**Supplementary material 1**

**Search strategy**

Web of Science

ICTAL onset pattern" (All Fields) or "seizure onset pattern" (All Fields) or "seizure pattern" (All Fields) or "ictal pattern" (All Fields) and intracranial EEG (All Fields) or SEEG (All Fields) or "STEREO-ELECTRO-ENCEPHALOGRAPHY" (All Fields)

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1. (((((((((Ictal onset pattern) OR (seizure onset pattern)) OR (seizure pattern)) OR (ictal pattern)) OR (limbic spiking)) OR (perictal spiking)) [All Fields] AND (intracranial EEG)) OR (SEEG)) OR (Stereoelectroencephalography)) OR (stereo-electro-encephalography)

Filters: Classical Article, Clinical Study, Clinical Trial, Comparative Study, Meta-Analysis, Multicenter Study, Observational Study, Humans, Exclude preprints

2. Seizure onset pattern [All Fields] AND intracranial EEG

3. Ictal onset pattern [All Fields] AND SEEG

4. Seizure onset pattern [All Fields] AND SEEG

5. Limbic spiking [All Fields] AND SEEG

6. Perictal spiking [All Fields] AND SEEG

7. Preictal spiking [All Fields] AND SEEG

8. Seizure pattern [All Fields] AND SEEG **Supplementary material 2 Definition of the SOPs in all the included papers**

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| --- | --- | --- | --- |
| **First author** | **SOP** | **Definition** | **Classification\*** |
|  |
| Velasco *et al.,* 2000 | Low-voltage fast activity | High-frequency, low- amplitude discharges over 10 Hz. | LVFA & sharp activity (theta, alpha) |  |
| Hypersynchronous activity | Low-frequency, high-amplitude spikes having a frequency under 2 Hz, and lasting more than 5 sec. | LFPS |  |
| Schuh *et al.,* 2000 | Ictal spiking | Repetitive rhythmic or periodic spike discharges occurring at a frequency of <2 Hz with a typical duration of 5—100 s seen before subsequent sustained rhythmic discharges of any frequency. | LFPS |  |
| Chassoux *et al.,* 2000 | LVFA | Amplitude < 10 µV and frequency at least in the Beta range. | LVFA |  |
| Rhythmic spike discharges | Preictal activity prior to LVFA with high frequency fast discharges (a brief (1-3 s) epoch between rhythmic spikes and LVFA, consisting of high frequency spikes (10 times the preceding rhythmic spikes)). | Preictal spiking prior to LVFA |  |
| Bartolomei *et al.,* 2005 | Slow rhythmic spikes | Low-frequency (*<*2 Hz); high-amplitude rhythmic spiking followed by a tonic discharge. | LFPS prior to LVFA |  |
| Tonic discharge | Tonic discharge without prior spiking activity | LVFA |  |
| Dolezalova *et al.,* 2013 | Fast ictal activity | Frequency ≥ 8 Hz. | LVFA & sharp activity (theta, alpha) |  |
| Slow ictal activity | Frequency <8 Hz. | Sharp activity theta, alpha), LFPS, & Delta activity |  |
| Attenuation of background activity | No clear-cut rhythmic activity during the first 3 s associated with changes of IEEG signal (increase of frequency, decrease of amplitude). | ED |  |
| Perucca *et al.,* 2014 | Low-voltage fast activity | Clearly visible rhythmic activity >13 Hz, usually 10 µV in initial amplitude. | LVFA |  |
| Low-frequency high-amplitude periodic spikes | High-voltage spiking at 0.5–2 Hz, lasting 5 s. | LFPS |  |
| Sharp activity | Sharp activity at ≤ 13 Hz, low- to medium-voltage sharply contoured rhythmic activity, most commonly in the alpha- theta range. | Sharp activity (theta, alpha) |  |
| Spike-and-wave activity | Medium- to high-voltage spike-and-wave complexes typically occurring at a frequency of 2–4 Hz. | Rhythmic spikes/spike-waves |  |
| Burst of high amplitude polyspikes | A single brief burst of repetitive high-voltage spikes. | Burst of polyspikes prior to LVFA |  |
| Burst suppression | Brief bursts of medium- to high-voltage repetitive spikes alternating with brief periods of voltage attenuation. | Burst suppression |  |
| Delta brush | Rhythmic delta waves at 1–2 Hz, with superimposed brief bursts of 20–30 Hz activity overriding each delta wave. | Delta-Brush |  |
| Lagarde *et al.,* 2016 | Low-voltage fast activity | Rhythmic fast oscillations >14 Hz (median frequency 36 Hz, range 14– 97) starting apparently with no initial changes and with low initial amplitude <30 µV. | LVFA |  |
| Preictal spiking followed by LVFA | Rhythmic spikes of low frequency (median 1.5 Hz, range 1–3), high amplitude (median 660 µV, range 450–1,400), prolonged duration (median 20 s, range 4–130) followed by LVFA with lower frequency than isolated LVFA (median 23 Hz, range 19.5–32). | LFPS prior to LVFA & preictal spiking prior to LVFA |  |
| Burst of polyspikes followed by LVFA | Burst of polyspikes of high frequency and amplitude (median frequency 19.3 Hz, range 12.5–24.5, median amplitude 420 µV, range 260–800) and short duration (median 3.3 s, range 0.5–6) followed by LVFA (median frequency 28 Hz, range 15.5–37). | Burst of polyspikes prior to LVFA |  |
| Slow wave/DC shift followed by LVFA | Slow wave or baseline shift (median amplitude 400 µV, range 250–500) followed by LVFA (median frequency 31 Hz, range 20–108). | Baseline shift prior to LVFA |  |
| Theta/alpha sharp waves | Theta/alpha sharp activity with the lowest frequency (median 9.5 Hz, range 6–11), and progressive increasing amplitude (median 400 µV, range 80–750). | Sharp activity (theta, alpha) |  |
| Rhythmic spikes/spike-waves | Rhythmic spikes or spike-waves, at lower frequency (median 3.5 Hz, range 4–18) and with high amplitude (median 1,200 µV, range 900–1,500). | Rhythmic spikes/spike-waves |  |
| Ferrari-Marinho *et al.,* 2016 | Low-voltage fast activity | Perucca et al\_2014. | LVFA |  |
| Low-frequency high-amplitude periodic spikes | LFPS |  |
| Sharp activity | Sharp activity (theta, alpha) |  |
| Spike-and-wave activity | Rhythmic spikes/spike-waves |  |
| Burst of high amplitude polyspikes | Burst of polyspikes prior to LVFA |  |
| Delta-Brush | Delta-Brush |  |
| Frauscher *et al.,* 2017 | Low-voltage fast activity | Clearly visible low voltage rhythmic activity over 10 Hz preceded or not by one spike-and-wave complex. | LVFA & sharp activity (theta, alpha), and herald spike prior to LVFA |  |
| Periodic spiking | Periodic continuous or discontinuous medium to high-voltage spiking activity at 0.5–2 Hz lasting over 5s. | LFPS |  |
| Tanaka *et al.,* 2018 | Low-voltage fast activity | Perucca et al\_2014. | LVFA |  |
| Low-frequency high-amplitude periodic spikes | LFPS |  |
| Sharp activity | Sharp activity (theta, alpha) |  |
| Spike-and-wave activity | Rhythmic spikes/spike-waves |  |
| Burst of high amplitude polyspikes | Burst of polyspikes prior to LVFA |  |
| Burst suppression | Burst suppression |  |
| Delta brush | Delta-Brush |  |
| Gnatkovsky *et al.,* 2018 | P-type seizures | Sharp‐onset/sharp‐offset transient superimposed on low‐voltage fast activity (126 ± 19 Hz). | Baseline shift prior to LVFA |  |
| L-type seizures | Low‐voltage fast activity superimposed on a slow potential shift. | Baseline shift prior to LVFA |  |
| Spasm like discharges | Short (1‐5 seconds) duration with a broad and synchronous cortical distribution. | NA |  |
| Unclassified | Rhythmic spikes or spikes‐ waves, Theta/alpha sharp activity. | NA |  |
| Lagarde *et al.,* 2019a | Low‐voltage fast activity (LVFA) | Rhythmic fast oscillations (>14 Hz) of low amplitude (<30 µV) starting without initial apparent changes. | LVFA |  |
| Preictal spiking followed by LVFA | Rhythmic spikes of low frequency (classically ≤3 Hz), high amplitude, and prolonged duration (>5 seconds, median = 20 seconds) followed by LVFA (usually of lower frequency than isolated LVFA). | LFPS prior to LVFA & preictal spiking prior to LVFA |  |
| Burst of polyspikes followed by LVFA | Burst of polyspikes of high frequency (typically >12 Hz) with high amplitude and short duration (<5 seconds) followed by LVFA. | Burst of polyspikes prior to LVFA |  |
| Slow wave/ DC shift followed by LVFA | Slow wave or baseline shift (equal to DC shift) followed by LVFA. | Baseline shift prior to LVFA |  |
| Sharp theta/alpha waves | Sinusoidal activity of low frequency (lower than LVFA, median = 9.5 Hz), median initial amplitude (higher than LVFA), and progressive increasing amplitude. | Sharp activity (theta, alpha) |  |
| Beta sharp waves | Sinusoid activity of beta-band frequency (lower than LVFA), median initial amplitude (higher than LVFA), and progressive increasing amplitude. | Beta sharp activity |  |
| Rhythmic spikes/spike‐waves | Rhythmic spikes or spike-waves, of low frequency (usually >6 Hz and constantly <14 Hz) and with high amplitude. | Rhythmic spikes/spike-waves |  |
| Delta‐brush | Bursts of low-amplitude rapid activity (within gamma frequency bands) superimposed upon low-frequency (delta) sinusoidal activity. | Delta-Brush |  |
| Di Giacomo *et al.,* 2019 | Low voltage fast activity | > 100 Hz fast activity and initial amplitude that starts abruptly and may be accompanied by DC shift or a slow wave. | LVFA & baseline shift |  |
| Fast activity | between 13 and 100 Hz with medium voltage amplitude, it is usually non-tonic activity, accompanied by DC shift or interictal spikes. | LVFA & baseline shift & preictal spiking |  |
| Rhythmic sharp activity | High-voltage sharply-contoured rhythmic activity in the alpha-theta range or spindle-like elements. | Sharp activity (theta, alpha) |  |
| Repetitive fast spikes bursts | Brief sequences of low-amplitude high frequency polyspikes, often preceded by repetitive spikes or spikes and wave complex, and followed by LVFA or FA. | Burst of polyspikes prior to LVFA |  |
| Slow burst | Repetitive high-voltage spikes or spikes and wave complex, typically recurring at a frequency of 0.5–4 Hz. | LFPS |  |
| Lagarde *et al.,* 2019b | Low‐voltage fast activity (LVFA) | Rhythmic fast oscillations (>14 Hz) of low amplitude (<30 µV) starting without initial apparent changes. | LVFA |  |
| Preictal spiking followed by LVFA | Rhythmic spikes of low frequency, high amplitude, and prolonged duration followed by LVFA. | LFPS prior to LVFA & preictal spiking prior to LVFA |  |
| Burst of polyspikes followed by LVFA | Burst of polyspikes of high frequency and amplitude and short duration followed by LVFA. | Burst of polyspikes prior to LVFA |  |
| Slow wave/ DC shift followed by LVFA | Slow wave or baseline shift followed by LVFA. | Baseline shift prior to LVFA |  |
| Sharp theta/alpha waves | Theta/alpha sharp activity with low frequency (lower than LVFA, and progressive increasing amplitude. | Sharp activity (theta, alpha) |  |
| Beta sharp waves | Rhythmic spikes of high amplitude within the beta frequency bands. | Beta sharp activity |  |
| Rhythmic spikes/spike‐waves | Rhythmic slow spikes at low frequency (under beta band) and with high amplitude. | Rhythmic spikes/spike-waves |  |
| Delta‐brush | Bursts of low-amplitude rapid activity (within gamma frequency bands) superimposed a low-frequency (delta) activity. | Delta-Brush |  |
| Feng et al., 2020 | Spike-and-wave activity | a. Spike-and-wave: high-voltage spike-and-wave or spike activity without DC shift at onset  b. Spike-and-wave DC shift: high-voltage spike-and-wave or spike activity followed immediately by DC shift at onset. | Rhythmic spikes/spike-waves |  |
| Low-voltage fast activity | fast rhythmic activity> 13 Hz, occasional >100 Hz, with low amplitude at start usually <10 mV. | LVFA |  |
| High-amplitude low-frequency periodic spikes | a. Periodic spikes subtype: high-amplitude periodic spike activities at 0.5–2 Hz, mixed with low-amplitude spike or spike-and-wave activities around 5 Hz  b. Periodic high-amplitude spike activities at 0.5–2 Hz initially, lasting > 5 s, usually evolving continuously with higher frequency. | LFPS |  |
| Burst of high amplitude polyspikes | Bursts of repetitive high- amplitude spikes lasting 1–2 s at onset. | Burst of polyspikes prior to LVFA |  |
| Rhythmic sharp activity | Low voltage rhythmic sharp activity at onset, usually within alpha theta range (at < 13 Hz). | Sharp activity (theta, alpha) |  |
| Makaram *et al.,* 2020 | Low-voltage fast activity | A low initial amplitude about <10 mV and frequency of >13 Hz with distinct observable rhythmic activity | LVFA |  |
| Low-frequency high-amplitude rhythmic spikes | High- voltage spikes at frequencies ranging between 0.5 and 2 Hz for a duration >5 s. | LFPS |  |
| Sharp activity | Sharply contoured rhythmic activity with a frequency (≤13 Hz) typically, observed in the alpha theta bands with low- to medium-amplitudes. | Sharp activity (theta, alpha) |  |
| Spike-and-wave activity | Signals with a frequency range between 2 and 4 Hz with spike and wave complexes with amplitude in medium- to high-voltage range. | Rhythmic spikes/spike-waves |  |
| Polyspikes | Repetitive spikes of high amplitude >13 Hz. | Beta sharp activity |  |
| Fierain *et al.,* 2020 | Low-voltage fast activity (LVFA) | Lagarde *et al*., 2019a, Lagarde *et al*., 2016. | LVFA |  |
| Preictal spiking followed by LVFA | LFPS prior to LVFA & preictal spiking prior to LVFA |  |
| Burst of polyspikes followed by LVFA | Burst of polyspikes prior to LVFA |  |
| Slow wave or baseline shift followed by LVFA | Baseline shift prior to LVFA |  |
| Sharp theta/alpha | Sharp activity (theta, alpha) |  |
| Rhythmic slow spikes | Rhythmic spikes/spike-waves |  |
| Beta sharp activity | Beta sharp activity |  |
| Delta-Brush | Delta-Brush |  |
| Steriade *et al.,* 2020 | Low voltage fast activity | NA | LVFA |  |
| Repetitive spikes | Repetitive spikes in amygdala, temporal pole, hippocampus. | LFPS |  |
| Synchronous onset involving the temporal pole, superior temporal gyrus and Hesch's gyrus | Repetitive spikes were recorded in the temporal pole with concurrent attenuation and low voltage fast activity was seen in Heschl’s gyrus and superior temporal gyrus. | Mixed |  |
| Synchronized spikes (amygdala, temporal pole, with early spread to peri-sylvian region) | A synchronous spike in the amygdala, temporal pole and anterior superior temporal gyrus is followed by low voltage fast activity in the Heschl’s gyrus then parietal operculum. | Herald spike prior to LVFA |  |
| Liu *et al.,* 2021 | Low-voltage fast activity | Low-voltage fast activity, followed by spikes with constant or progressive increasing amplitude confined inside the hamartoma. | LVFA |  |
| Repetitive spikes | Repetitive spikes were observed without initial apparent changes or clear-cut ictal discharges. Different from pattern A, onset discharges were observed to propagate in most of the contacts of the same electrode, including those in subcortical structures and contacts near the cortex. | Rhythmic spikes/spike-waves & LFPR |  |
| Ilyas *et al.,* 2022 | Low amplitude fast activity (LAFA) | Low voltage (<10 µV) high frequency (>13 Hz) activity. | LVFA |  |
| Hypersynchronous | Low frequency (0.5–2 Hz) high amplitude periodic spiking for more than 5 seconds. | LFPS |  |
| Sharp rhythmic activity | Rhythmic sharp activity < 13 Hz. | Sharp activity (theta, alpha) |  |
| Cui *et al.,* 2022 | LVFA | Generally fast-onset activity > 13 Hz, with an initial amplitude < 10 μV. | LVFA |  |
| Spike-and-wave activity | Medium- to high-voltage spike-and-wave complex or spike activity at seizure onset. | Rhythmic spikes/spike-waves |  |
| Low frequency high-amplitude periodic spikes | Periodic high-voltage spikes, initially at 0.5–2 Hz, lasting > 5 s. | LFPS |  |
| Burst of high amplitude polyspikes | Burst of high-amplitude repetitive spikes at seizure onset. | Burst of polyspikes prior to LVFA |  |
| Rhythmic sharp activity | Low- to medium- amplitude rhythmic, sharp activity ≤ 13 Hz, usually in the alpha–theta range. | Sharp activity (theta, alpha) |  |
| Michalak *et al.,* 2023 | Low-voltage fast activity | Rhythmic activity > 13 Hz, usually < 10uV in initial amplitude with gradually increasing amplitude. | LVFA |  |
| Herald spike followed by LVFA | A single spike, polyspiking, or spike bursts lasting < 5 seconds, followed by LVFA. | Herald spike prior to LVFA |  |
| Herald polyspike followed by LVFA |  |
| Herald burst followed by LVFA | Burst of polyspikes prior to LVFA |  |
| Low-frequency repetitive spiking | High- amplitude spiking of ≤3Hz and lasting for >5 s. | LFPS |  |
| Repetitive spiking in the theta frequency range | High-amplitude repetitive spikes in the theta, alpha, or beta frequency range (5–25 Hz), lasting for >5 s. | Rhythmic spikes/spike-waves |  |
| Repetitive spiking in the alpha frequency range |  |
| Repetitive spiking in the beta frequency range | Beta sharp activity |  |
| Rhythmic slowing in the theta, delta frequency range | Rhythmic onset of delta or theta sinusoidal/ slowing activity, with or without embedded high frequency activity. | Sharp activity (theta, alpha) & rhythmic delta activity |  |
| Electrodecrement | Attenuation of background amplitude with or without superimposed fast activity. | ED |  |

LVFA: low-voltage fast activity, LFPS: low frequency, high amplitude, periodic spikes, ED: electrodecrement, classification\*: classification based on our suggested 14 SOPs.

**Supplementary material 3 Classification of the SOPs into SOPs with and without LVFA**

|  |  |  |  |
| --- | --- | --- | --- |
| SOPs with LVFA | LVFA | SOPs without LVFA | Sharp activity (rhythmic theta/alpha activity) |
| Beta sharp activity |
| LFPS |
| Rhythmic spikes/spike-waves\* |
| Burst of polyspikes prior to LVFA |
| Burst suppression |
| Herald spike prior to LVFA | Delta activity |
| Preictal activity prior to LVFA | Delta-Brush without LVFA\* |
| Baseline shift prior to LVFA | Mixed pattern |
| Delta-Brush prior to LVFA\* | Electrodecrement |
| Rhythmic spikes/spike-waves prior to LVFA\* |

SOP: seizure onset pattern, LVFA: low-voltage fast activity, LFPS: Low-frequency periodic spikes, \* subtypes of SOP from the 14 categorized SOP (see Figure 5 in the manuscript).