Idiopathic Autonomic Neuropathy

Comparison of Cases Seropositive and Seronegative for Ganglionic Acetylcholine Receptor Antibody

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**Background:** The clinical characteristics of autoimmune autonomic neuropathy are only partially defined. More than 50% of patients with high levels of ganglionic acetylcholine receptor (AChR) autoantibodies have a combination of sicca complex (marked dry eyes and dry mouth), abnormal pupillary light response, upper gastrointestinal tract symptoms, and neurogenic bladder.

**Objective:** To compare patients with idiopathic autonomic neuropathy who were seropositive (n=19) and seronegative (n=87) for ganglionic AChR antibodies.

**Design:** Retrospective review of autonomic programmatic database.

**Setting:** Autonomic Disorders Program Project at Mayo Clinic College of Medicine, Rochester, Minn.

**Patients:** We evaluated a cohort of 87 patients with idiopathic autonomic neuropathy who had undergone full autonomic testing and neurological evaluation and who had a complete panel of paraneoplastic and ganglionic AChR antibodies. We compared patients seropositive (n=19) and seronegative (n=87) for ganglionic AChR antibodies.

**Results:** The seropositive group had a significant over-representation of abnormal pupillary responses (12/18 [67%] vs 12/87 [14%]; *P*<.001), sicca complex (9/15 [60%] vs 11/47 [23%]; *P*=.01), and lower gastrointestinal tract dysautonomia (16/19 [84%] vs 48/85 [56%]; *P*=.02). A subacute mode of onset was more common in the seropositive group (12/19 [63%] vs 23/84 [27%]; *P*=.004). Results of quantitative autonomic function tests differed significantly in the 2 groups only in the cardiovascular domain. Because subacute onset was overrepresented in the seropositive group, we analyzed the data separately, controlling for temporal profile (ie, the relationship between antibody status and symptoms while controlling for rate of onset). The relationships between antibody status and clinical profile (eg, presence of sicca complex, pupillary abnormalities, and lower gastrointestinal tract symptoms) generally remained significant regardless of onset rate, indicating that the associations are not due to temporal profile.

**Conclusions:** These observations support the concept that ganglionic AChR antibodies are diagnostically and pathophysiologically important. Patients with orthostatic hypotension and prominent cholinergic dysautonomia are most likely to be seropositive for ganglionic AChR antibody.

Arch Neurol. 2004;61:44-48

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The clinical characteristics of autonomic neuropathies are disorders of the peripheral nervous system with selective or disproportionate involvement of autonomic nerve fibers or ganglia. After known causes such as diabetes and amyloidosis are excluded, there is a large residuum of acquired cases, often designated *idiopathic autonomic neuropathy*. Serological detection of ganglionic acetylcholine receptor (AChR) autoantibody, which is a putative effector of autoimmune dysautonomia, permits definition of the entity of autoimmune autonomic neuropathy (AAN). We recently reported the clinical features of a group of patients who were seropositive for ganglionic AChR antibody and demonstrated that the clinical spectrum of AAN is broader than previously recognized. In addition to cases with subacute onset, AAN can have insidious onset and be indistinguishable from pure autonomic failure. To gain additional insights into the potential role of ganglionic AChR antibody as an effector of dysautonomia, we studied a large group of patients with neurogenic orthostatic hypotension and compared the autonomic phenotype of 19 patients seropositive for ganglionic AChR antibody with that of 87 seronegative patients.

**METHODS**

Patients were identified from the database of the Mayo Autonomic Laboratory, Rochester,
Minn (January 1, 1997, through December 31, 2001). We reviewed all cases assigned a diagnosis of orthostatic hypotension, defined as a systolic blood pressure reduction of at least 30 mm Hg or a mean blood pressure reduction of at least 20 mm Hg within 3 minutes of head-up tilt. This definition is generally accepted and is supported by normative data. The medical record review and data analysis were conducted in accordance with Institutional Review Board regulations and with Institutional Review Board approval from Mayo Medical Center, Rochester. Only the medical charts of patients who agreed to have their records reviewed for research purposes were considered.

All medical records were reviewed carefully, and secondary forms of orthostatic hypotension (eg, diabetes-, multiple system atrophy-, and medication-induced hypotension) were excluded. A total of 819 charts were reviewed, and 288 cases were identified as idiopathic orthostatic hypotension. Of these, 106 had undergone testing for ganglionic AChR antibody. We considered these cases for further analysis and comparison. From these 106 cases, we extracted demographic, clinical, and the following laboratory variables: autonomic testing scores, thermoregulatory sweat test results, ganglionic AChR antibody levels, and plasma orthostatic catecholamine measurements. Subacute onset was defined as autonomic failure reaching a peak within 3 months. Chronic onset was defined as reaching a peak after 3 months (or having a progressive course).

GANGLIONIC AChR AUTOANTIBODY

Autoantibodies were detected by means of an immunoprecipitation assay in which AChR antigen is solubilized from a human neuroblastoma and complexed with iodine 125–labeled epibatidine.

AUTONOMIC FUNCTION TESTS

Cardiovagal, adrenergic, and postganglionic sudomotor functions were evaluated as follows. The Quantitative Sudomotor Axon-Reflex Test, an evaluation of the postganglionic sympathetic sudomotor axon, is routinely recorded at 4 sites (forearm, proximal lateral leg, medial distal leg, and proximal foot). The stimulus is iontophoresed acetylcholine, and responses are recorded in a single compartment of a multicompartamental sweat cell that is separate from the stimulus compartment. The axon reflex is mediated by postganglionic sympathetic sudomotor fibers. Control values were derived from studies on 223 healthy subjects aged 10 to 83 years.

Cardiovagal function evaluation is based on heart rate response to deep breathing (HRsb) and the Valsalva ratio. The HRsb is the range of heart rate in response to respiratory sinus arrhythmia with the subject supine and breathing 6 times per minute. For the Valsalva maneuver, the subject was rested, recumbent, and requested to maintain a column of mercury at 40 mm Hg for 15 seconds. The Valsalva ratio is the ratio of the maximal to minimal heart rate. Control values were based on 157 healthy subjects aged 10 to 83 years.

The symptom of difficulty focusing was recorded only if confirmed by results of neurological examination of the pupil. We specifically sought reduced pupillary responses to light and/or accommodation, indicative of Adie pupil. Twelve (67%) of 18 patients in the Ab+ group had abnormal pupillary responses compared with 12 (14%) of 87 patients in the Ab– group (P < .001; Table 1).

THERMOREGULATORY SWEAT TEST

The thermoregulatory sweat test was conducted in a cabinet with a moderately hot and humid environment (45°C-50°C air temperature; 35%-40% relative humidity). Mean skin temperature was kept at 39.0°C. Oral temperature rose at least 1.0°C or to 38.0°C (whichever was higher). Maximal sweating was achieved in 30 to 65 minutes. Sweating was demonstrated by an indicator powder, and the percentage of anhidrosis on the anterior body surface was calculated from images created from digital photographs of the sweat distribution.

DATA ANALYSIS

We used χ² or Fisher exact tests to examine the unadjusted associations between antibody status (seropositive vs seronegative) and categorical clinical and demographic variables. Associations between antibody status and continuous variables were evaluated with 2-sample t tests or Mann-Whitney tests in the case of skewed data. Variables found to have a significant bivariate relationship with antibody status were reexamined while adjusting for rate of symptom onset using Cochran-Mantel-Haenszel tests. P < .05 was considered significant.

RESULTS

Nineteen patients were seropositive for ganglionic AChR antibody (Ab+) and 87 were seronegative (Ab–). Clinical and autonomic characteristics of the Ab+ cohort have been detailed previously. In this study, we focused on the comparison between the Ab+ and Ab– groups.

DEMOGRAPHICS

The Ab– and Ab+ cohorts did not differ significantly by age (mean ages, 61.9 and 63.4 years, respectively [P = .68]) or sex (47 [54%] and 14 [74%] female, respectively; P = .11), although the Ab+ group had a female predominance (female: male ratio, 14:5).

PUPILLARY ABNORMALITIES

Because dry eyes or dry mouth in isolation is frequently reported in otherwise healthy subjects, we required both complaints to be unequivocal and consistent (ie, the full sicca complex) to record an abnormal finding. We ex-
The presence of neurogenic bladder and sexual dysfunction were recorded, with care to exclude symptoms attributable to nonautonomic causes (most commonly, postsurgical dysfunction and stress incontinence). Symptoms attributable to neurogenic bladder were present in 32 (41%) of 78 patients in the Ab– cohort and 10 (53%) of 19 in the Ab+ group (P = .36; Table 1). Because of difficulty attributing sexual dysfunction to dysautonomia in women, we could only analyze self-reported male erectile dysfunction, taking care to exclude preexistent conditions (mostly prostatectomy or medication effects). The small number of male patients in the Ab+ group did not allow for χ² analysis, but 4 (80%) of 5 male patients in the Ab+ group reported severe dysfunction (ie, complete inability to obtain an erection) vs 18 (45%) of 40 in the Ab– group. In the latter group, an additional 8 patients (20%) reported partial erectile dysfunction.

THERMOREGULATORY FUNCTION

A reduced ability to sweat and intolerance of heat were reported in 14 patients (74%) in the Ab+ group; 39 (57%) of 68 patients in the Ab– group reported similar problems. The difference did not reach statistical significance (P = .19; Table 1).

ANTECEDENT ILLNESS

More patients in the Ab+ group (8 [42%]) reported an antecedent event (presumed viral illness) than did those in the Ab– group (22 [25%]), but the difference was not statistically significant (P = .15; Table 1).

TEMPORAL PROFILE

In the Ab+ group, 12 patients (63%) had a subacute onset (<3 months), compared with 23 (27%) of 84 patients in the Ab– group, in which insidious onset and a chronic disease course was more common (P = .004; Table 1).

AUTONOMIC FUNCTION TESTS

Table 1. Comparison of Cases Seropositive and Seronegative for Ganglionic AChR Antibody by Clinical Features*

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. ( % ) of Patients</th>
<th>Unadjusted χ²</th>
<th>Adjusted χ²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ab+ (n = 19)</td>
<td>Ab– (n = 87)</td>
<td></td>
</tr>
<tr>
<td>Antecedent event</td>
<td>8/19 (42)</td>
<td>22/87 (25)</td>
<td>2.0</td>
</tr>
<tr>
<td>Subacute symptom onset</td>
<td>12/19 (63)</td>
<td>23/84 (27)</td>
<td>8.4§</td>
</tr>
<tr>
<td>Sicca complex</td>
<td>9/15 (60)</td>
<td>11/47 (23)</td>
<td>6.6§</td>
</tr>
<tr>
<td>Pupil abnormalities</td>
<td>12/18 (67)</td>
<td>12/85 (14)</td>
<td>19.7§</td>
</tr>
<tr>
<td>Upper GI symptoms</td>
<td>8/18 (44)</td>
<td>26/75 (35)</td>
<td>0.59</td>
</tr>
<tr>
<td>Lower GI symptoms</td>
<td>16/19 (84)</td>
<td>48/85 (56)</td>
<td>5.6§</td>
</tr>
<tr>
<td>Bladder symptoms</td>
<td>10/19 (53)</td>
<td>32/78 (41)</td>
<td>0.82</td>
</tr>
<tr>
<td>Abnormal sweat test result</td>
<td>14/19 (74)</td>
<td>39/85 (57)</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Abbreviations: Ab+, seropositive for the acetylcholine receptor (AChR) antibody; Ab–, seronegative for the AChR antibody; GI, gastrointestinal tract; NA, not applicable.

*Group sizes vary owing to lack of data.
†Calculated by means of likelihood ratio χ² tests.
‡Calculated by means of Cochran-Mantel-Haenszel tests adjusted for the rate of symptom onset. We performed the test only in variables with significant bivariate relationship to autoantibody status.
§P<.01.
||P<.05.

cluded cases with symptoms attributable to medication effect. The sicca complex was present in 9 (60%) of 15 patients in the Ab+ group, but in only 11 (23%) of 47 patients in the Ab– group (P = .01; Table 1).

UPPER GASTROINTESTINAL TRACT COMPLAINTS

Symptoms of postprandial bloating, early satiety, nausea, and vomiting were recorded as possibly indicative of gastroparesis. Patients with comorbidities (eg, hiatal hernia) that could account for the symptoms were excluded. No significant difference in upper gastrointestinal tract complaints was observed between the Ab– (8/18 [35%]) and Ab+ groups (26/75 [35%]) (Table 1).

LOWER GASTROINTESTINAL TRACT COMPLAINTS

Diarrhea and constipation were considered. Because the nonspecific complaint of constipation is quite frequent in the general population, this symptom was accepted as an indicator of dysautonomia only when we could ascertain that it represented a clear change in the patient’s usual bowel pattern and was of at least moderate severity (ie, requiring specific treatment beyond diet modification). Thus, we were confident that it could be attributed to the autonomic disorder and not to a preexistent condition or medication effect. Abnormal bowel function was reported in 16 (84%) of 19 patients in the Ab+ group compared with 48 (56%) of 85 in the Ab– group (P = .02). In both groups, constipation was more common than diarrhea (Ab+ group, 14/19 [74%] vs 2/19 [11%]; Ab– group, 38/85 [45%] vs 10/85 [12%]).
toms develop insidiously. We therefore analyzed the data separately on the basis of the temporal profile, irrespective of the autoantibody status. We considered all cases with a time from onset to peak of 3 months or less as subacute and cases with onset to peak of greater than 3 months as chronic. The subacute onset group was characterized by significantly more frequent sicca syndrome (9/15 [60%] vs 11/47 [23%]; P = .02), lack of heat-induced sweating (20/28 [71%] vs 21/46 [46%]; P = .03), and pupillary abnormalities (15/33 [45%] vs 9/67 [13%]; P = .01). Although lower gastrointestinal tract symptoms were more frequent in patients with subacute onset (26/35 [74%] vs 38/67 [57%]), this difference did not reach statistical significance (P = .08).

Because mode of onset was significantly associated with several clinical features, we next repeated the analysis for variables that showed a significant bivariate relationship to autoantibody status (sicca complex, pupillary abnormalities, and lower gastrointestinal tract function), while controlling for symptom onset (subacute vs insidious). The significant relationships of autoantibody status to the sicca complex and pupillary abnormalities held (P = .03 and P < .001, respectively), but the relationship between autoantibody status and abnormal lower gastrointestinal tract function no longer reached significance (P = .08; adjusted χ² values [Table 1]). These findings suggest that the relationship between autoantibody status and these symptoms is not fully accounted for by rate of symptom onset.

**COMMENT**

Idiopathic neurogenic orthostatic hypotension has been traditionally classified by temporal profile and disease course. Cases with acute onset, often with antecedent viral infection, and monophasic course were considered the autonomic equivalent of Guillain-Barré syndrome and termed acute pandysautonomia or panautonomic neuropathy. The identification of a candidate pathogenic autoantibody and the significant correlation between autoantibody level and severity and distribution of autonomic failure supports an autoimmune basis for many patients with subacute presentation.4 Anecdotal reports of improvement after immunomodulatory therapy further support this hypothesis. At the other end of the spectrum, cases with insidious onset and progressive course were considered to be degenerative and variously called pure autonomic failure or Bradbury-Eggleston syndrome. However, this classification is imprecise because some cases of AAN have insidious onset and slow progression.2

The main findings of the present study are that, in patients with neurogenic orthostatic hypotension, the presence of ganglionic AChR antibody is associated with sicca complex, abnormal pupils, lower gastrointestinal tract dysfunction, and subacute onset of the neuropathy. Although subacute onset is more common in the seropositive cohort, our analysis demonstrated that the association of autoantibody status with cholinergic function, especially cholinergic secretomotor function, remained significant after controlling for temporal profile. This finding indicates that the time factor is not as critical as originally thought and cannot be the sole basis for diagnosis of AAN.

In an earlier publication, we reported that a combination of sicca complex, abnormal pupillary light response, upper gastrointestinal tract symptoms, and neurogenic bladder occurred in more than 50% of patients with high autoantibody levels.2 Higher autoantibody values correlated with greater autonomic dysfunction and a greater frequency of cholinergic dysautonomia. These observations support the concept that ganglionic AChR antibody is diagnostically and pathophysiologically important. Our previous observations were confined to patients who were seropositive for ganglionic AChR antibody. The results of the present study comparing seropositive and seronegative cohorts further support pathophysiological importance for this autoantibody. The only variables that significantly separated these cohorts were those previously identified, although lower gastrointestinal tract complaints (not analyzed in our first study) proved to be more significant than upper gastrointestinal tract complaints in this study. That the antibody is responsible for the generalized autonomic neuropathy in patients with AAN is suggested by the correlation between antibody levels and total autonomic deficits2 and by the development of experimental AAN in rabbits producing ganglionic AChR antibody in response to immunization with a fragment of this AChR protein, with the severity of dysautonomia paralleling serum autoantibody levels.9

The ganglionic AChR autoantibody acts at the level of autonomic ganglia on postsynaptic adrenergic and cholinergic neurons. Therefore, the sympathetic and parasympathetic systems should be affected equally. Although deficits are present in both systems, an intriguingly robust relationship is observed between the degree of involvement of parasympathetic secretomotor functions and

<p>| Table 2. Comparison of Cases Seropositive and Seronegative for Ganglionic AChR Antibody by Autonomic Function Test Results* |
|--------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Patient Groups, Mean ± SEM</th>
<th>Ab+ (n = 19)</th>
<th>Ab− (n = 87)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASS-total</td>
<td>7.6 ± 0.43</td>
<td>6.9 ± 0.25</td>
<td>0.27†</td>
</tr>
<tr>
<td>CASS-sudomotor</td>
<td>2.2 ± 0.22</td>
<td>2.1 ± 0.11</td>
<td>0.92†</td>
</tr>
<tr>
<td>CASS-cardiovagal</td>
<td>2.1 ± 0.27</td>
<td>1.5 ± 0.13</td>
<td>0.04†</td>
</tr>
<tr>
<td>CASS-adrenergic</td>
<td>3.5 ± 0.16</td>
<td>3.4 ± 0.09</td>
<td>0.46†</td>
</tr>
<tr>
<td>% of anhidrosis</td>
<td>41.6 ± 7.4</td>
<td>49.3 ± 4.2</td>
<td>0.43‡</td>
</tr>
<tr>
<td>Supine norepinephrine level, pg/mL</td>
<td>129.2 ± 47.2</td>
<td>186.7 ± 24.4</td>
<td>0.10†</td>
</tr>
<tr>
<td>Standing norepinephrine level, pg/mL</td>
<td>229.8 ± 88.6</td>
<td>338.2 ± 51.9</td>
<td>0.32†</td>
</tr>
<tr>
<td>Change in norepinephrine level, pg/mL (supine to standing)</td>
<td>100.6 ± 64.7</td>
<td>137.6 ± 30.2</td>
<td>0.39†</td>
</tr>
</tbody>
</table>

Abbreviations: Ab+, seropositive for the acetylcholine receptor (AChR) antibody; Ab−, seronegative for the AChR antibody; CASS, Composite Autonomic Severity Score.

SI conversion factor: To convert norepinephrine to nanomoles per liter, multiply by 0.00591.

*Group sizes vary owing to lack of data.
†Calculated by means of the Mann-Whitney test.
‡Calculated by means of the 2-sample t-test.
the serum level of antibody, as evidenced by the correlation between the severity of autonomic failure and the overrepresentation of these symptoms in the seropositive cohort of this study. We do not have a clear explanation for this finding but can postulate a number of testable hypotheses. Perhaps the postganglionic cholinergic neuron is more sensitive to antibody than the postganglionic adrenergic neuron. Neurons in these 2 systems differ cytoarchitecturally. Parasympathetic cholinergic postganglionic neurons that affect tearing in the pterygopalatine ganglion, salivation in the submandibular ganglion, pupillary constriction in the ciliary ganglion, and smooth muscle contraction are unusually small compared with sympathetic ganglia. These parasympathetic ganglia are located closer to or within the target organs. The site of action of the ganglionic AChR antibody is at the proximal end of the postganglionic neuron. Sympathetic neurons residing in proximal ganglia of the sympathetic chain may have a more protective blood-ganglion barrier than parasympathetic ganglia at more peripheral locations. An alternative explanation for their greater susceptibility to functional impairment is that cholinergic neurons may present additional targets for the antibodies, including nicotinic autoreceptors on nerve terminals. (The quantitative sudomotor axon reflex response is evidence of nicotinic AChR on the distal sudomotor axon.) Another potential explanation is that cholinergic neurons may present additional targets for the antibodies, including nicotinic autoreceptors on nerve terminals. (The quantitative sudomotor axon reflex response is evidence of nicotinic AChR on the distal sudomotor axon.) Another potential explanation is the dominance of parasympathetic tone over pupillary and secretomotor functions. The net effect is that the pathophysiological outcome of antibody binding is more prominent in affected parasympathetic ganglia.

Despite clear-cut clinical differences, we found a statistically significant abnormality only in the cardiovascular score of autonomic tests performed in the seropositive and seronegative groups. There are a number of possible explanations for this. First, the clinical differences that were significant between groups (secretomotor, pupillary, and gastrointestinal tract function) were not quantitated. Salivation and tear production are not routinely tested. In individual cases, quantitative measurement of these secretomotor functions was markedly reduced in patients with sicca syndrome, but similar recordings were not performed routinely in most seropositive patients and not at all in seronegative patients. Only a limited number of patients had gastrointestinal motility studies. Second, there was a selection bias in that the two groups were balanced by severity of adrenergic failure (ie, all had documented orthostatic hypotension). Our routine autonomic tests define the severity of autonomic disturbance but are relatively insensitive in determining the site of pathophysiology (central nervous system vs ganglia vs nerve). More detailed autonomic studies, including pharmacological dissection of autonomic dysfunction, would likely be more sensitive in differentiating autonomic neuropathy due to ganglionopathy.

CONCLUSIONS

Although a positive result in ganglionic AChR antibody testing is useful diagnostically and guides specific treatment strategies, some seronegative patients have a clinical course and features that are compatible with AAN. Furthermore, some individual seronegative patients respond to immunotherapy (P.A.L. unpublished observations). The frequency of idiopathic autonomic neuropathy will likely shrink as other autoantibody specificities and neuronal antigen-specific effector T lymphocytes are discovered.

Accepted for publication September 17, 2003.

Author contributions: Study concept and design (Drs Sandroni, Vernino, Klein, Lennon, and Low); acquisition of data (Drs Vernino, Klein, Lennon, Benrud-Larson, and Low and Mr Sletten); drafting of the manuscript (Drs Sandroni and Low); critical revision of the manuscript for important intellectual content (Drs Vernino, Klein, Lennon, Benrud-Larson, and Low and Mr Sletten); statistical expertise (Dr Benrud-Larson); obtained funding (Dr Low); administrative, technical, and material support (Drs Vernino, Lennon, Low, and Mr Sletten); study supervision (Dr Low).

This study was supported by the following grants from the National Institutes of Health, Bethesda, Md: NS22352 (Dr Low), NS32352 (Dr Low), NS39722 (Dr Low), M01 RR00585 (Dr Low), 1K08NS/00247 (Dr Vernino), HD07447 (Dr Benrud-Larson), 5 K23 RR15537 (Dr Sandroni); and by Mayo Foundation Funds, Rochester, Minn.

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