From Waveforms to Workflows: EDx and the Supportive Role of LLMs in Neuromuscular care

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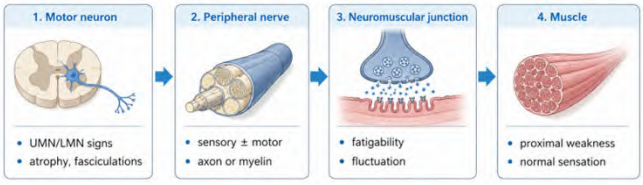
Roadmap

1. How to localize weakness
2. What EMG and NCS actually measure
3. How EDx studies support clinical reasoning
4. Why longitudinal follow-up studies matter
5. How LLMs can help
6. Pitfalls to LLM implementation

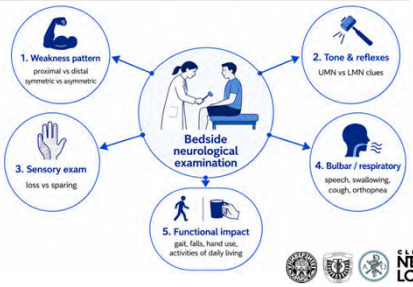
Localizing the source of weakness



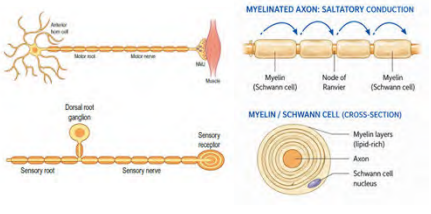
Same symptom – different anatomical level

The neurological examination

1. Bedside examination
2. Localization hypothesis
3. Advanced diagnostics



What are EDx studies?



KEY CONCEPTS

Peripheral nerves contain motor and sensory fibers

Myelin enables fast conduction between nodes of Ranvier

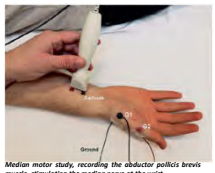
Conduction velocity depends mainly on fiber diameter and degree of myelination

Edx evaluates large myelinated fibers

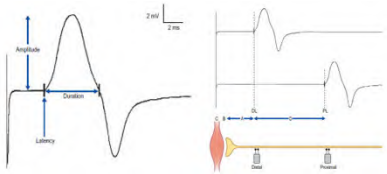
Saltatory conduction and myelination are the foundation of nerve studies

Fiber Type(s)	Name	Subtype	Diameter (mm)	Conduction Velocity (m/s)	Alternative Classification
Myelinated Somatic Afferent/Efferent					
Cutaneous afferent	A	β δ	6–12 1–5	35–75 5–30	α
Muscle afferent	A	α β δ	12–21 6–12 1–5	80–120 35–75 5–30	I Ia, Ib II III
Muscle efferent Anterior horn cells (α and γ motor neurons)	A		6–12	35–75	
Myelinated Autonomic Efferent					
Preganglionic efferent	B		3	3–15	
Unmyelinated Somatic/Autonomic Afferent/Efferent					
Postganglionic efferent	C		0.2–1.5	1–2	
Afferent to dorsal root ganglion (pain)	C		0.2–1.5	1–2	IV
Sensory Receptor	**Fiber Type**				
Hair follicle	Aβ				
Skin follicle	Aβ				
Muscle spindle	Aα				
Joint receptor	Aβ				
Pain, temperature	Aδ, C				

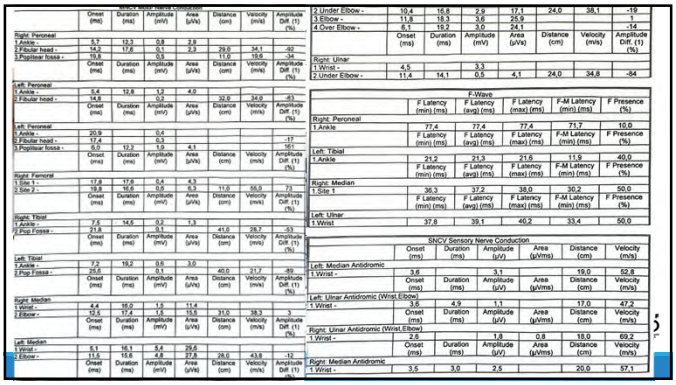
Motor Nerve Conduction Studies



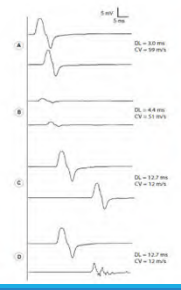
Median motor study, recording the abductor pollicis brevis muscle, stimulating the median nerve at the wrist.



Compound muscle action potential	Motor conduction velocity
Latency is the time to initial negative deflection	A) Nerve to neuromuscular junction time
Amplitude is from baseline to negative peak	B) Neuromuscular junction time
Duration is time from deflection to baseline crossing	C) Muscle depoliraziton time
	D) Nerve conduction time from proximal to distal



Basic patterns



Patterns of NCS abnormality

A) Normal study; Normal distal latency (DL) <4.4 ms, amplitude >4 mV, and conduction velocity (CV) >49 m/s

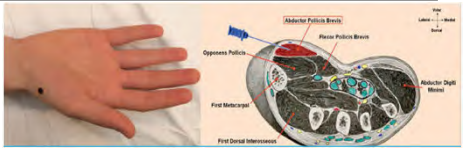
B) Axonal loss; In axonal loss lesions, amplitudes decrease; CV is normal or slightly slowed and DL is normal or slightly prolonged, The morphology of the potential does not change between proximal and distal sites.

C) Demyelination; Uniform slowing is most often associated with inherited conditions. CV is markedly slowed and DL is markedly prolonged. The morphology of the potential does not change between proximal and distal sites.

D) Demyelination with conduction block/temporal dispersion; Marked slowing of conduction velocity and distal latency, but also with change in potential morphology (conduction block/temporal dispersion) between distal and proximal stimulation sites.

Basic electromyography

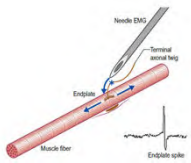
Concetric needle electrode – G1 active electrode in the center, G2 reference electrode in needle shaft



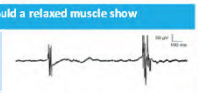
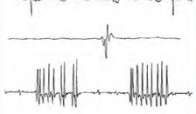
Patient preparation and examination

- First muscle selection / needle insertion into relaxed muscle
- Patient is relaxed / assessment of insertional and spontaneous activity
- Ask the patient to contract muscle / assess motor unit action potentials (MUAPs)
- Proceed to next muscle

Basic electromyography



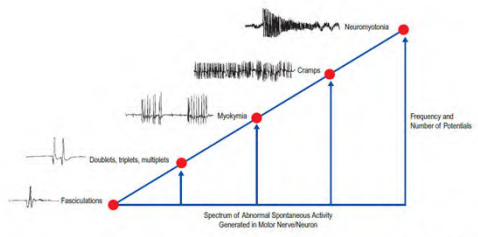
Generation of spikes on EMG

What should a relaxed muscle show	
1) Insertional activity	
2) Normal resting muscle	
3) Abnormal activity: 3a – fibrillation; 3b – fasciulation; 3c – myokimic	

Key messages

- Relaxed skeletal muscle should be mostly silent.
- Insertional activity is normal if brief.
- Fibrillations and positive sharp waves suggest active denervation or muscle membrane irritability.
- Fasciculations are spontaneous motor unit discharges and must be interpreted in clinical context.

Basic electromyography



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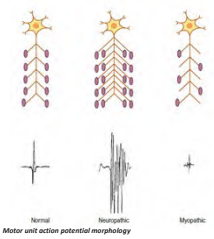


Motor unit action potential morphology

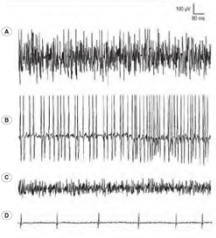
Interference pattern

A) Normal study; many motor unit action potentials (MUAPs) fire during maximal contraction that differentiating individual motor unit action potentials is difficult.

B) Neuropathic pattern; a reduced number of MUAPs fire at a high frequency, resulting in an incomplete interference pattern

C) Myopathic pattern; the number of MUAPs is normal, the interference pattern consists of short-duration, small-amplitude MUAPs, which fire with a small amount of force.

D) Central nervous system disorder; the number of MUAPs is reduced, it is appropriate for the level of firing.



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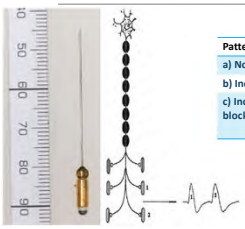
Advanced electromyography

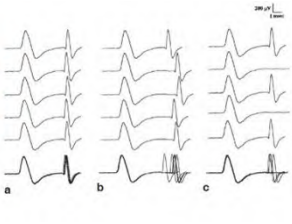

Single fiber EMG needle electrode and the variation of potential intervals

Patterns of abmormality

a) Normal study

b) Increased jitter

c) Increased jitter with blocking



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From Clinical Suspicion to EDx studies

Clinical Suspicion	EDX Strategy	What we want to know	Key tools
Motor neuron disease	NCS + needle EMG in multiple body regions	Evidence of denervation / Distribution /Exclude treatable mimics	NCS, Needle EMG
Peripheral neuropathy	Motor + Sensory NCS / Distal and proximal sampling	Axonal / Demyeliniting Focal / Generalized Sensory / Motor / Both	NCS
Neuromuscular junction Disorder	Repetitive Nerve Stimulation Single-Fiber EMG	Decrement response Increased jitter/blocking	RNS, SFEMG
Primary myopathy	Needle EMG Sample proximal muscles NCS usually normal	Myopathic pattern Irritability (active disease) Severity	Needle EMG

Clinical Question → EDX Protocol → Clinical Interpretation

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Example case

A 54-year-old woman with progressive lower-limb weakness

Timeline and symptoms

8 month progressive course

Left foot drop first

Contralateral leg involved 2 months later, also with foot drop

No pain, paresthesias or sensory loss

No upper-limb complaints

Neurologic examination

- Upper extremities: normal
- Lower extremities: spasticity
- Marked wasting below both knees
- Bilateral foot drop
- Distal > proximal leg weakness
- Brisk leg reflexes, ankle clonus
- Bilateral extensor plantar responses
- Sensory examination: normal

Clinical interpretation

Progressive pure motor symptoms

Lower motor neuron signs

Upper motor neuron signs

Sensory sparing

Clinical question: motor neuron disease, neuropathy, myopathy or other disease?

EDx should test the hypothesis, confirm LMN involvement and exclude mimics

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EDx findings in this case

Motor NCS

- Median, ulnar, tibial and peroneal motor studies are perserved;
- Normal conduction velocities with mildly prolonged distal latencies
- No abnormal proximal CMAP / No conduction block

No demyelination or conduction block

Sensory NCS

- Median, ulnar, radial and sural sensory studies are perserved;
- Normal sensory latencies and conduction velocities;

Sensory system is electrophysiologically intact

Needle EMG

- Fibrillation and fasciculation potentials in both lower limbs;
- Large amplitude and long duration MUAPS;
- Decreased recruitment;
- Diffuse denervation with reinnervation in upper extremities
- Fibrillation potentials in paraspinal muscles (T6/T8)

Active and chronic changes in multiple body regions

Changes consistent with an active, generalized disorder of motor neurons, their axons or both!

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Follow-up / Longitudinal Care

Baseline
Follow-up
Long term care decisions

Care coordination
- Neurology
- Pulmology
- PM&R
- Nutrition
- Psychology
- Caregiver support

Respiration aid
- Dyspnea /orthopnea
- Weak cough
- FVC / VC
- SNIP / MIP
- Nocturnal testing
- NIV pathway

Symptom managment
- Speech changes
- Swallowing
- Saliva regulation
- Weight changes

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The role of LLM

Summarize
Turn long notes into a structured summary

Compare
Track changes accross visits
FVC / weight / swallowing

Flag
Highlight missing data

Communicate
Draft referrals and patient-friendly explanations

INSPIRE framework, a multi-agent Edx reporting framework - 92.2% accuracy compared with 62.6% accuracy of base LLM[1]

Prospective clinical studies support physician-supervised LLM workflows[2]– High semantic similarity but shorter and more structured

Caution:
errors and workflow limitations remain

1. Gorenshtein A, Sorko M, et al. ***Agent-guided AI-powered interpretation and reporting of nerve conduction studies and EMG (INSPIRE).*** *Clinical Neurophysiology. 2025;177:2110792. doi: 10.1016/j.clinph.2025.2110792*

2. Gorenshtein A, Weisblat Y, et al. ***AI-Based EMG Reporting: A Randomized Controlled Trial.*** *Journal of Neurology. 2025;272(9):586. doi: 10.1007/s00415-025-13261-3*

The role of LLM

EDx input:
NCS / EMG tables, waveforms, symptoms

EDx validator:
Checks values against reference tables

Knowledge integrator:
Retrieval-augmented generation (RAG) adds context

Report draft synthesis:
A structured interpretation ready for review

Clinician review
Verify, edit, sign off

- Missed some mild abnormalities
- Single-fiber EMG errors occurred
- Wrong reference/column interpretation
- Hallucinated abnormal values

Not autonomous — clinician oversight remains essential

The role of LLM

Study design
Randomized controlled trial

Participants
200 EDX patients

Comparison
Physician-only reporting vs Physician + AI draft

Main finding

No significant improvement

Physician + AI did not significantly outperform physician-only reporting

What was measured?
- AIGERS report quality
- Physician acceptance / usability

Physician feedback

Trust	3.7 / 5
Efficiency	2.0 / 5
Ease of use	1.7 / 5
Workload reduction	1.7 / 5

Why it matters
- Good benchmark performance is not enough
- Workflow integration was the main barrier
- Usability and trust shape real-world value

Safety and pitfalls in LLM integration

Potential failure modes

Wrong reference values
Incorrect normal ranges or age-related thresholds

Table / column misread
Latency, amplitude, jitter or velocity interpreted incorrectly

Missing mild abnormalities
Subtle radiculopathy or early neuropathic changes

Hallucinated abnormalities
Normal values described as pathological

Context mismatch
EDX pattern does not fit the clinical question

Clinician-in-the-loop

Guardrails

Structured input
Clean NCS/EMG tables and standardized report fields

Reference locking
Use validated local / AANEM reference values

Explainable draft
Link each conclusion to specific EDX findings

Clinician sign-off
Verify localization, physiology and clinical fit

Audit trail
Track edits, errors and overridden AI suggestions

Take-home Messages

1. Edx is not just a test – it is an extension of the neurological exam
2. NCS and EMG help localize, characterize and follow diseases
3. LLMs can help reporting, summarization and tracking
4. Purpose directed LLMs are better than simple chatbots
5. No autonomous sign-off: the clinican remains responsible

Recommended reading:

Thank you for your attention!

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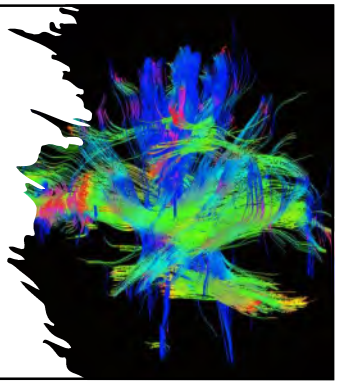
From Brain Images to Diagnostic Intelligence: CT, MRI and AI in Neuroradiology

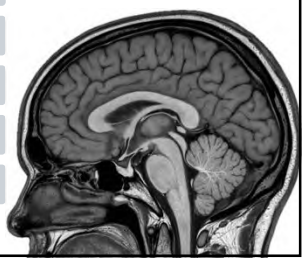


Isidora Svetozarević, MD
Center for Radiology, University Clinical Center Niš, Serbia
ChatMED Summer School: Neurology and AI Fusion

May 2026, Sokobanja, Serbia

Learning objectives

- When and why is CT used in neuroradiology?
- When and why MRI is used, and what are the major MRI sequences?
- How imaging data becomes AI tasks: segmentation, registration, classification, and longitudinal tracking.
- Why LLMs are relevant in diagnostics.
- Why diagnostic uncertainty must be preserved, not erased.



The diagnostic pathway

Examples:

- "Is this stroke or migraine?"
- "Is there bleeding?"
- "Are these white matter lesions demyelinating?"
- "Has the tumor progressed?"
- "Are there new lesions compared with the previous scan?"

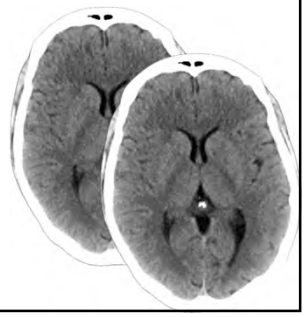
AI does not interpret images in isolation. It enters a clinical workflow.

Computed tomography - CT IN NEURORADIOLOGY

- Fast
- Widely available
- Excellent for acute neurological emergencies
- Often, the first imaging test in the emergency department.

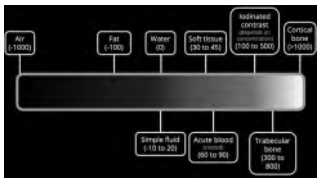
Typical clinical questions:

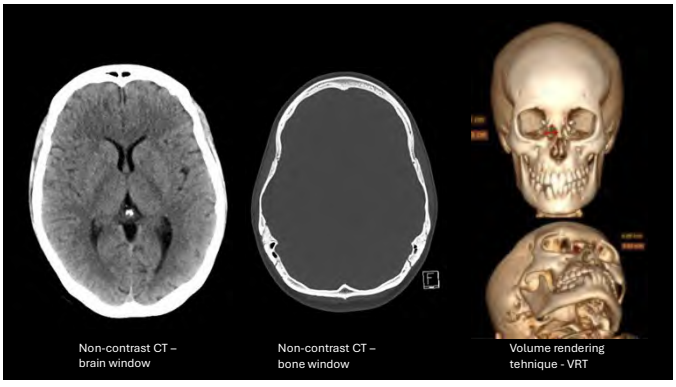
- Is there bleeding?
- Is there a large infarct?
- Is there trauma?
- Is there hydrocephalus?
- Is there mass effect?



How CT works

- CT involves ionizing radiation and X-rays to create cross-sectional images.
- Different tissues absorb X-rays differently; CT measures how much X-rays are attenuated by tissue.
- These values are expressed in **Hounsfield Units — HU**.
- The human eye cannot display or interpret the full HU range at once. Therefore, CT images are displayed using **window width** and **window level**.

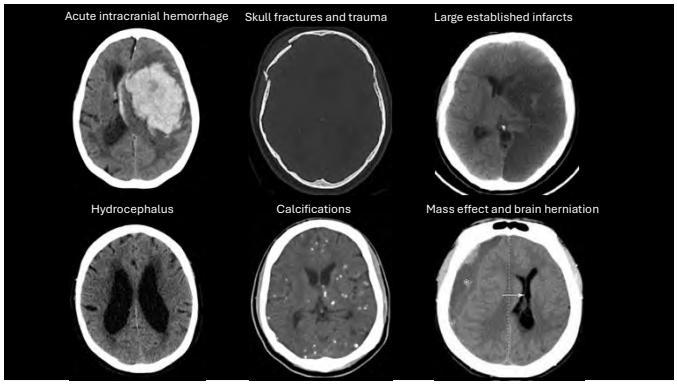




Non-contrast CT – brain window

Non-contrast CT – bone window

Volume rendering tehnique - VRT



CT angiography and CT perfusion

CT angiography - CTA

Shows arteries and occlusions.
Useful for detecting large vessel occlusion.

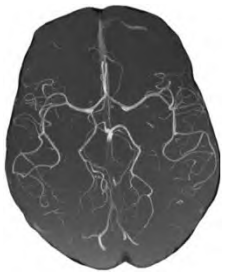
- Acute Ischemic Stroke or TIA
- Subarachnoid Hemorrhage (SAH)
- Intracerebral Parenchymal Hemorrhage
- Cerebral Venous Thrombosis (CVT)
- Aneurysm Screening:
- Vascular Stenosis & Dissection
- Vasculitis & Moyamoya Disease

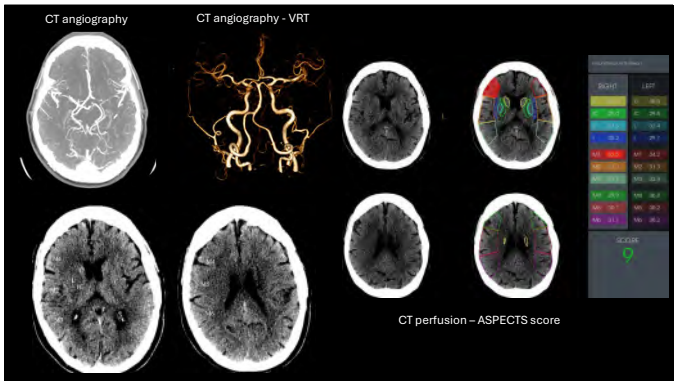
CT perfusion

Estimates blood flow.

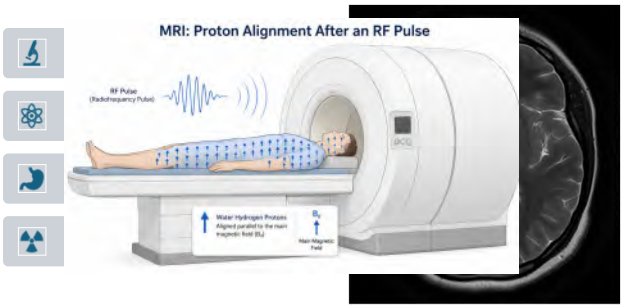
Helps distinguish infarct core from potentially salvageable penumbra.

Important for thrombectomy decisions.





How MRI works



MRI Sequences: Basic vs Advanced

Basic sequences form the routine backbone of MRI interpretation. Advanced sequences add functional, metabolic, perfusion and connectivity information.

Basic sequences		Advanced sequences	
T1-weighted Best for anatomy, brain structure and post-contrast assessment.	**T2-weighted** Highlights increased water content: edema, gliosis, tumors and inflammation.	**fMRI** Maps eloquent cortex based on blood-oxygen-level changes during brain activation.	**MR Spectroscopy** Provides metabolic information such as choline, NAA and lactate peaks.
FLAIR Suppresses CSF signal and improves detection of white matter and cortical/subcortical lesions.	**DWI / ADC** Evaluates water diffusion; critical for acute ischemia, abscess and cytotoxic edema.	**Perfusion MRI** Estimates cerebral blood volume/flow; useful in tumors and ischemia.	**DTI / Tractography** Assesses white matter microstructure and reconstructs fiber tracts.
SWI / GRE Sensitive to blood products, microbleeds, susceptibility effects and calcification correlation.	**Post-contrast T1** Shows enhancement related to blood-brain barrier disruption, tumor or inflammation.	**MRA / MRV** Non-invasive vascular imaging of arteries and veins without conventional angiography.	**Quantitative / research tools** Examples include ASL, susceptibility mapping and volumetric post-processing.

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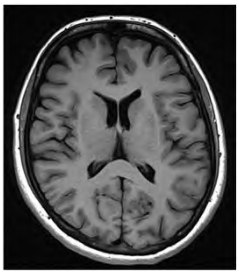

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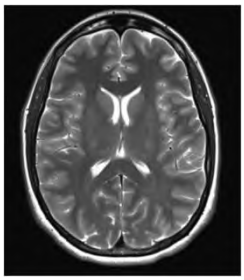

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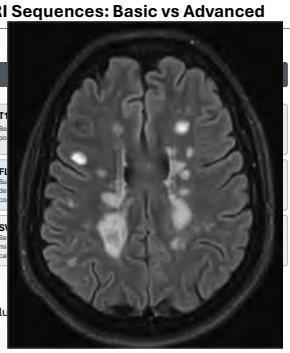

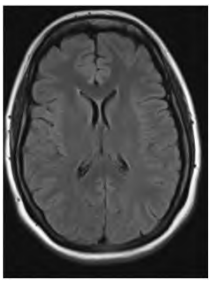

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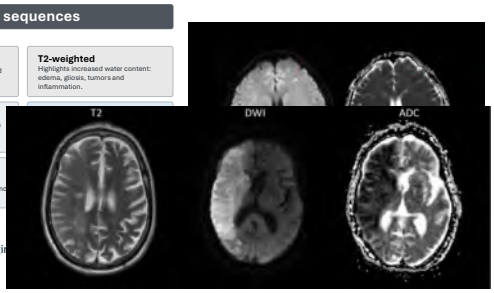
Post-contrast T1
Shows enhancement related to blood-brain barrier disruption, tumor or inflammation.

Diffusion-Weighted Imagi



MRI Sequences: Basic vs Advanced

Basic sequences

T1-weighted
Best for anatomy, brain structure and post-contrast assessment.

T2-weighted
Highlights increased water content: edema, gliosis, tumors and inflammation.

FLAIR
Suppresses CSF signal and improves detection of white matter and cortical/subcortical lesions.

DWI / ADC
Evaluates water diffusion; critical for acute ischemia, abscess and cytotoxic edema.

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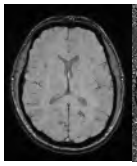
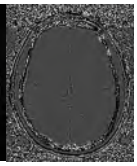
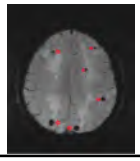
Susceptibility Weighted Imaging (SWI)



SWI: MAGNITUDE IMAGE



SWI: PHASE IMAGE



MICROBLEED APPEARANCE IN SWI

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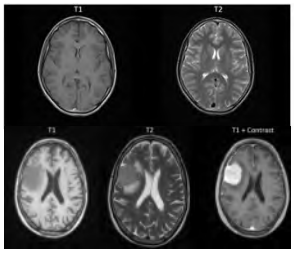

MRI Sequences: Basic vs Advanced

Basic sequences form the routine backbone of MRI interpretation. Advanced sequences add functional, metabolic, perfusion and connectivity information.

Basic sequences

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Advanced sequences

fMRI
Maps eloquent cortex based on blood-oxygen-level changes during brain activation.

MR Spectroscopy
Provides metabolic information such as choline, NAA and lactate peaks.

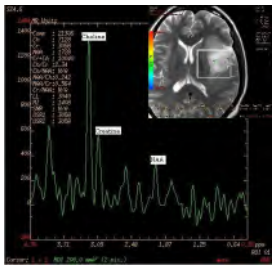
Perfusion MRI
Estimates cerebral blood volume/flow; useful in tumors and ischemia.

DTI / Tractography
Assesses white matter microstructure and reconstructs fiber tracts.

MRA / MRV
Non-invasive vascular imaging of arteries and veins without conventional angiography.

Quantitative / research tools
Examples include ASL, susceptibility mapping and volumetric post-processing.

MRI Sequences: Basic vs Advanced



Advanced sequences

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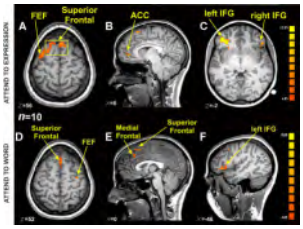

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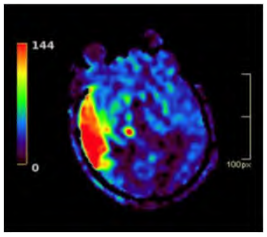

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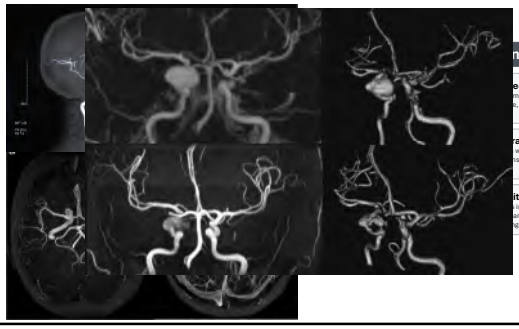
Arterial spin labeling (ASL) sequences

MRI Sequences: Basic vs Advanced



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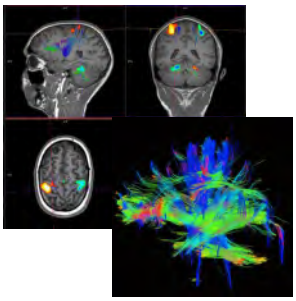

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MRI Sequences Overview

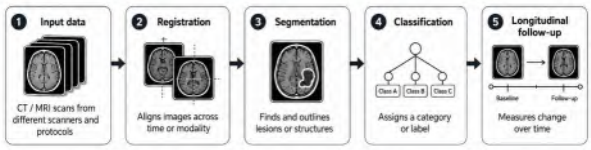
Sequence	Category	Main purpose	Typical clinical use
T1-weighted	Basic	Anatomy and structural detail	Baseline anatomy, atrophy, post-contrast imaging
T2-weighted	Basic	Sensitive to water content	Edema, gliosis, tumor, inflammation, chronic lesions
FLAIR	Basic	Suppresses CSF to show parenchymal lesions better	White matter disease, MS, small vessel disease, cortical/subcortical lesions
DWI / ADC	Basic	Assesses diffusion restriction	Acute ischemic stroke, abscess, highly cellular lesions
SWI / GRE	Basic	Detects susceptibility effects and blood products	Microbleeds, hemorrhage, cavernomas, calcification correlation
Post-contrast T1	Basic	Shows enhancement and BBB disruption	Tumors, metastases, infection, active inflammation
fMRI	Advanced	Functional activation mapping	Pre-surgical mapping of eloquent cortex
MR Spectroscopy	Advanced	Metabolic tissue characterization	Tumor evaluation, necrosis vs recurrence, selected metabolic disorders
Perfusion MRI	Advanced	Cerebral blood flow and volume assessment	Tumor grading, treatment response, ischemia
DTI / Tractography	Advanced	White matter microstructure and tract mapping	Pre-surgical planning, connectivity and white matter pathway assessment

CT vs MRI in Neuroradiology

	CT Fast. Widely available. First-line in emergencies.	MRI Detailed tissue characterization.
Speed	Very fast — usually minutes	Slower — often 20–45 minutes
Availability	Widely available, especially in emergency departments	Less available, depends on scanner access and protocols
Emergency use	First-line in many acute neurological emergencies	Often second-line or problem-solving; urgent MRI is less available
Best for	Acute intracranial hemorrhage Skull fractures and trauma Calcifications Hydrocephalus and mass effect CTA / vascular occlusion Large established infarcts	Early ischemia (DWI/ADC) Demyelination (T2/FLAIR) Tumors and metastases Inflammation and infection Epilepsy work-up Posterior fossa / spinal cord
Radiation	Uses ionizing radiation	No ionizing radiation
Contrast agent	Iodinated contrast; limited by renal function and allergy	Gadolinium-based contrast; also requires renal risk assessment in selected patients
Limitations	Lower soft tissue contrast Less sensitive for early ischemia Less sensitive for demyelination	Slower examination Less available in emergency settings Motion-sensitive; implant/claustrophobia limits

Take-home message: CT answers urgent questions quickly. MRI answers detailed tissue questions more precisely.

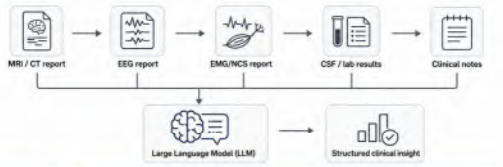
Core AI Tasks in Neuroradiology



Generalization
Ensures the model remains reliable across scanners, protocols and hospitals

Clinically useful AI must not only detect findings — it must also remain robust across time and across institutions.

Why LLMs matter in diagnostics



Key idea:
Many diagnostic results are stored and communicated in narrative form. LLMs are relevant because they can organize, summarize and relate this language-based data.

LLMs are useful because diagnostics is not only images — it is also text.

Potential LLM applications

Key idea: LLMs can structure and connect diagnostic language across multiple sources.

LLMs can support diagnostics by organizing text — not by replacing clinical judgment.

Example: preserving uncertainty

1 MRI report
Scattered nonspecific white matter lesions. Demyelination cannot be excluded.

2 Unsafe LLM output
The patient has multiple sclerosis.

3 Better LLM output
MRI shows nonspecific white matter lesions. Demyelination is possible but not confirmed; clinical correlation, lesion distribution, temporal evolution, CSF findings and exclusion of mimics are required.

Key risk: LLMs may turn diagnostic possibilities into confirmed diagnoses.

A safe LLM must preserve uncertainty rather than erase it.

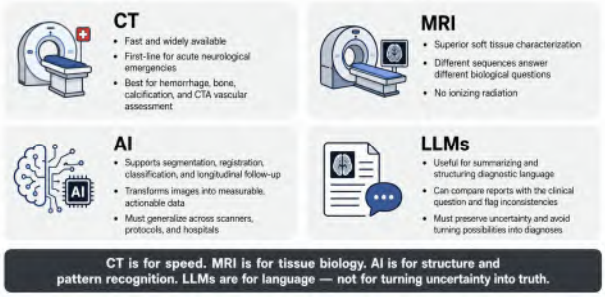
Key risks and take-home message

Key risk	Safer LLM behavior
Possibility becomes diagnosis	Distinguish findings from diagnoses
Ambiguous wording becomes overconfidence	Preserve uncertainty
Missing context becomes a false conclusion	State when clinical context is missing
Narrative uncertainty becomes apparent certainty	Support — not replace — clinical reasoning

Take-home lesson: LLMs can summarize diagnostic data, but they must not treat reports as absolute truth.

In diagnostics, the safest LLM is one that keeps uncertainty visible.

Take-home messages



Summer School: Neurology and AI fusion

Sokobanja, 2026

Funded by the European Union
Grant ID 101159214

EEG & EP

-for the PhD students in computer science-

Stevo Lukić

MAY 28

Content

- EEG
- Evoked potentials

MAIN GOALS

- EEG and evoked potentials are functional diagnostic tests, not direct disease labels
- Clinical interpretation depends on the clinical question, patient state, technical quality, timing, and artifacts

- AI can help detect and quantify signal patterns;
- LLMs can help structure reports and clinical context
- The goal is not to replace the clinical neurophysiologist, but to build tools that improve reliability, speed, documentation, and communication

What clinicians want engineers to learn?

- EEG and evoked potentials are generated by physiology, but interpreted through clinical reasoning
- The same waveform can have different meaning depending on age, sleep state, medication, illness, and indication

- Recording quality, montage choice, stimulus parameters, and artifacts are part of the data-generating process
- Clinical reports often express uncertainty; this uncertainty should be preserved in AI/LLM systems

Electroencephalography (EEG)

Electroencephalography - EEG

First EEG recording (1924)

Hans Berger (1873-1941)

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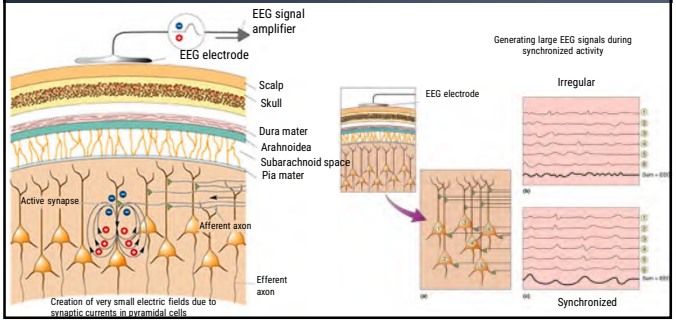
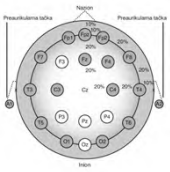
Registration of electrical activity of the brain



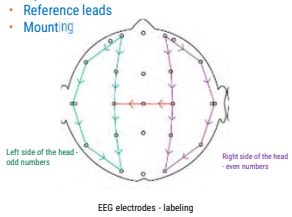
Electroencephalography - EEG

Electrodes
- Standard: superficial
- Special
  - sphenoidal, subdural, cortical...
- Connection system10/20



10/20 electrode placement system
The distance between adjacent electrodes is equal (10% or 20% of the distance from inion to nasion)

EEG potentials = potential difference between 2 points on the scalp
- Bipolar
- Reference leads
- Mounting



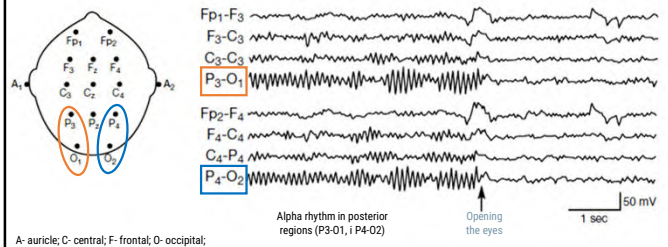
EEG electrodes - labeling

A- auricle; C- central; F- frontal; O- occipital; P- parietal. p- polar, z- mediosagittal

Electroencephalography - EEG

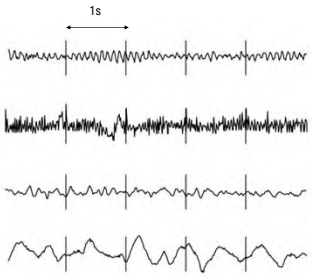
- **Standard EEG**
  - ≈ 20 min
  - Isolated, comfortable conditions
  - Activation methods:
    - Opening and closing eyes (10s)
    - Hyperventilation (3-4 min)
    - Photostimulation (1-60Hz)
- **EEG during sleep or after sleep deprivation**
- **Polygraphy (polysomnography)**

Normal EEG
Awake



A- auricle; C- central; F- frontal; O- occipital; P- parietal. p- polar, z- mediosagittal

Continuous EEG changes (rhythms)



ALPHA rhythm (8-13 Hz)
- Symmetrical, with eyes closed
- Present in occipital regions
- Disappears with eyes open

BETA rhythm (> 13 Hz)
- Above the frontal and central regions

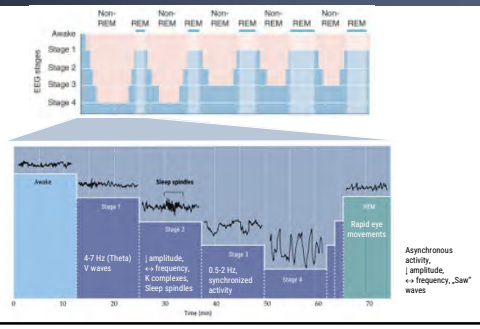
TETHA rhythm (4-7 Hz)
- Awake ⊖
- Some activity in the elderly (T)
- Slow-wave sleep ⊕

DELTA rhythm (< 4 Hz)
- Awake ⊖
- Slow-wave sleep ⊕

Normal EEG
Sleep

Stages of sleep during the one night

EEG during the first circle of sleep



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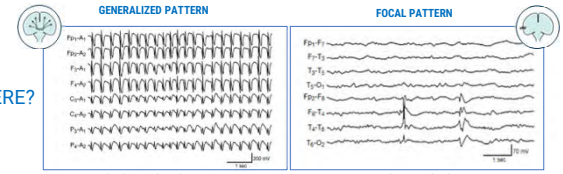
Transient EEG abnormalities

1 WHAT?

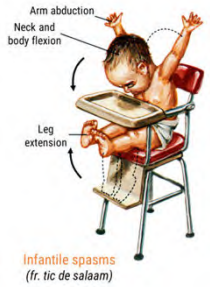
2 WHERE?



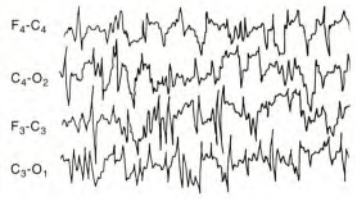
Generalized 3Hz spike and wave
Absence seizures

Right temporal spike
Focal seizures originating on the right

EEG abnormalities



Infantile spasms
(fr. tic de salaam)



Hypsarrhythmia
Generalized spikes and Delta-Theta slow waves, high amplitude

EEG

Indications	Useful dg. procedure	Contraindications
▪ Epilepsy, seizure ▪ 1 EEG → Sn 50% ▪ 3 EEG → Sn 90% ▪ Extended (video) monitoring	▪ Episodic loss of consciousness ▪ Continuous loss of consciousness ▪ Dementia vs. pseudodementia ▪ Sleep disorders ▪ Certifying brain death	▪ No absolute (safe method) ▪ Contraindicated use of certain activation methods ▪ Hyperventilation in: • Chronic obstructive pulmonary disease • Recent myocardial infarction • Recent CVI

Sn- sensitiveness

EEG

- Functional rather than structural test
- Non-invasive method
- Extension of clinical findings
  - A normal EEG does not exclude neurological disease
  - A pathological EEG may be without clinical consequences

EEG findings can only be interpreted in the context of the clinical presentation.

EEG: what it measures?

Useful, indirect, and artifact-prone

- EEG mainly reflects synchronized cortical postsynaptic potentials recorded at the scalp
- It has high temporal resolution but limited spatial resolution
- Routine EEG is a short sample; ambulatory EEG and video-EEG provide longer or more contextual recordings
- A normal EEG does not exclude epilepsy; an abnormal EEG does not automatically diagnose epilepsy

EEG: common clinical uses

Why neurologists order EEG

- Evaluation of suspected epileptic seizures and seizure mimics
- Detection of interictal epileptiform discharges
- Assessment of encephalopathy, coma, delirium, and non-convulsive status epilepticus
- Long-term monitoring in epilepsy units or ICUs
- Support for classification, prognosis, and treatment planning, always in clinical context

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EEG interpretation: core concepts

Patterns are not diagnoses by themselves

- Background rhythm
  - organization, symmetry, reactivity, and slowing
- Epileptiform activity
  - spikes, sharp waves, spike-and-wave, periodic discharges.
- Ictal vs interictal activity
  - captured seizure vs between-seizure abnormality
- Focal vs generalized abnormalities
  - localization and network implications
- Clinical state matters
  - awake, drowsy, asleep, sedated, encephalopathic

Artifacts: the engineer's trap

Not every pattern is brain activity

- Eye movements, blinking, muscle activity, ECG, electrode pop, movement, sweat, and electrical noise can mimic pathology
- Artifact removal must not remove clinically relevant signal
- Models trained on poorly curated EEG may learn recording environment, montage, or artifact rather than disease
- Data quality metadata should be treated as clinically meaningful features

Evoked potentials

Evoked potentials (EP)

- **Stimulation of different sensory systems**
  - vision, hearing, touch
- **Registration of evoked electrical responses (EP)**
  - over the regions of the cerebral cortex where the centers for those specific modalities of sensitivity are located
- **Registered using surface electrodes**
- **According to the tested sensory modality:**
  - Visual evoked potentials (VEP)
  - Auditory evoked potentials (AEP and BAEP)
  - Somatosensory evoked potentials (SEP)

Evoked potentials (EP)

Principle

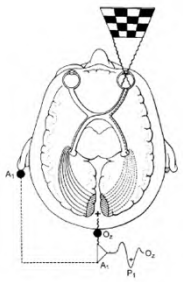
- Assess the functional integrity of sensory systems from the site of stimulation, along pathways to centers
- Measurement of evoked response characteristics
  - Individual stable latencies
  - Amplitude
  - Shape of response

Application in clinical practice

- Subclinical and clinically silent lesions (MS)
- Localization of pathological processes in the CNS
- Monitoring the functional state over a longer period of time in patients at risk
  - e.g. intraoperatively or during the evolution of the disease
  - Determining the prognosis of coma and brain death

Visual evoked potentials (VEP)

- **Stimulation of each eye separately**
  - Flashes of light (children)
  - Black and white checkerboard squares that change colors at certain time intervals
  - Entire visual field or ½ visual field
- Registering responses above the occipital lobe



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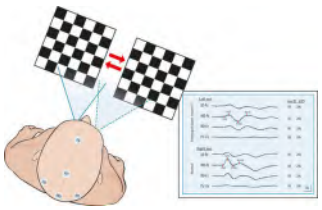
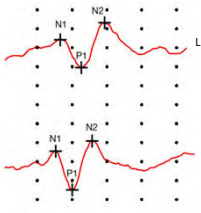
Vizuelni evocirani potencijali

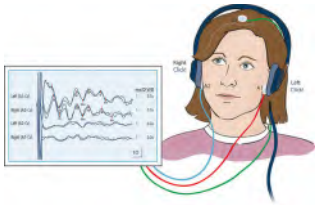




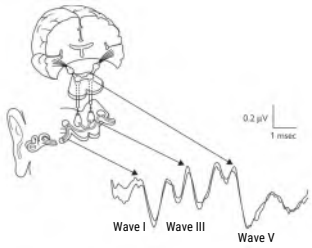
Left eye optic neuritis

Brainstem auditory evoked potentials (BAEP)

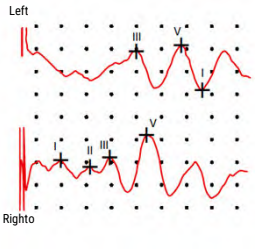
- Monaural stimulation with acoustic stimuli
- Registered responses correspond to different parts of the acoustic system
  - Cochlear nerve (Wave I)
  - Brainstem (Waves II – VI)
- Application
  - Hearing assessment in young children
  - Brainstem structures (Acoustic neuritis)



Brainstem auditory evoked potentials (BAEP)



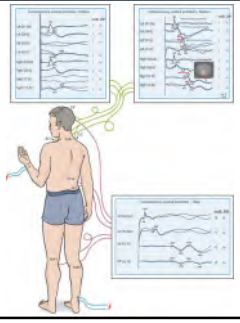
Schematic representation of the auditory pathways and the origin of BAEP waves, with an example of a normal finding after stimulation of one ear



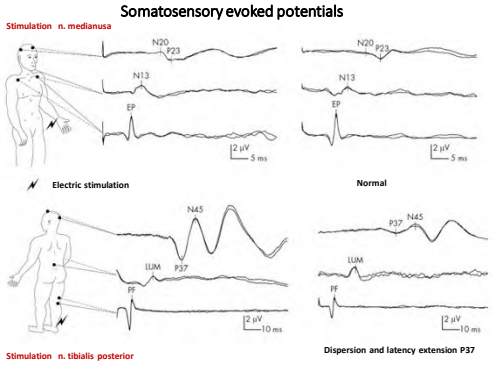
BAEP findings support the clinical diagnosis of left brainstem lesion

Somatosensory evoked potentials (SSEP)

- Stimulation of the sensory nerve
  - n. medianus (in the arm area)
  - n. tibialis (at the level of the medial malleolus)
- Registered responses correspond to different parts of the sensory system
  - Brachial plexus
  - KM
  - M. trunk
  - Somatosensory cortex



Somatosensory evoked potentials



Evoked potentials: what they add

Testing pathway function

- Visual evoked potentials: optic pathway function and conduction delay.
- Somatosensory evoked potentials: peripheral, spinal, brainstem, and cortical sensory pathways.
- **Brainstem auditory evoked potentials:** auditory brainstem pathway integrity.
- Latency and amplitude provide functional information, but findings are not disease-specific

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AI cooperation ideas

General AI in electrophysiology

- Automated EEG quality assessment and artifact detection
- Spike, sharp wave, seizure, and non-convulsive status detection
- ICU EEG trend analysis and alerting systems
- Evoked potential waveform detection and latency/amplitude measurement
- Device/protocol harmonization and multicenter reproducibility tools
- Decision-support dashboards that show uncertainty, confidence, and signal quality

Husain, 2025; IFCN position statement on AI in clinical neurophysiology, 2026.

LLM cooperation ideas

LLMs should organize context, not "read EEG" alone

- Extract indication, patient state, medications, background rhythm, abnormalities, seizures captured, artifacts, and conclusion from EEG reports
- Generate standardized report drafts from structured outputs of validated signal models
- Summarize longitudinal EEG history across multiple reports
- Explain EEG or EP reports to patients in non-technical language
- Flag missing clinical context before interpretation

Wunsch et al. (2026)

Safe vs unsafe LLM behavior

Preserve uncertainty and clinical context

Unsafe output
- "This EEG proves epilepsy."
- "The evoked potential test diagnoses multiple sclerosis."

Safer output
- "Epileptiform discharges may support epilepsy in the appropriate clinical context."
- "Delayed visual evoked potentials suggest optic pathway conduction delay but are not disease-specific."

LLM outputs should separate findings, interpretation, limitations, and recommended clinical correlation

Take-home messages

- EEG and evoked potentials are functional tests, not direct disease labels
- Interpretation depends on clinical question, technical quality, patient state, and artifacts
- AI can support pattern detection and signal quality
- LLMs can structure reports, context, and communication
- Clinical neurophysiology tools must remain expert-supervised, auditable, and validated