Tight link between our sense of limb ownership and self-awareness of actions

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Abstract

Background and Purpose: Hemiparetic stroke patients with disturbed awareness for their motor weakness (anosognosia for hemiparesis/-plegia [AHP]), may exhibit further, abnormal attitudes towards or perceptions of the affected limb(s). The present study investigated the clinical relationship and the anatomy of such abnormal attitudes and AHP.

Methods: In a new series of 79 consecutively admitted acute stroke patients with right brain damage and hemiparesis/-plegia, different types of abnormal attitudes towards the hemiparetic/plegic limb (asomatognosia, somatoparaphrenia, anosodiaphoria, misoplegia, personification, kinaesthetic hallucinations, supernumerary phantom limb) were investigated.

Results: Ninety-two percent of the patients with AHP showed additional “disturbed sensation of limb ownership” (DSO) for the paretic/plegic limb: The patients had the feeling that their contralesional limb(s) do not belong to their body or even belong to another person. Analysis of lesion location revealed that the right posterior insula is a crucial structure involved in these phenomena.

Conclusion: DSO for hemiparetic/-plegic limbs and AHP are tightly linked both clinically and anatomically. The right posterior insula seems to be a crucial structure involved in the genesis of our sense of limb ownership and self-awareness of actions.
Stroke patients with AHP typically deny the paralysis and/or behave as if it would not exist. Only few studies indicated that AHP might be associated with other abnormal attitudes towards or perceptions of the paretic/plegic limb. For example, patients may experience their limb as not belonging to them (asomatognosia) or attribute their own body parts to other persons (somatoparaphrenia). The present study investigated the clinical relationship and the anatomy of such abnormal attitudes and AHP.

**Methods**

We investigated a new series of 79 acute stroke patients with right brain damage and left-sided hemiparesis/-plegia. Eleven of the 79 patients showed abnormal attitudes towards or perceptions of the paretic/plegic limb. For the anatomical analysis we compared these patients with a control group of 11 patients without AHP and without such attitudes, randomly selected from the investigated sample. The two groups were comparable with respect to their clinical an epidemiological data (Table 1).

AHP was examined using the anosognosia scale suggested by Bisiach et al. For a firm diagnosis of AHP only patients were selected who did not acknowledge hemiparesis/-plegia even after a specific question about the strength of their limb(s) (grade 2 and 3). Patients in the control group scored grade 0, i.e. spontaneously mentioned the disorder. A questionnaire investigated whether the patient was unable to recognize his/her own limbs as belonging to the own body (asomatognosia); whether he/she attributed his/her own limbs to other persons...
had a lack of appropriate concern of the paretic/plegic limb (anosodiaphoria); expressed negative feelings for his/her limb (misoplegia); gave his/her limb names (personification); feels his/her limb moving automatically (kinaesthetic hallucinations); or was convinced that a new, intact limb had appeared (supernumerary phantom limb).

MRI scans were performed in 14, spiral-CT scans in 8 patients. The FLAIR sequence was acquired with 19 axial slices with an interslice gap of 1 mm. DWI was performed with a slice thickness of 5 mm and CT scanning with a slice thickness of 3 mm infratentorial and 8 mm supratentorial. The mean time between lesion and the MRI was 1.7 days (SD 1.4), between lesion and the CT scans 3.1 days (SD 3.3). By using MRJcro software (Rorden & Brett, 2000) lesions were mapped on slices of a T1-weighted template MRI scan from the Montreal Neurological Institute.

Results

Twelve (=15.2%) of the 79 patients showed AHP. Eleven (=91.7%) of these 12 subjects with AHP demonstrated abnormal attitudes towards and/or perceptions of the paretic/plegic limb. The type of such attitudes is illustrated in Figure 1.

Two of the 6 patients who attributed their limb to another person (somatoparaphrenia), attributed their limb to their wife, three to the examiner, and 1 to the room neighbour. The patients who neither attributed their limb to themselves nor to somebody else nevertheless had
the feeling that their limb, belongs to another person (asomatognosia). However, neither of the latter patients clearly denied that their arm/leg definitely does not belong to somebody else. On the other hand, 4 of the 6 subjects who attributed their limb to other persons did not seem to be entirely certain by using terms like "perhaps", etc. This suggests that the two diagnoses (somatoparaphrenia/asomatognosia) rather point to a continuum of conviction that the contralesional limb does not belong to the own body. "Disturbed sensation of limb ownership" (DSO) thus seems to be a unifying term to describe these feelings (see also Fig. 1).

To identify the structures that were commonly damaged in patients with DSO but were typically spared in patients without DSO, we contrasted the 11 patients with AHP plus DSO versus 11 subjects without AHP and without DSO (the latter randomly selected from the patient sample; see above) by subtraction (Fig. 2a). The area specifically related to DSO and AHP was the right posterior insula (Fig. 2b). We found this structure 72% more frequently affected in patients showing DSO and AHP than in controls. While all of the 11 patients with DSO and AHP had a lesion involving this region, we found it affected in only three patients from the control group ($\chi^2=12.57; p<0.01$).

**Discussion**

We found AHP in about 15% of an unselected sample of right brain damage stroke patients. The new finding is that patients with AHP typically show a disturbed sensation of limb ownership (DSO) in addition. Our sense of limb ownership and our awareness of limb movement thus seem to be tightly linked. This became obvious also on the anatomical level.
We found the right posterior insula commonly damaged in patients having DSO and AHP but significantly less affected in brain damaged patients without these disorders.

Supporting evidence for the role of the right posterior insula for limb ownership and self-awareness of limb actions comes from recent positron emission tomography experiments \(^9,10\), as well as reports of stroke patients with lesion restricted to the insula \(^11\). Together with our present and earlier \(^12\) findings these studies allow to speculate that self-attribution of actions and the sense of limb ownership might represent the front and the reverse side of one coin. Processes leading to one’s awareness about a movement and the knowledge that a limb belongs to oneself seem to typically co-occur and to be represented in the same neural structure, namely the right posterior insula. However, since three of the control patients also had damage to this structure, it is possible that its damage is necessary but not always sufficient for the presence of AHP/DSO.

The present study is limited by the small sample size of 12 patients with AHP. However, the data were straightforward in that all but one of these patients showed DSO. They thus suggest a tight behavioural as well as anatomical relationship between a disturbed sensation of ownership for the contralesional limb (DSO) and AHP. The right posterior insula seems to be a crucial structure integral to the genesis of our sense of limb ownership and to self-awareness to one's belief about limb movement.
References


**Table 1.** Demographic and clinical data of the right brain damaged patients selected for the analysis of lesion location.

<table>
<thead>
<tr>
<th></th>
<th>AHP and disturbed sensation of limb ownership (DSO)</th>
<th>Controls (no AHP/no DSO)</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>11</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>7/4</td>
<td>6/5</td>
<td>0.665</td>
</tr>
<tr>
<td>Age [median (range)]</td>
<td>63(54-82)</td>
<td>69(55-83)</td>
<td>0.340</td>
</tr>
<tr>
<td>Etiology</td>
<td>11 infarcts</td>
<td>9 infarcts, 2 hemorrhages</td>
<td></td>
</tr>
<tr>
<td>Time since lesion (days [median (range)]</td>
<td>3 (1-10)</td>
<td>3(1-9)</td>
<td>0.504</td>
</tr>
<tr>
<td>Lesion size (%RH volume) [median (range)]</td>
<td>7.7(3.9-30.7)</td>
<td>5.8(1.8-47.1)</td>
<td>0.490</td>
</tr>
<tr>
<td>Paresis % present</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Severity of arm paresis [median (range)]</td>
<td>1(0-4)</td>
<td>1(0-3)</td>
<td>0.757</td>
</tr>
<tr>
<td>Severity of leg paresis [median (range)]</td>
<td>3(0-5)</td>
<td>3(2-4)</td>
<td>0.919</td>
</tr>
<tr>
<td>Visual field defects % present</td>
<td>0</td>
<td>27</td>
<td>0.158</td>
</tr>
<tr>
<td></td>
<td>% tnp</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Neglect % present</td>
<td>27</td>
<td>36</td>
<td>0.631</td>
</tr>
<tr>
<td></td>
<td>% tnp</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>Median (range) 19(15-29)</td>
<td>22(10-24)</td>
<td>0.246</td>
</tr>
</tbody>
</table>

AHP, anosognosia for hemiparesis/-plegia; DSO, disturbed sensation of limb ownership; M, male; F, female; MMSE, mini-mental state examination; tnp, testing not possible. The degree of paresis was scored with the usual clinical ordinal scale, where “0” stands for no trace of movement and “5” for normal
movement. Visual field defects were assessed using standardized neurological confrontation technique. Spatial neglect was diagnosed when the patient showed the characteristic clinical behavior and a disturbance in the Bells test.
Legends

**Figure 1:** Type of abnormal attitudes towards or perceptions of the paretic/plegic limb (in percent) found in the patients with AHP.

**Figure 2. (A),** Overlay lesion plots of the patients with AHP and DSO for their contralesional limb (n=11) and of the control patients with right brain damage without AHP or DSO (n=11). The number of overlapping lesions is illustrated by different colors coding increasing frequencies from violet (n=1) to red (n=11). MNI z-coordinates of each transverse slice are given. **(B),** Overlay plot of the subtracted superimposed lesions of the patients with DSO and AHP minus the control group. The percentage of overlapping lesions of the group with DSO and AHP after subtraction of controls is illustrated by five different colors coding increasing frequencies from dark red (difference 1-20%) to white-yellow (difference 81-100%). Each color represents 20% increments. The colors from dark blue (difference -1 to –20%) to light blue (difference -81 to -100%) indicate regions damaged more frequently in the control patients than in patients with DSO and AHP.
Disturbed sensation of limb ownership (DSO) and AHP

Figure 2