A proposal of new diagnostic pathway for fatal familial insomnia

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ABSTRACT

Background In absence of a positive family history, the diagnosis of fatal familial insomnia (FFI) might be difficult because of atypical clinical features and low sensitivity of diagnostic tests. FFI patients usually do not fulfill the established classification criteria for Creutzfeldt–Jakob disease (CJD); therefore, a prion disease is not always suspected.

Objective To propose an update of diagnostic pathway for the identification of patients for the analysis of D178–M129 mutation.

Design and methods Data on 41 German FFI patients were analysed. Clinical symptoms and signs, MRI, PET, SPECT, polysomnography, EEG and cerebrospinal fluid biomarkers were studied.

Results An algorithm was developed which correctly identified at least 81% of patients with the FFI diagnosis during early disease stages. It is based on the detection of organic sleep disturbances, either verified clinically or by a polysomnography, and a combination of vegetative and focal neurological signs and symptoms. Specificity of the approach was tested on three cohorts of patients (MM1 sporadic CJD patients, non-selected sporadic CJD and other neurodegenerative diseases).

Conclusions The proposed scheme may help to improve the clinical diagnosis of FFI. As the sensitivity of all diagnostic tests investigated but polysomnography is low in FFI, detailed clinical investigation is of special importance.

INTRODUCTION

The most common genetic form of prion disease worldwide is caused by a point mutation at codon 200 of the PRNP.1 In contrast, in Germany, the most frequently occurring mutation is located at the codon 178 of the PRNP (D178N mutation in coupling with methionine at codon 129; (D178N, 129M)) and leads subsequently to fatal familial insomnia (FFI). Clinopathological features compatible with FFI have been described as early as in 1939 and 1963.3,4 Lugaresi et al.5 were the first to describe FFI in a patient with a family history of insomnia and autonomous disorders. Postmortem examination revealed marked atrophy of the anterior and dorsomedial thalamic nuclei. Later the disorder was classified as a prion disease and its transmissibility was confirmed in animal experiments.6 So far, a number of FFI patients with heterogeneous clinical phenotypes have been reported.7 The clinical phenotype in FFI seems also to depend on the M129V polymorphism.7–9 In most cases, the clinical diagnosis of FFI is hardly possible on the basis of the criteria established for sporadic Creutzfeldt–Jakob disease (sCJD) or familial CJD.10–13 Disease duration in FFI is as rule prolonged and CJD typical signs such as myoclonus are either absent or seen only very late in the disease course. Laboratory tests and technical investigations which are frequently positive in other prion diseases (14-3-3 proteins in cerebrospinal fluid (CSF), EEG, MRI) are usually normal or non-specifically changed and so they do not provide any further clues to the diagnosis.7,14 Clinical criteria of FFI proposed several years ago are helpful in the diagnosis of FFI.15,16 However, sensitivity and specificity of these criteria have to be determined in a context of differential diagnosis of rapid progressive dementia. Moreover, some new data have been collected since publication of the criteria, and the role of the codon 129 genotype in FFI phenotype has been recently demonstrated.15 The aim of the present study was to develop a scheme to support the clinical diagnosis of possible FFI and to provide a basis for the selection of patients who should be subjected to a PRNP analysis in the absence of clear family history for FFI. In addition, such a scheme might be helpful when PRNP analysis is not available for various reasons.

Design AND METHODS

Study design Patients with suspected prion disease were reported to the CJD Surveillance Unit in Göttingen and examined at the notifying hospital by the authors; the clinical data were collected as described previously.17 Data on sleep disturbances were obtained from anamnestic means (patients, their relatives, treating physicians), especially in the absence of polysomnography. CSF, blood samples and copies of the diagnostic tests (EEG, MRI, [18F]FDG positron emission tomography (PET), 123I-IMP single-photon emission CT (SPECT), polysomnography, laboratory tests) were taken. Because genetic testing was not available at the time as patients were enrolled into the study, they were classified according to established diagnostic criteria of sCJD.10,11

MRI and EEG findings

The MRI images were classified as CJD-typical according to the established criteria.18 The EEGs were analysed according to established criteria.19

Polysomnography

Polysonomographic recordings were obtained at the notifying hospitals according to standard
PET and SPECT
PET and SPECT were performed at the notifying hospitals as described previously. Special attention was paid to thalamic hypometabolism.

Neuropathological and molecular studies
Western blot analysis and immunohistochemistry (in biopsied/autopsied patients) and the analysis of PRNP were performed using standard methods.

Biochemical CSF analysis
The 14-3-3 protein analysis was performed at least twice in each CSF sample as described previously.

Statistical analysis
Significations were tested by Student t test, Mann–Whitney rank sum test or χ² test/Fisher exact test. A p value <0.05 was considered as statistically significant.

RESULTS
Study collective
From 1 June 1993 to 31 May 2005, 105 patients with a confirmed PRNP mutation were detected. Out of these patients, 32 were diagnosed with FFI. In addition, we included nine further FFI patients with available clinical data from the same families. Since in a few cases some data (eg, on the 14-3-3 test or MRI) were incomplete, some results were obtained on the basis of lower case numbers. In all, 28 patients were male and 13 were female (ratio 2.2:1). The median age at disease onset was 56 (range 23–73) years. The median disease duration was 11 (range 6–24) months. There were 20 MM (12 male, eight female) and eight MV (seven male, one female) patients. In 13 patients, no M129V genotype was available, but the diagnosis had been confirmed by autopsy, and family history for (genetically proven) FFI was positive. The median age at disease onset in MM patients was 55 years (range 27–73), and the median disease duration was 10 months (range 6–21). The median age at disease onset in MV patients was 60 years (range 23–69) and the median disease duration was 19 months (range 10–24).

Disease onset and duration varied by codon M129V genotype (table 1), with a non-significantly earlier onset and significantly shorter duration in methionine homozygous (MM) patients (p=0.007). Male gender was associated with an earlier age at onset and a more rapid disease course. However, this association was not statistically significant.

Clinical findings
Data on the clinical findings have been previously published by the authors. The clinical features varied by M129V genotype (figure 1). The time of occurrence of symptoms and signs during disease course also varied depending on the M129V genotype (table 2).

Neuropathological studies
Autopsy was performed on 21 of our FFI patients. Overall, 20 of 21 patients showed FFI typical neuropathological findings with prominent thalamo-olivary pathology. Severe astrocytic gliosis and nerve cell loss but weak spongiform changes were observed. Fine reticular PrPSc deposits in the thalamus were only detectable with the PET blot method. This pattern resembles PrPSc type 1, although an electrophoretic mobility comparable with PrPSc type 2 was described in FFI patients. Only one patient with confluent vacuoles (this without thalamo-olivary pathology) showed perivascular PrPSc deposits, which were detectable with conventional immunohistochemical staining methods.

Diagnostic tests
Detailed data on the diagnostic tests have been published previously. Almost all clinical and paraclinical tests revealed no or only slight non-specific changes. In FFI patients, the 14-3-3 test in the CSF, otherwise helpful in diagnosing prion diseases, was positive in two of 28 cases only. In one of them, inflammatory CSF changes (slight pleocytosis and oligoclonal bands) were detected.

Family history of FFI
Data on family history were available in 29 patients. Family history was negative in 10 of these patients (35%) and positive in 19 (65%).

Development of the diagnostic pathway for FFI
All possible combinations of symptoms and signs were tried and that with the highest sensitivity was selected. The weighting was performed by dividing the frequency of symptoms by week at appearance. The most common clinical symptoms and signs were grouped into three categories (A, B, C) (table 3). The first category comprises organic sleep disturbances (A), which were observed in almost all patients (96%). The second category (B) consists of symptoms and signs frequently occurring in sCJD, which is the major differential diagnosis of FFI (CJD-like symptoms). 12 30 The third category (C) comprises symptoms and signs which are typical for FFI, 7 31–34 and are not included in the diagnostic criteria of sCJD. 10 To select the items required for the diagnosis of FFI, we weighted them in terms of their chronological occurrence (table 4). Some signs and symptoms were not evaluated either because they were observed in few cases only or, in most cases, because they could not be linked to a particular disease stage. In a second step, we divided the items into major and minor diagnostic parameters. The most important parameter was sleep disturbance, which occurred as the first symptom of FFI in all patients, except in one case. The minor parameters were selected and weighted according to their frequency and chronological occurrence (category C). Our aims were:

1. High sensitivity
2. High specificity
3. Reliable classification as FFI no later than in the middle of the disease course
4. Easy applicability (analogously to the CJD criteria).

In accordance with this scheme, all patients must have organic sleep disturbances (clinically apparent or by polysomnography). In addition, at least one symptom typical for FFI and two CJD-like symptoms are required for diagnosis of suspected FFI (figure 2). In these patients, a PRNP analysis is required as the subsequent diagnostic step.

Verification of accuracy and applicability
The proposed scheme reached a sensitivity of 91% in our original patient group. Based on their use, it was possible to establish the diagnosis of FFI within a median of 17 weeks (4.4 months) after disease onset. While a sensitivity of 100% was found in our MV FFI patients, it was 88% in MM FFI patients. The median disease duration was 11 months, so the diagnosis based on the proposed criteria was established early in the disease course. We tested the applicability in an additional cohort of FFI patients who were seen in a prospective setting since June 2005 and were not included in the dataset for the scheme development. In these patients (n=16), the proposed scheme correctly identified 13 of 16 (81.3%) of the patients. Major reasons for failure were lack of autonomic disturbances and no data on weight loss or no weight loss.

To test specificity of our diagnostic approach for differentiation of FFI and sCJD, we applied our scheme to 40 randomly selected MM1 sCJD patients (24 women, 16 men; age range 54–86, median 68 years; median disease duration 4, range 1–19 months) representing classical CJD. For randomisation, 40 subsequent MM1 patients diagnosed during the time period of the FFI recruitment for this study were taken. Only seven of these 40 sCJD patients fulfilled the criteria of FFI, so that the specificity within this group was high (83%). This control group was selected because it represents the most frequent classical CJD type.

Loss of weight with a cut-off point of more than 10 kg during the last 6 months was observed in 5% of sCJD patients in comparison with 83% in FFI (p<0.001). Vegetative signs were found in only 33% of MM1 patients compared with 83% in FFI (p<0.001). Husky voice was noticed in none of MM1 patients, but in 22% of FFI patients (p=0.005).

| Table 2 | Time of occurrence of symptoms/signs present both in codon 129 MM and codon 129 MV patients |
|---------|-----------------------------------------------|
| Symptom/sign Genotype | N patients (%) | Means±SD (weeks) | Median (weeks) |
| | MM (n=17) | MV (n=6) | MM (n=17) | MV (n=6) | MM (n=17) | MV (n=6) |
| Vegetative | 13 (77) | 6 (100) | 4±0 | 18.5±3 | 0 | 23 |
| Sleep disturbances | 17 (100) | 5 (83) | 3±0 | 15±0 | 0 | 0 |
| Bulbar | 5 (29) | 5 (83) | 19±0.5 | 23±16 | 11 | 20 |
| Visual | 11 (65) | 5 (83) | 13±1 | 6±2 | 12 | 2 |
| Cognitive/mnestic | 14 (82) | 6 (100) | 13±0 | 16±0 | 12 | 20 |
| Hallucinations | 12 (71) | 2 (33) | 16±0 | 57.5±19 | 14 | 57.5 |
| Spatial disorientation | 13 (77) | 2 (33) | 20±2 | 38.5±1 | 16 | 38.5 |
| Ataxia | 13 (77) | 6 (100) | 21±4 | 9±2 | 20 | 4 |
| Dysarthria | 10 (59) | 4 (67) | 21±0 | 27±0.5 | 20 | 28.5 |
| Myoclonus | 13 (77) | 3 (50) | 16±1 | 32±0.5 | 21 | 32 |
| Pyramidal | 8 (47) | 2 (33) | 29.5±5 | 28±5 | 26 | 28 |

Krasniianski A, et al. J Neurol Neurosurg Psychiatry 2014;85:654–659. doi:10.1136/jnnp-2013-305978
We also applied our algorithm to 40 randomly selected sCJD patients (23 MM, nine MV, eight VV genotype). There were 28 women, 12 men; age range was 41–81 years, median age was 73 years; and median disease duration was 10 months (range 2–28 months). For randomisation, 40 subsequent patients with excluded PRNP mutation diagnosed during the time period of the FFI recruitment for this study were taken. Only seven of these 40 sCJD patients fulfilled the criteria of FFI, and so the specificity within this group was high (83%).

Loss of weight with a cut-off point of more than 10 kg during the last 6 months was observed in 3% of neuropathologically confirmed non-prion disease patients compared with 83% in FFI (p<0.001). Vegetative signs were found in only 30% of non-prion disease patients in comparison with 83% in FFI (p<0.001). Husky voice was absent in non-prion disease patients, but reported in 22% of FFI patients (p=0.012).

**DISCUSSION**

The aim of the present study was to develop a scheme for the clinical diagnosis of FFI. In addition, such a scheme might be also helpful when PRNP analysis is not available for various reasons.

As discussed previously and shown in table 2, there is a significant phenotypic variability between MM and MV genotypes. Myoclonus, spatial disorientation and hallucinations were more frequent in the MM patients.7 9 Bulbar disturbances and vegetative dysfunction were more common in MV FFI patients. Phenotypic differences between MV and MM FFI patients may be caused by different rates of PrPc to PrPSc conversion.15

Differently from our previous study,9 we analysed the clinical data in FFI patients in order to develop a scheme for early identification of patients who should be subjected to PRNP analysis. The rationale for this study is given in the Introduction section. To our knowledge, diagnostic criteria of FFI have been suggested twice.15 16 They are based on data from 24 FFI patients. No

**Table 3** Frequency of clinical symptoms and signs in fatal familial insomnia patients (n=23)

| Symptoms and signs            | N | %   |
|-----------------------------|---|-----|
| Category A                  |   |     |
| Organic sleep disturbances* | 22| 96  |
| Category B                  |   |     |
| Cognitive/mnestic deficits  | 20| 87  |
| Spatial disorientation       | 15| 65  |
| Psychiatric                  | 20| 87  |
| Hallucinations†              | 14| 61  |
| Personality change           | 13| 57  |
| Depression                   | 5 | 22  |
| Anxiety                      | 4 | 17  |
| Aggressiveness               | 2 | 9   |
| Disinhibition                | 2 | 9   |
| Listlessness                 | 2 | 9   |
| Others†, each               | 1 | 4   |
| Ataxia                       | 19| 83  |
| Myoclonus                    | 16| 70  |
| Visual                       | 16| 70  |
| Category C                  |   |     |
| Loss of weight              | 19| 83  |
| Vegetative signs            | 19| 83  |
| Hyperhidrosis                | 13| 57  |
| Newly diagnosed arterial hypertension | 6 | 26 |
| Tachycardia                  | 4 | 17  |
| Obstruction                  | 3 | 13  |
| Hyperthermia                 | 2 | 9   |
| Others††, each              | 1 | 4   |
| Bulbar symptoms             | 10| 43  |
| Husky voice                  | 5 | 22  |
| Dysphagia                    | 3 | 13  |
| Bulbar speech                | 3 | 13  |
| Tongue fasciculation         | 1 | 4   |
| Pruritus                     | 3 | 13  |

*Including polysomnography; insomnia, hypomnia, restless sleep and sleep attacks.
†Optical in 14 patients, additionally acoustic in two of them.
‡Paranoia, fearfulness and rage to clean up.
§Seeing of flashes, poor vision, sliding field of vision and bad spatial vision.
¶Pseudobulbar and cerebellar.
**Nearly equally rigour, tremor and dystonia, mostly in combination.
††Tachypnoea, arterial hypotonia, intolerance of warmth, goose bumps, cardiac arrhythmia and abrogated day–night rhythm of blood pressure.

**Table 4** Symptoms in fatal familial insomnia patients (n=23) stratified by time of occurrence

| Symptom/sign                     | Frequency* | Time of occurrence (d) | Frequency weighted by time |
|---------------------------------|------------|------------------------|----------------------------|
| Loss of weight (<10 kg)         | 19         | 14                     | 1.357                      |
| Husky voice                     | 5          | 14                     | 0.357                      |
| Psychiatric                     | 20         | 84                     | 0.238                      |
| Sleeping disturbances           | 22         | 107                    | 0.206                      |
| Vegetative                      | 19         | 124                    | 0.153                      |
| Visual                          | 16         | 157                    | 0.102                      |
| Cognitive/ mnestic              | 20         | 207                    | 0.097                      |
| Frontal lobe signs              | 2          | 22                     | 0.091                      |
| Myoclonus                       | 16         | 226                    | 0.071                      |
| Ataxia                          | 19         | 273                    | 0.070                      |
| Bulbar                          | 10         | 145                    | 0.069                      |
| Extrapyramidal                  | 5          | 78                     | 0.064                      |
| Spatial disorientation          | 15         | 260                    | 0.058                      |
| Dysarthria†                     | 14         | 259                    | 0.054                      |
| Pyramidal                       | 10         | 205                    | 0.049                      |

*Number of patients with positive symptom/sign.
CONCLUSIONS

Summarizing, we attempted to establish an easily applicable scheme allowing reliable classification as FFI no later than in the middle of the disease course. This facilitates differentiation both from the classical CJD and non-CJD cases initially classified as possible CJD as the most frequent classification in FFI patients according to CJD criteria.10 11 Suspicions of FFI and consecutive order of appropriate genotyping by clinicians can be more frequent and could arise earlier, if updated, easily applicable clinical criteria are available. The scheme would also allow the clinical diagnosis in cases with no available genetic testing. A specificity of at least 80% and a sensitivity of 81.3%-91% could be reached. Early diagnosis of FFI might be important for early and sufficient counseling of patients and their relatives, also concerning the risk of inheritance, and potentially also for treatment studies. We hope that this attempt may improve the early recognition of this peculiar and rare prion disease.

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Ethics approval Any necessary ethics committee approval was secured for the study reported by the local ethic committee of the Medical University of Goettingen.

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