

Video atlas of lateralising and localising seizure phenomena

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ABSTRACT – The detailed analysis of seizure semiology is an essential tool for diagnosing epileptic patients and is particularly important in the evaluation of patients considered for epilepsy surgery. The meticulous clinical observation of epileptic seizures provides information about the localisation and lateralisation of the symptomatogenic zone. Here, we present a video atlas showing a variety of ictal and postictal localising and lateralising phenomena. [*Published with video sequences*]

Key words: seizure semiology, symptomatogenic zone, epileptogenic zone, lateralizing, localizing, video-atlas epilepsy, video-EEG

A variety of signs and symptoms may occur during epileptic seizures, some of which have a lateralising or localising significance based on systematic EEG-video recordings. This video atlas displays different lateralising and localising seizure phenomena in adult patients. A comprehensive review of lateralising seizure phenomena without video examples is available elsewhere (Loddenkemper and Kotagal, 2005) and an excellent review of postictal lateralising and localising signs including a few selected video examples has also been published (Leutmezer and Baumgartner, 2002). Without simultaneous EEG-video recordings, it is sometimes impossible to identify whether a sign or symptom occurs during the ictal phase of a seizure or postictally. In this video atlas, with few exceptions, we therefore refer only to signs and symptoms which were analysed on the basis of simultaneous EEG and video recordings.

Lateralising ictal signs

Ictal motor phenomena

Unilateral clonic seizure

The significance of localisation and lateralisation was first recognised in unilateral clonic seizures (Jackson, 1890) which consist of more or less regular, repeated, short contractions of various muscle groups (0.2-5 Hz). These often involve the distal part of the extremities or face and most probably originate from the primary motor or premotor area (Noachtar and Arnold, 2000). Unilateral clonic seizures are present in several focal epilepsies. In frontal lobe epilepsy, clonic seizures occur early in seizure evolution (*patient 1; see video sequence 1*) and consciousness typically remains unclouded at the beginning of the clonic activity (Manford *et al.*, 1996). In contrast, in temporal lobe epilepsy, clonic seizures typically occur after automatisms and



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consciousness is disturbed (*patient 2*; see *video sequence 2*) (Noachtar and Arnold, 2000). This evolution of seizure semiology reflects the spread of epileptic activity from the temporal to the frontal lobe. Unilateral clonic seizures have a positive predictive value of 92% for seizure onset in the contralateral hemisphere (Janszky et al., 2001).

Legend for video sequence 1

Patient 1: A 32-year-old man with focal epilepsy, secondary to a glioma in the left central region. At the age of 20, surgery was performed. Ictal EEGs showed a left frontocentral seizure pattern.

Somatosensory aura of the right hand → clonic seizure of the right hand.

19:31:57 Patient talks to a visitor, experiences a somatosensory aura of the right hand and immediately presses the alarm button on the left side of his bed.

19:32:06 Test to remember the word "banana"

19:32:08 Patient follows commands to raise his arms and turn his hands such that the palms face upwards

19:32:14 Patient says his first name

19:32:18 Patient describes his aura as tingling in the right arm

19:32:26 Unilateral clonic seizure begins in the right little finger

19:32:32 Unilateral clonic jerking affects the right hand

Legend for video sequence 2

Patient 2: A 44-year-old woman with right neocortical temporal lobe epilepsy of unknown origin. EEG seizure onsets were localised to the right posterior temporal region.

Automotor seizure → Clonic seizure of the left side of the face

18:00:37 Oral and manual automatisms

18:01:33 Clonic twitching of the left side of the face

18:01:36 Does not follow commands

18:02:00 Not responsive

18:02:06 End of clonic seizure

18:02:17 Follows commands

Unilateral tonic seizure

Tonic seizures consist of a unilateral or bilateral contraction of one or more muscle groups, usually lasting for more than three seconds and leading to tonic posturing (Noachtar and Arnold, 2000). If tonic seizures are clearly unilateral, they have a high lateralising value for seizure onset in the contralateral hemisphere (*patient 3*; see *video sequence 3*). Tonic seizures occur more often in extratemporal lobe

epilepsies (79%) than in temporal lobe epilepsies (1.7%) (Werhahn et al., 2000).

Generally, tonic activity is generated by epileptic activation of the cortical motor areas, i.e. the primary motor and supplementary sensorimotor areas (Bleasel et al., 1997; Lüders and Noachtar, 2000; Penfield and Jasper, 1954).

Legend for video sequence 3

Patient 3: A 25-year-old man with left focal epilepsy, secondary to a left perinatal MCA infarction, leaving him with mild right-sided hemiparesis. Ictal EEGs showed a left frontal seizure pattern.

Tonic seizure of the right arm → GTCS.

20:17:52 Right arm tonic posturing; patient presses alarm button with his left hand

20:18:08 Figure 4 sign with the right arm extended, followed by a GTCS

20:23:03 Postictally, patient describes the beginning of the seizure with involuntary movement of the right arm

20:23:10 Unable to hold the right paretic arm outstretched and shows that the right arm is flaccid

20:23:20 Unable to push physician's hand with his right hand

Head and eye deviation

The lateralising significance of ictal head deviation has been subject to controversy (McLachlan, 1987; Ochs et al., 1984; Robillard et al., 1983; Wyllie et al., 1986a). Versive seizures consist of a lateral eye deviation, which is followed by a head and frequently also a trunk deviation in the same direction. If defined as a forced and involuntary head movement resulting in sustained unnatural positioning (Wyllie et al., 1986a), versive head seizures have a high specificity (>90%) of lateralisation for a contralateral seizure onset zone (Chee et al., 1993; Steinhoff et al., 1998), particularly when occurring immediately prior to generalisation (Kernan et al., 1993). Non-forced head deviation is not a lateralising sign unless it ends before generalisation or is followed by contralateral forced head deviation (*patients 4 and 16*; see *video sequences 4 and 16*) (Kernan et al., 1993; Wyllie et al., 1986b). It has been shown that in temporal lobe epilepsy, initially the head turns ipsilaterally and then contralaterally before secondary generalisation (O'Dwyer et al., 2007). It is highly probable that versive seizures express the epileptic activation of the frontal eye field which is contralateral to the side to which the eyes or head turn (Penfield and Jasper, 1954). Head and eye deviations in frontal lobe epilepsy occur significantly earlier in seizure evolution (*patient 4*; see *video sequence 4*) (Bleasel et al., 1997). Versive seizures in temporal

lobe epilepsy occur later following a disturbance of consciousness, reflecting the spread of epileptic activity to the frontal lobe. This may be due to different pathways of seizure propagation in temporal lobe epilepsies compared with extratemporal lobe epilepsies (*patients 5, 9 and 14; see video sequences 5, 9 and 14*).

Asymmetric termination of generalised tonic-clonic seizures

The clonic phase of a generalised tonic-clonic seizure (GTCS) may end asymmetrically with clonic jerks persisting in the limbs ipsilateral to the hemisphere of seizure onset (*patients 4, 6 and 10; see video sequences 4, 6 and 10*).

Based on two series of patients with temporal lobe epilepsy (Leutmezer *et al.*, 2002; Trinka *et al.*, 2002), asymmetric termination of a GTCS was shown to be a frequent lateralising sign (43% and 66%, respectively). For both series, this phenomenon occurred 80% ipsilaterally to the seizure onset zone and interobserver reliability was excellent.

Dystonic hand posturing

Unilateral dystonic hand posturing, defined as unnatural tonic posturing with a rotatory component (*patients 7 and 21; see video sequences 7 and 21*), reliably indicates seizure onset in the contralateral hemisphere (Bleasel *et al.*, 1997; Chee *et al.*, 1993; Kotagal *et al.*, 1989; Newton *et al.*, 1992; Steinhoff *et al.*, 1998). In these studies the positive predictive value of seizure onset in the contralateral hemisphere was between 92-100%. Dystonic hand posturing occurs significantly more often in patients with mesial temporal lobe epilepsy than in patients with neocortical temporal lobe epilepsy (Pfänder *et al.*, 2002) and occurs later in seizure evolution in patients with temporal lobe epilepsy than in patients with extratemporal lobe epilepsy (Lieb *et al.*, 1991, Lieb *et al.*, 1986). Simultaneous manual automatisms can often be observed in the contralateral hand (*patients 6 and 8; see video sequences 6 and 8*).

The "figure 4 sign"

Asymmetric tonic limb posturing, a striking asymmetry of limb posture at the onset of secondary GTCS, is a valuable lateralising sign; one elbow is extended while the other is flexed during the initial tonic phase of a GTCS (*patients 3, 4, 5, 6 and 9; see videos 3, 4, 5, 6 and 9*). In 35 of 39 patients with secondary GTCS, the extended elbow was found to be contralateral to the side of ictal EEG onset (Kotagal *et al.*, 2000).

In some patients the figure 4 sign seems to shift between sides during the seizure.

At the end of the figure 4 sign, both arms may become tonically extended, followed by bilateral clonic movements. The clonic movements may at first be more

Legend for video sequence 4

Patient 4: A 23-year-old woman with right frontal lobe epilepsy. MRI was normal. Ictal EEGs showed right frontal seizure patterns.

Left versive seizure → GTCS.

07:13:10 Patient wakes up

07:13:18 Forced head and eye version to the left (to the side and up)

07:13:27 Figure 4 sign with the left arm extended; mouth pulled to the left and a GTCS begins

07:14:20 Clonic jerking of the right arm (asymmetric termination of GTCS)

Legend for video sequence 5

Patient 5: A 32-year-old man with temporal lobe epilepsy. Seizure patterns were documented from both temporal lobes. MRI was normal. Ictal EEG showed unilateral right temporal rhythmic delta activity.

Aura → Automotor seizure → left versive seizure → GTCS.

20:24:08 Bimanual and oral automatisms

20:24:18 Patient presses alarm button, but will not remember the aura after the seizure

20:24:28 Oral automatisms

20:24:30 Patient does not follow commands, left manual automatisms (note: no dystonic posturing of the right arm)

20:24:47 Forced head and eye version to the left

20:24:52 Figure 4 sign, left arm extended; followed by GTCS

Legend for video sequence 6

Patient 6: A 52-year-old woman with left mesial temporal lobe epilepsy. MRI revealed mesial temporal sclerosis. Ictal EEGs were localised to the left mesio-temporal region.

Automotor seizure → GTCS.

09:35:22 Mild oral automatisms

09:35:27 Non-forced head deviation to the left

09:35:37 Dystonic posturing of the right hand, mild left manual automatisms

09:35:49 Does not follow commands

09:36:18 Figure 4 sign, right arm extended

09:36:20 Beginning of GTCS

09:37:17 Clonic jerking of the left leg (asymmetric termination of GTCS)

obvious in the limb that was extended earlier, thus giving the false impression that the figure 4 sign shifted between sides during the seizure (*patient 10; see video sequence 10*). The initial asymmetric limb

Legend for video sequence 7

Patient 7: A 31-year-old man with left mesial temporal lobe epilepsy, secondary to left mesial temporal sclerosis. EEGs were localised to the left mesiotemporal region.

Epigastric aura → aphasic seizure.

09:19:15 Presses alarm button because of an epigastric aura

09:19:24 Follows command to raise the right arm

09:19:34 Unable to name objects

09:19:36 Dystonic right hand posturing; left hand covered, but close inspection ruled out any movement

09:19:40 Follows the command (protrudes his tongue)

09:19:55 Still dystonic posturing of the right hand; catches pen with the left hand, although he is right-handed

09:20:00 Unable to name a pen but describes its function (ictal aphasia)

Legend for video sequence 8

Patient 8: A 44-year-old man with left mesial temporal epilepsy, secondary to hippocampal sclerosis. Ictal EEGs showed seizure patterns in the left temporal region.

Aura → automotor seizure.

15:39:30 Presses alarm button

15:39:36 Left manual automatisms (unilateral automatism)

15:39:38 Does not respond or follow commands

15:39:44 Dystonic posturing of the right hand

15:39:58 Still does not respond or follow commands

15:40:30 Does not move the right arm (immobile limb)

15:40:39 Says his first name

15:40:43 Postictal nose rubbing with the left hand

15:40:45 Follows commands

15:40:49 Unable to name objects, still does not move right arm (postictal immobile limb)

15:40:52 Describes the function of a toothbrush (postictal aphasia)

15:40:57 Unable to name a spoon

15:41:19 Unable to name a pen

15:41:25 Describes the function of a pen

posturing is contralateral to the side of ictal onset (Kotagal *et al.*, 2000).

The patients in *video sequences 11* and *12* demonstrate that the lateralising features should always be interpreted in the context of seizure evolution and recorded ictal EEG, otherwise false lateralising information may be given.

In *video sequence 11*, the first position, in which the right arm is extended and the left arm flexed, resembles asymmetric limb posturing (18:20:17), although this should not be considered at this stage of the seizure as a significant lateralising sign since the seizure does not undergo secondary generalisation (EEG shows a right temporal seizure pattern). The figure 4 sign which occurred later (18:21:32) with the right arm extended prior to the GTCS has lateralising significance and leads to the conclusion that seizure onset is in the left hemisphere. The asymmetric tonic limb posturing gives lateralising information regarding propagation (EEG shows a left temporal seizure pattern seconds before), but not about the seizure onset zone (which is right temporal).

In *video sequence 12*, the patient shows a figure 4 sign-like position (13:08:04) with the right arm extended and the left arm flexed at the elbow. When asked to raise her arms, she was able to follow the command (13:07:46) and voluntarily extended the left elbow with the right arm outstretched, but not tonically extended. The seizure did not undergo secondary generalisation. The posture of this patient should therefore not be referred to as a figure 4 sign. We observed some clonic jerks of the left arm (13:08:07), indicating that the seizure onset was located in the right hemisphere. For a figure 4 sign, the left arm would normally be tonically extended. Paying attention to seizure evolution rather than overemphasising single seizure phenomena is necessary for accurate analysis of seizure semiology (Henkel *et al.*, 2002).

Legend for video sequence 9

Patient 9: A 21-year-old man with left focal epilepsy of unknown origin. EEGs showed seizure patterns in the left frontotemporal region.

Dialectic seizure → right versive seizure → GTCS.

01:33:35 Does not respond or follow commands (for 90s)

01:33:38 Head version to the right (late in seizure evolution)

01:33:53 Figure 4 sign, right arm extended

01:33:55 GTCS

Unilateral ictal eye blinking

Unilateral blinking as a lateralising sign in seizures originating from the temporal lobe was first reported by Wada (Wada, 1980). Ictal eye blinking (*patient 13*; see *video sequence 13*) is a rare motor phenomenon (0.8–1.5%) which is observed in temporal and extratemporal epilepsies and is highly suggestive of ipsilateral seizure onset (Benbadis *et al.*, 1996; Henkel *et al.*, 1999). The symptomatogenic zone generating ipsilateral blinking is still unclear.

Legend for video sequence 10

Patient 10: A 35-year-old man with bitemporal epilepsy. Ictal EEG of the video-documented seizure was localised to the right temporal region.

Left versive seizure → GTCS.

20:38:33 Non-forced head version to the right

20:38:36 Patient falls back in bed, head version to the left

20:38:43 Proximal movement of both legs

20:38:46 Figure 4 sign, left arm extended; mouth pulls to the left; generalised tonic phase of the following GTCS

20:38:50 Extension of both arms

20:38:56 Bilateral clonic movements more prominent in the left arm, while the right arm remains extended (note: situation may be subject to false description due to “side-shifting” of figure 4 sign)

20:39:24 Clonic movements of the right arm and leg (asymmetric termination of the GTCS)

Ictal nystagmus

Ictal nystagmus is associated with ictal EEG onset, contralateral to the fast phase of the nystagmus (*patient 14*; see *video sequence 14*). This lateralising sign often occurs in epilepsies originating from posterior brain regions (Kaplan and Tusa, 1993; Stolz *et al.*, 1991; Tusa *et al.*, 1990) and has been observed in 10% of patients with occipital lobe epilepsy (Salanova *et al.*, 1992).

Negative motor phenomena

Epileptic negative myoclonus

An epileptic negative myoclonus consists of short (ca. 30–400 ms) phases of muscle atonia and is clinically observed only during muscle contraction, *i.e.*, it does not occur when the patient is at rest (*patient 15*; see *video sequence 15*) (Tassinari and Gastaut, 1969). Generalised and focal negative myoclonic seizures have been described previously (Guerrini *et al.*, 1993). Polygraphic recordings have shown that the focal negative motor phenomena are frequently preceded by epileptiform discharges in the contralateral central region (20–30 ms before atonia). The primary somatosensory motor cortex (Ikeda *et al.*, 2000), the premotor cortex (Baumgartner *et al.*, 1996; Meletti *et al.*, 2000) and the postcentral cortex (Noachtar *et al.*, 1997) have been identified as possible generators.

Ictal unilateral akinesia/immobile limb

Ictal akinesia (*patients 8, 16 and 17*; see *video sequences 8, 16 and 17*) was observed in 5.8% of patients with focal epilepsy (Oestreich *et al.*, 1995) and 11.8% of patients with temporal lobe epilepsy (Bleasel *et al.*, 1997) and points to the contralateral hemisphere as the site of seizure onset (Bleasel *et al.*,

Legend for video sequence 11

Patient 11: A 39-year-old woman with right focal epilepsy, secondary to a right perinatal lesion. The EEG description is given for this patient because the ictal EEG pattern switches between sides and the lateralising signs can only be appreciated with regards to the ictal EEG and the spread pattern.

Aura of left arm → left-sided clonic seizure → right versive seizure → GTCS.

18:19:37 Presses alarm button, recognizes “crampling” of the left arm

EEG: Generalised attenuation

18:19:47 Follows commands, says her first name

18:19:53 Trembling of the left arm

18:19:55 Does not follow the command to stretch both arms

18:20:08 Jerking of the left arm

18:20:17 Flexed left elbow and extended right arm; the resulting position resembles asymmetric tonic limb posturing but should not be classified as figure 4 sign because the seizure does not undergo secondary generalisation at this point

18:20:18 Non-forced eye and head-deviation to the left, and irregular jerking of the left leg and right arm

18:20:45 Clonic movements more prominent on the left (face, arm, and leg)

EEG: Right posterior temporal rhythmic theta activity

18:21:22 Cessation of jerks on the left

18:21:23 Head and eye deviation to the right

EEG: left rhythmic theta activity

18:21:32 Figure 4 sign (right arm extended, left arm flexed) evolving into a secondary GTCS

EEG: artefact obscured

1997; Noachtar and Lüders, 1999; Oestreich *et al.*, 1995). Since there was a poor interobserver agreement for this lateralising sign in a previous study (Bleasel *et al.*, 1997), increased muscle tone or dystonic posturing as an explanation for the absence of movement must be clearly ruled out. Akinetic seizures of the contralateral arm seem to be caused by epileptic activation of one of the negative motor areas which is located in the frontal lobe, immediately anterior to the motor face area, close to Broca's speech area and anterior to the face region of the supplementary sensorimotor area (Lüders *et al.*, 1995).

Ictal automatisms

Unilateral manual automatisms

Unilateral automatisms (*patients 16 and 17*; see *video sequences 16 and 17*) were reported to be associated with ipsilateral seizure onset (Wada, 1982). This observation is frequently associated with more or less

Legend for video sequence 12

Patient 12: A 44-year-old woman with right neocortical temporal lobe epilepsy of unknown origin. Ictal EEGs revealed seizure patterns in the right posterior temporal region.

Automotor seizure.

13:07:37 Oral automatisms

13:07:43 Test to remember the word "blue"

13:07:46 Follows the command to raise both arms

13:07:48-13:08:04 Says her first name, names objects and remembers the word "blue" (automatisms with preserved responsiveness)

13:08:04 Left elbow flexed, while right arm is outstretched (no figure 4 sign)

13:08:07 Some clonic jerks of the left arm

13:08:14 Follows command to raise both arms

13:08:30 Describes nausea

Legend for video sequence 13

Patient 13: A 39-year-old man with left temporo-parietal lobe epilepsy of unknown origin. Seizures consisted of somatosensory auras of the right side of the face and body followed by aphasic seizures.

Aphasic aura.

0:00 Left eye blinking, patient describes difficulties in speaking and speaks slowly but coherently

0:30 End of unilateral eye blinking

Legend for video sequence 14

Patient 14: A 23-year-old woman with focal epilepsy of unknown origin. Ictal EEGs were localised to the left occipital region.

Clonic seizure affecting the eyes (right nystagmus) → right versive seizure (→ GTCS).

14:30:15 Nystagmus (fast phase of the nystagmus to the right)

14:30:17 Does not say her first name, does not follow commands, and speaks incoherently

14:30:15 Forced head and eye version to the right (followed by a GTCS)

obvious dystonia of the contralateral hand or arm. The lateralising significance of dystonic hand posturing alone is greater than that of ipsilateral automatisms alone (*patients 6 and 8; see video sequences 6 and 8*) (Kotagal, 1991; Mirzadjanova et al., 2010). In Patient 5, unilateral left-sided automatisms without contralateral dystonic posturing gave false lateralising information whereas during seizure evolution, the left-sided versive seizure and the figure 4 sign pointed to seizure onset in the right hemisphere.

Legend for video sequence 15

Patient 15: A 21-year-old woman with left perirolandic epilepsy, secondary to centroparietal dysplasia. Seizures consisted of somatosensory auras of the right hand followed by focal clonic seizures of the right arm, evolving into GTCS. Since the age of six she had negative myoclonic jerks of the right arm. Epileptic negative myoclonus occurred whenever she exerted tonic activity in the right arm. EMG, recorded from the right thenar and deltoid muscles, demonstrated silent periods of EMG activity lasting for approximately 100 to 200 ms.

Right arm negative myoclonic seizure.

14:53:32 Follows the command to raise both arms and negative myoclonus is observed during muscle activation of the right arm

14:53:52 Follows the command to protrude the tongue

Legend for video sequence 16

Patient 16: A 42-year-old man with right temporal lobe epilepsy of unknown origin. Ictal EEGs were localised to the right mesiotemporal region.

Automotor seizure.

16:56:51 Presses alarm button

16:56:55 Right manual automatisms (repetitive hitting on the thigh), left arm and leg are immobile, repetitive sniffing

16:57:10 Does not follow commands

16:57:12 Non-forced eye and head deviation to the right, bilateral eye blinking, oral automatisms

16:57:27 Repetitive head-nodding, proximal right leg movements and right manual automatisms, whereas left arm and leg are immobile

16:58:04 Says his first name

16:58:07 Follows command to raise both arms

Automatisms with preserved responsiveness

Preserved responsiveness during automatisms (*patients 12, 18 and 22; see video sequences 12, 18 and 22*) was observed in 10% of patients with right temporal lobe epilepsy (Ebner et al., 1995; Noachtar et al., 1992). So far, one patient with left mesial temporal lobe epilepsy and right hemisphere speech dominance has been reported (Park et al., 2001).

Ictal autonomic symptoms

Ictal urinary urge

Urinary urge is typically expressed ictally or postictally. Patient 19 (*see video sequence 19*) with right frontal lobe epilepsy presented with an urge to go to the bathroom immediately postictally after each of his five

Legend for video sequence 17

Patient 17: A 41-year-old woman with left focal epilepsy of unknown origin. EEG during this seizure revealed a non-lateralised seizure pattern.

Automotor seizure.

14:30:13 Bilateral manual automatisms (fumbling)
14:30:24 Unilateral left manual automatisms; right arm is immobile
14:31:26 Cessation of left manual automatisms
14:31:37 Tonic abduction of the right arm (no simultaneous left manual automatisms)

Legend for video sequence 18

Patient 18: A 31-year-old man with right temporal lobe epilepsy, secondary to mesial temporal sclerosis. Ictal EEGs were localised to the right temporal lobe.

Automotor seizure.

15:09:05 Automatisms, right > left hand and left foot
15:09:19 Test to remember the word "car"
15:09:23 Does not respond or follow commands
15:09:31 Follows commands during automatisms
15:09:34 Says his first name
15:09:38 Unable to stop automatisms
15:09:44 Able to name a water bottle
15:10:00 Able to name a cup

Legend for video sequence 19

Patient 19: A 44-year-old man with right frontal lobe epilepsy of unknown origin who became seizure-free after resective surgery of the right frontal lobe. In the event of a seizure, he felt an urge to go to the bathroom postictally.

Automotor seizure.

01:54:42 Repetitive high-amplitude manual automatisms, repetition of verbal phrases
01:54:55 Unable to say his first name; manual automatisms
01:55:02 Follows the command to raise arms
01:55:04 Says his first name
01:55:12 Able to name objects
01:55:19 Gets up to go to the bathroom with urinary urge

Legend for video sequence 20

Patient 20: A 26-year-old man with right temporal lobe epilepsy of unknown origin. Ictal EEGs showed right temporal seizure pattern.

Dialeptic seizure.

13:16:13 Repetitive spitting
13:16:16 Does not respond or follow commands

recorded seizures. This symptom was associated with non-dominant temporal lobe seizure onset in a series of six patients, whose seizures were characterised by an aura of ictal urinary urge (Baumgartner *et al.*, 2000). These results were confirmed by an additional six patients (0.4% of all patients with temporal lobe epilepsy) in a series of 3,446 patients who underwent video-EEG monitoring (Loddenkemper *et al.*, 2003).

Ictal spitting

Ictal spitting (*patient 20; see video sequence 20*) is a rare epileptic phenomenon in focal epilepsy and indicates a seizure onset in the non-dominant temporal lobe. Of the patients studied in monitoring units, 0.3% presented with ictal spitting. EEG onset was lateralised to the right non-dominant hemisphere in all 12 patients evaluated recently (Kellinghaus *et al.*, 2003). In another study (Voss *et al.*, 1999), ictal spitting was present in five of 2,500 patients; all five patients had right temporal lobe epilepsy as determined by seizure freedom or greater than 90% seizure reduction after epilepsy surgery (Voss *et al.*, 1999). Recently, a case with ictal spitting in a patient with a left mesial temporal epilepsy was reported (Ozkara *et al.*, 2000). Interestingly, the intracarotid amobarbital test demonstrated a right hemispheric speech dominance. Thus, this observation again supports the finding that ictal spitting is associated with seizure onset in the non-dominant hemisphere.

Periictal water drinking

Periictal water drinking (*patient 21; see video sequence 21*) as a localising sign was first reported in a large series of patients in 1981 by Remillard; it was proposed that ictal drinking is caused by epileptic discharges arising from the temporal lobe (Remillard *et al.*, 1981). The lateralising significance of this phenomenon was later described in seven patients with

Legend for video sequence 21

Patient 21: A 37-year-old woman with right temporal lobe epilepsy of unknown origin. Ictal EEG showed a right temporal seizure pattern.

Aura → automotor seizure.

06:44:12 Patient wakes up, opens her eyes
06:44:29 Presses alarm button
06:44:37 Fumbling with the right hand
06:44:46 Reaches for a bottle
06:44:49 Speaks incoherently to the EEG technician
06:44:53 Opens a bottle and drinks water
06:45:03 Dystonic posturing of the left arm

temporal lobe epilepsies of the non-dominant hemisphere and the incidence was reported to be 15.3% (Trinka *et al.*, 2003).

Ictal unilateral piloerection

Pilomotor seizures occur unilaterally or bilaterally and are classified as a subtype of autonomic seizures. Unilateral piloerection is a rare phenomenon in epileptic seizures (0.14%), predominantly occurring in patients with temporal lobe epilepsy (Loddenkemper *et al.*, 2004) and usually associated with a seizure onset in the ipsilateral hemisphere (Scoppetta *et al.*, 1989, Yu *et al.*, 1998).

Ictal vomiting

Ictal vomiting, defined as early paroxysmal vomiting or retching, is a rare lateralising sign in epileptic seizures. Ictal emesis was observed in 2.8% of 178 patients with medically refractory temporal lobe epilepsy (Baumgartner *et al.*, 1999). In a series of 31 patients with temporal lobe epilepsy, 10% showed ictal vomiting or retching and an epigastric aura was strongly correlated with the occurrence of ictal vomiting (Kotagal *et al.*, 1995). This symptom predicts an ictal onset in non-dominant temporal lobe epilepsy (Devinsky *et al.*, 1995; Kotagal *et al.*, 1995; Kramer *et al.*, 1988). Three patients with ictal emesis during dominant temporal lobe onset seizures have also been described (Chen *et al.*, 1999; Schauble *et al.*, 2002). Former studies suggest that the insular cortex and medial and lateral temporal structures are associated with nausea and vomiting in epileptic seizures (Baumgartner *et al.*, 1999; Fiol *et al.*, 1988; Kramer *et al.*, 1988; Penfield and Jasper, 1954)

Ictal speech

Ictal speech (*patient 22; see video sequence 22*), defined as "intact speech mechanisms consisting of identifiable (clearly understandable) words or phrases well articulated and linguistically correct" (Gabr *et al.*, 1989) usually indicates the non-dominant hemisphere as the site of seizure onset. In 83-100% of the investigated patients with ictal speech, seizures arose from the non-dominant temporal lobe (Chee *et al.*, 1993; Fakhoury *et al.*, 1994; Koerner and Laxer, 1988; Steinhoff *et al.*, 1998). Ictal speech and automatisms with preserved responsiveness overlap with one another to some extent (Ebner *et al.*, 1995; Noachtar *et al.*, 1992), however, these two phenomena have so far not been evaluated simultaneously.

Postictal lateralising signs

Postictal aphasia

Postictal aphasia (*patients 8 and 23; see video sequences 8 and 23*) is a common feature in seizures originating from the temporal lobe and is suggestive of a seizure onset in the speech dominant hemisphere (Fakhoury *et al.*, 1994; Gabr *et al.*, 1989). It can be difficult to clarify the type of aphasia, such as motor (Broca) aphasia or sensorial (Wernicke) aphasia or distinguish between aphasia and impaired consciousness with motor dysfunction. Therefore, specialised testing during and after the seizure in video-EEG monitoring

Legend for video sequence 22

Patient 22: A 50-year-old man with temporal lobe epilepsy. The video documents part of a status epilepticus with recurrent right temporal EEG seizure patterns.

Confusional status epilepticus.

All along Plays a game of dice with her visitor

15:28:48 EEG: beginning of right temporal seizure pattern

15:29:04 Erroneously thinks it is the partner's turn; the partner corrects her: "it is your turn" but she does not respond properly

15:29:16 Speaks in grammatically correct sentences ("It's your turn. Come on. It's your turn again...")

15:29:22 Singing-like vocalization

15:29:55 Arrest reaction, staring

15:30:22 EEG: end of rhythmic right temporal seizure pattern

Legend for video sequence 23

Patient 23: A 26-year-old woman with temporal lobe epilepsy (who was diagnosed with hippocampal sclerosis and meningitis at the age of 2.5 years). During video-EEG monitoring, ictal EEG onset from both temporal lobes was documented. The video-documented seizure shows ictal EEG onset in the left mesiotemporal region.

End of dialectic seizure.

21:24:15 Does not respond or follow commands

21:24:30 Unable to name a pen

21:24:36 Demonstrates the function of a pen

21:24:44 Describes the function of a pen, but unable to name a pen

21:25:06 Unable to name a spoon

21:25:17 Describes the function of a spoon

21:25:31 Unable to name a toothbrush, but demonstrates its use

units is required. Postictal aphasia can be observed more frequently than ictal aphasia (*patient 7*; see *video sequence 7*). A possible reason for this observation may be the frequently altered consciousness during seizures originating from the non-dominant temporal lobe which makes it difficult to reliably test ictal speech (Gabr *et al.*, 1989).

Postictal nose rubbing

Postictal nose rubbing (*patients 8, 24 and 25*; see *video sequences 8, 24 and 25*) is a frequent and easy-to-assess lateralising sign in patients with temporal lobe epilepsy (Geyer *et al.*, 1999; Leutmezer *et al.*, 1998a; Wennberg, 2001). The hand used for nose rubbing was ipsilateral to the hemisphere of seizure onset in 45.2-97.3% of all patients with temporal lobe epilepsy (Hirsch *et al.*, 1998; Leutmezer *et al.*, 1998a; Wennberg, 2001) with no statistically significant difference between right and left temporal lobe epilepsy. The ipsilateral hand is most probably used due to mild paresis or neglect of the contralateral arm (Leutmezer *et al.*, 1998a).

Legend for video sequence 24

Patient 24: A 31-year-old woman with multifocal epilepsy due to bilateral perisylvian dysplasia. The video-documented seizure shows left temporal EEG seizure onset.

Postictal phase of a dialeptic seizure.
 13:26:48 EEG: end of left temporal seizure pattern
 13:27:20 Does not respond
 13:27:26 Unable to name a pen
 13:27:29 Coughing and repetitive nose rubbing with the left hand
 13:27:33 Does not respond or follow commands

Postictal coughing

Postictal coughing (*patients 24 and 25*; see *video sequences 24 and 25*) can be observed in patients with temporal lobe epilepsy in 9-13% and seems to be associated with postictal nose rubbing (Gil-Nagel and Risinger, 1997; Wennberg, 2001). It is less common in patients with extratemporal epilepsy (Fauser *et al.*, 2004; Wennberg, 2001). Formerly, postictal coughing was considered as a right mesiotemporal seizure sign without statistical significance (Gil-Nagel and Risinger, 1997; Wennberg, 2001), however, Fauser *et al.* recently published a statistically significant predominance of left temporal seizure onset in seizures with postictal coughing. The lateralising value of postictal coughing therefore remains unclear.

Legend for video sequence 25

Patient 25: A 36-year-old man with right temporal lobe epilepsy. MRI revealed right-sided hippocampal sclerosis. Ictal EEGs showed seizure onset in the right temporal lobe.

End of automotor seizure.
 16:48:15 EEG: beginning of right temporal seizure pattern
 16:48:55 Does not respond or follow commands
 16:49:00 EEG: end of rhythmic right temporal seizure pattern
 16:49:06 Coughing
 16:49:09 Nose rubbing with right hand
 16:49:11 Coughing
 16:49:15 Does not say his first name

Postictal paresis

Postictal paresis (*patients 1, 3 and 8*; see *video sequences 1, 3 and 8*) is one of the oldest known lateralising signs, first published in 1827 (Bravais, 1827). It is a relatively frequent lateralising sign and incidence ranges in different studies from 6.1-40% (Adam *et al.*, 2000; Gallmetzer *et al.*, 2004; Leutmezer *et al.*, 1998b; Rolak *et al.*, 1992). Postictal paresis provides excellent lateralising information as it appears regularly contralateral to the seizure onset zone (Adam *et al.*, 2000; Gallmetzer *et al.*, 2004; Kellinghaus and Kotagal, 2004; Leutmezer *et al.*, 1998b). Postictal paresis seems to be more frequent in patients with underlying focal brain lesions (Adam *et al.*, 2000; Rolak *et al.*, 1992), as well as in seizures with tonic or clonic phenomena (Gallmetzer *et al.*, 2004; Kellinghaus and Kotagal, 2004).

Conclusion

The purpose of this review was to illustrate common lateralising semiological features. The semiological analysis of the signs and symptoms occurring during epileptic seizures provides important information for the localisation of the epileptogenic zone. It is important to pay attention to seizure evolution rather than overemphasising single seizure phenomena. This information is helpful for the evaluation of patients considered for epilepsy surgery. □

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