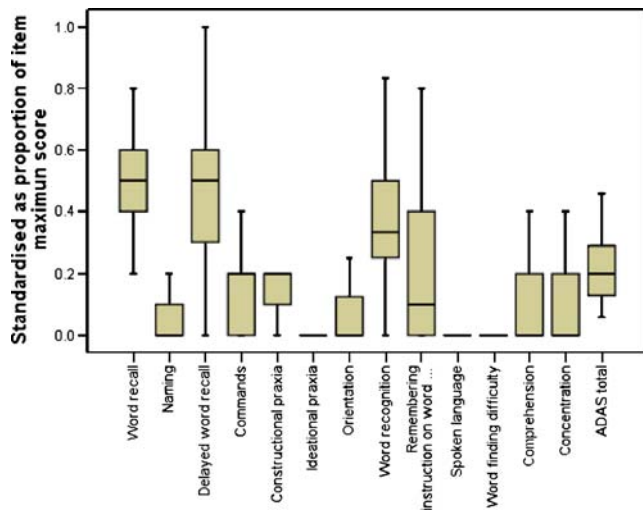
The ADAS-cog in terms of the proportion of item maximum scores is depicted in Fig. 1. Items such as spoken language, ideational praxia, and word-finding difficulty were mostly unaffected, which reflected intact function. The main areas of low performance (in terms of proportion of maximum item score, mean  $\pm$  SD) were word recall ( $48.5 \pm 17.0\%$ ), delayed word recall ( $51.3 \pm 26.0\%$ ), word recognition ( $40.6 \pm 33.3\%$ ), and remembering testing instructions on word recognition tests ( $23.0 \pm 27.0\%$ ). The subtest scores of FAB are depicted in Fig. 2. There was variable involvement in the different subtests, with the lowest mean scores in programming (mean score = 1.85) and inhibitory control (mean score = 1.95). The subtest scores of RBMT are depicted in Fig. 3. With the exception of date orientation, there was uniform low performance over all item scores, with the lowest mean score in appointment recall (mean score = 0.74). ADAS-cog scores were negatively correlated with FAB scores ( $r = -0.85$ ,  $p < 0.001$ ) and RBMT scores ( $r = -0.82$ ,  $p < 0.001$ ), and FAB scores were positively correlated with RBMT scores ( $r = 0.7$ ,  $p < 0.001$ ), implying a strong positive relationship for poor cognitive performance between the three different tests.

The cognitive function scores were not associated with age or WFNS grade on presentation. Location of the aneurysm in the anterior communicating artery, compared with other locations, was not associated with the cognitive function scores listed (FAB:  $14.9 \pm 4.6$  vs  $13.0 \pm 4.4$ ,  $p = 0.154$ ; ADAS-cog:  $18.4 \pm 11.6$  vs  $21.8 \pm 13.6$ ,  $p = 0.434$ ; RBMT:  $16.3 \pm 6.9$  vs  $12.9 \pm 6.6$ ,  $p = 0.164$ ). Chronic hydrocephalus which required ventriculoperitoneal shunt insertion was associated with poor cognitive performance in terms of FAB ( $15.1 \pm 2.5$  vs  $12.7 \pm 4.8$ ,  $p = 0.049$ ) but not ADAS-cog ( $19.4 \pm 6.8$  vs  $21.5 \pm 15.4$ ,  $p = 0.541$ ) or RBMT ( $13.5 \pm 6.3$  vs  $14.1 \pm 7.1$ ,  $p = 0.781$ ). Clipping, compared with coiling, was not associated with poor cognitive performance in terms of FAB ( $14.6 \pm 2.9$  vs  $13.0 \pm 4.7$ ,  $p = 0.201$ ), ADAS-cog ( $16.9 \pm 8.0$  vs  $22.7 \pm 14.6$ ,  $p = 0.112$ ) or RBMT ( $13.2 \pm 6.0$  vs  $14.2 \pm 7.2$ ,  $p = 0.652$ ). In the six patients with complications arising from aneurysm treatment, there were no significant differences in cognitive scores (ADAS-cog:  $15.3 \pm 5.4$  vs  $21.7 \pm 13.8$ ,  $p = 0.272$ ; FAB:  $15.3 \pm 2.7$  vs  $13.2 \pm 4.4$ ,  $p = 0.269$ ; RBMT:  $15.0 \pm 3.2$  vs  $13.7 \pm 7.2$ ,  $p = 0.670$ ).

Nine patients with clinical vasospasm had lower RBMT scores ( $11.0 \pm 7.7$  vs  $14.8 \pm 6.3$ ,  $p = 0.546$ ) though not reaching statistical significance. Five patients with docu-

**Table 1** Clinical profiles of subarachnoid haemorrhage patients recruited (*M* male, *F* female, *ACoM*A anterior communicating artery, *MCA* middle cerebral artery, *WFNS* World Federation of Neurological Surgeons Grading System, *GOSE* Glasgow Outcome Scale Extended)

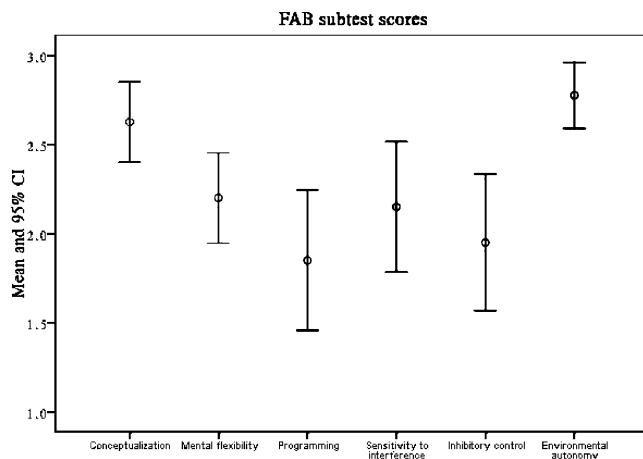
Sex	Age	WFNS	Aneurysm	Treatment	GOSE	Post-operative complication	Clinical vasospasm	Vasospasm-induced infarct	VP shunt
F	61	4	ACoM	Coiling	7	No	Yes	No	Yes
F	52	4	Posterior circulation	Coiling	8	No	No	No	No
F	63	2	ACoM	Coiling	8	No	No	No	No
F	48	4	MCA	Coiling	4	No	No	No	No
F	41	1	No aneurysm	No	6	No	No	No	No
F	66	3	Internal carotid	Coiling	5	No	No	No	No
M	55	3	ACoM	Coiling	7	Infection	No	No	Yes
F	44	3	MCA	Clipping	6	No	No	No	Yes
M	46	2	ACoM	Coiling	8	No	No	No	No
F	61	4	ACoM	Coiling	6	No	No	No	No
F	61	4	Internal carotid	Coiling	8	No	No	No	No
F	63	2	Internal carotid	Clipping	7	No	Yes	No	Yes
F	47	1	Internal carotid	Clipping	7	Dysphasia	Yes	Yes	No
F	51	4	ACoM	Clipping	4	Infection	No	No	Yes
F	51	4	Posterior circulation	Coiling	5	No	No	No	No
M	51	4	ACoM	Clipping	7	No	No	No	Yes
M	76	2	Internal carotid	Coiling	8	No	No	No	No
M	51	5	No aneurysm	No	6	No	Yes	Yes	Yes
F	71	2	Internal carotid	Clipping	7	No	No	No	No
M	47	4	MCA	Coiling	8	No	No	No	No
F	47	1	ACoM	Coiling	7	No	No	No	No
F	70	1	Internal carotid	Coiling	8	No	No	No	No
F	51	4	MCA	Coiling	4	No	Yes	Yes	No
M	51	1	Posterior circulation	Coiling	3	No	No	No	Yes
F	47	2	Internal carotid	Coiling	7	No	No	No	No
F	65	1	ACoM	Clipping	8	No	Yes	No	No
M	48	2	Internal carotid	Coiling	7	No	No	No	No
M	61	5	ACoM	Coiling	5	Deep vein thrombosis	Yes	Yes	Yes
F	63	3	MCA	Clipping	4	Infection	No	No	Yes
F	69	4	MCA	Clipping	7	No	Yes	No	Yes
F	47	1	MCA	Clipping	8	No	No	No	No
F	50	2	ACoM	Coiling	8	No	No	No	No
F	49	2	Posterior circulation	Coiling	8	No	No	No	Yes
F	43	1	MCA	Clipping	7	No	No	No	No
F	74	1	Internal carotid	Coiling	8	No	No	No	No
F	80	5	Internal carotid	Clipping	3	No	No	No	Yes
M	52	2	Posterior circulation	Clipping	6	Ataxia	No	No	No
M	42	1	No aneurysm	No	7	No	No	No	No
M	53	2	Internal carotid	Coiling	7	No	No	No	No
F	19	5	ACoM	Coiling	6	No	Yes	Yes	Yes



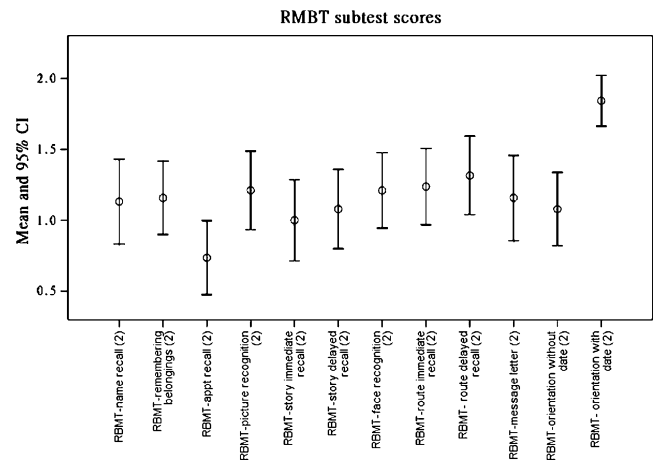
**Fig. 1** Subtest scores of ADAS-cog. Raw scores for each item were expressed as a proportion of its maximum possible score. A higher proportion represents poorer performance

mented cerebral infarction had lower RBMT scores ( $11.8 \pm 7.9$  vs  $14.2 \pm 6.7$ ,  $p = 0.208$ ) and higher ADAS-cog scores ( $23.0 \pm 9.7$  vs  $20.5 \pm 13.5$ ,  $p = 0.808$ ) though again not reaching statistical significance.

Thirty-six patients had pupillometry assessments performed. Using cognitive impairment in terms of RBMT, there was a difference in the mean dilation ratio of the right pupil under scotopic illumination levels (mean  $\pm$  SD:  $1.32 \pm 0.31$  vs  $1.13 \pm 0.12$ ,  $p = 0.019$ ), but not at mesopic low or mesopic high illumination levels. The finding was not confirmed with the relative dilation ratio (mean  $\pm$  SD:  $1.26 \pm 0.32$  vs  $1.17 \pm 0.13$ ,  $p = 0.253$ ). There was no difference in the mean dilation ratio or the relative dilation ratio for cognitive performance on the FAB or the ADAS-cog.



**Fig. 2** Subtest scores of FAB



**Fig. 3** Subtest scores of RBMT

### Discussion

In this study, we documented that poor cognitive performance was a common occurrence (up to 43.6%) following aneurysmal subarachnoid haemorrhage. Memory disturbance was prominent, as noted in the word recall, delayed word recall, memory of testing instructions on word recognition, and word recognition in the ADAS-cog, as well as in the RBMT. The attention subtest scores of the ADAS-cog seemed to be less affected than memory function. The RBMT was a reliable, valid, and sensitive test for everyday memory function, with implications for the activities of daily life. The overall deficits seemed to weight significantly on memory function. Our findings were consistent with those of Vilkki et al. [25] in that focal injury as a result of infarction was associated with worse verbal memory test performance. FAB showed that frontal dysfunction happened to a lesser extent in 27.5% of the discharged patients in the outpatient clinic. The lesser effect on executive function and judgment allowed patients to maintain a certain degree of independence. Nevertheless, they may exhibit frontal lobe dysfunction in the form of programming and inhibitory control problems. Moreover, there was a trend of association between cognitive impairment and the return to work and social activity, and this association restated the importance of cognition in addition to motor deficit in return to work and social activity.

The recovery of cognitive function after surgery for aneurysmal subarachnoid haemorrhage was previously investigated by Samra et al. [20]. In that cohort, cognitive function continued to improve beyond 3 months, with a plateau between 9 and 15 months. All of our patients were beyond 6 months after the ictus of aneurysmal subarachnoid haemorrhage, with most patients recruited beyond 9 months after the initial ictus. Therefore, our results should represent the expected long-term cognitive deficits. In the

clinical setting, the Mini Mental State Examination was a better tool than the Telephone Interview of Cognitive State, as suggested by King et al. [11], to screen for the presence of cognitive impairment for further assessment. In this study, we selected three tests for the analysis of cognitive function. FAB was used to assess frontal lobe function, RBMT was used to assess everyday memory function, and ADAS-cog was used to assess the global cognitive function. From the data of our study, it seemed that memory dysfunctions were more prominent than frontal lobe dysfunction. Cognitive deficits, such as verbal memory and executive function, had been previously reported in patients with ruptured anterior communicating artery aneurysm [2, 7]. In this study, we did not find aneurysm site in the anterior communicating artery to be associated with poorer cognitive performance than other aneurysm locations. We did not find clipping as a significant factor for poor cognitive performance in our study. This is similar to the prospective randomized study by the Kuopio group, which showed that the 1-year neuropsychological outcomes were comparable after early microsurgical and endovascular treatment of ruptured intracranial aneurysm [12]. There existed a possibility that some functions, such as executive functions, might be worse in the clipping group [8]. Other parameters, which were correlated to cognitive dysfunction in the literature, included post-operative neurological events, clinical vasospasm and phenytoin exposure [16, 22, 24]. We use sodium valproate instead of phenytoin for anticonvulsant prophylaxis, and the uniform prescription pattern precluded exposure analysis. Our results suggest that patients required ventriculoperitoneal shunt insertion is at a higher risk for frontal lobe cognitive dysfunction. This may be related to the damaging effect of chronic hydrocephalus, which is not apparent clinically. Organization of future drug trials and cognitive rehabilitation should take into account the above risk factor analysis.

The underlying pathophysiology of cognitive impairment was initially thought to be a combination of diffuse brain injury (from the initial haemorrhage and raised intracranial pressure) and focal injury (infarction or haematoma). Cholinergic innervation of the cerebral cortex came from the nucleus basalis of Meynert, which played a major role in the regulation of memory and attention. The report from Takao et al. [23] suggested that this may also be related to cholinergic dysfunction similar to Alzheimer's disease, in which drug treatment had been shown to be beneficial. The hypothesis was that the basal subarachnoid haemorrhage caused functional damage to the cholinergic neurons in the Edinger-Westphal nucleus of the midbrain concurrently with that in the basal forebrain. Using a more detailed cognitive assessment with the ADAS-cog, the FAB, and the RBMT, we failed to identify a consistent relationship between pupillary cholinergic dysfunction and

cognitive dysfunction in aneurysmal subarachnoid haemorrhage patients. However, it must be noted that it is still possible for forebrain cognitive dysfunction in some of the aneurysmal subarachnoid haemorrhage patients to be related to cholinergic dysfunction, even though no such relationship was revealed in the current analysis.

The strength of the current study was that patients were managed under the same protocol in the same neurosurgical unit. It showed the contemporary management outcome in terms of cognition in the post-ISAT era in Chinese population in Hong Kong. Weakness of the study was the small size of the sample and the absence of a matched control group for cognitive assessment. Nevertheless, we were able to generate useful data, as mentioned above, for future research design.

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#### Comment

The issue of cognitive performance after subarachnoid haemorrhage is important, and the study adds to the information available on the topic. The study has been carefully conducted on a homogeneous group of patients treated in the same centre. The cognitive tests chosen show some ceiling effects, and a matched control group would allow more precise interpretation of the findings. Nonetheless, the study indicates that cognitive impairment is common, and this should serve to stimulate further work on this topic.

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