Title: Clinical Use of EEG in the ICU: Technical Setting.
Authors: Alvarez V, Rossetti AO
Journal: Journal of clinical neurophysiology : official publication of the American Electroencephalographic Society
Year: 2015 Dec
Volume: 32
Issue: 6
Pages: 481-5
DOI: 10.1097/WNP.0000000000000194

Clinical use of EEG in the ICU: Technical setting

Running title: "EEG in the ICU: technical setting"

Vincent Alvarez, MD [1,2,3] & Andrea O. Rossetti, MD [2]

Invited review for a special topical issue called **"Clinical use of EEG and SSEP in the ICU"** edited by Peter W Kaplan & Andrea O Rossetti.

Affiliations:

[1]Department of Neurology, Hôpital du Valais, Sion, Switzerland

[2]Department of Clinical Neurosciences, CHUV and Lausanne University, Lausanne, Switzerland

[3]Department of Neurology, Brigham and Women's Hospital, Harvard Medical School, Boston, USA

Contents:

Abstract: 106 words

Text: 2413 words

2 Tables + 1 Figure

38 References

Key words: impedance, electrodes, the 10-20 system, montages, amplifiers, filters

Address for correspondence:

Dr. Vincent Alvarez
Hôpital du Valais
Service de Neurologie
Av. du Grand-Champsec 80
CH-1950-Sion
Switzerland

Phone: +4127-603 4000
Fax: +4127-603 4001
e-mail: vincent.alvarez@hopitalvs.ch

Disclosure of conflicts of interest:

Dr. Alvarez has nothing to disclose.

Dr. Rossetti receives research support from the Swiss National Scientific Fund (CR32I3_143780), and received research support from Sage therapeutics and UCB Pharma.

Abstract:

Neurophysiology is an essential tool for clinicians dealing with patients in the intensive care unit (ICU). Because of consciousness disorders, clinical examination is frequently limited. In this setting, neurophysiological examinations provides valuable information about seizure detection, treatment guidance, and neurological outcome. However, in order to acquire reliable signals some technical precautions need to be known. Electroencephalography (EEG) is prone to artifacts, and the ICU environment is rich in artifact sources (electrical devices including mechanical ventilation, dialysis, as well as sedative medications, and frequent noise…). This review will discuss and summarize the current technical guidelines for EEG acquisition and also some practical pitfalls specific for the ICU.

1. Introduction:

Neurophysiology represents an essential tool for clinicians dealing with patients in the intensive care unit (ICU). Because of consciousness disorders, clinical examination is limited, and therefore in this clinical setting, neurophysiology provides valuable information about seizure detection, treatment guidance, and neurological outcome (Sutter *et al.*, 2013). However, in order to acquire reliable signals some technical precautions are required. Electroencephalography (EEG) is prone to artifacts and ICU is rich in electrical and artifact sources, such as mechanical ventilation, medication pumps, and other electrical devices, sedative medications, and environmental noises.

In recent years, this field has undergone a significant development, particularly with the introduction of digital EEG machines allowing to stock quite easily a large amount of data. Quantitative EEG (qEEG) signals provide clinicians with efficient tools to read prolonged recording rapidly and reliably (Moura *et al.*, 2014). Also, a growing literature demonstrates increasingly the yield of prolonged EEG recording in terms of seizure detection (Claassen *et al.*, 2004). Continuous EEG monitoring (cEEG) is, for all this reasons, a rapidly evolving and spreading application, especially in the Western world.

Since important decisions are potentially based on information provided by EEG, it is essential that acquisition happens under the best conditions as possible and following international guidelines. The aim of this article is to review current recommendations and to describe some practical aspects to obtain good traces.

2. Theoretical considerations

a. Basic neurophysiology

The pyramidal neurons located in the cortical layer of the brain are the main signal generators of the EEG (Fisch, 1999a); their columns generate electrical fields. Summations of postsynaptic potentials of thousands of these cells are needed to create a scalp potential. Approximately 6 cm^2 (≅ one square inch) of synchronized neuronal tissue is necessary to capture a change in electrical potentials on the scalp. The potentials recorded at the scalp are measured in microvolt (μV), typically 10-100, while, in comparison, the electrocardiogram measures are in millivolt (mV).

b. Impedances

In addition to their small amplitudes, cortical signals have to cross several electrical barriers (such as the cerebrospinal fluid, the dura, the skull and the skin). Then, electrodes and wires will also represent an obstacle. This opposition to the electrical signal is called “impedance” in an alternating current circuit, and is measured in Ω (Ohms). According to the International Federation of Clinical Neurophysiology (IFCN) guidelines and the American Clinical Neurophysiology Society (ACNS) recommendations, each electrode impedances should be checked before every recording and should ideally not exceed 5000Ω (=5kΩ) (American Clinical Neurophysiology Society, 2008), (Nuwer *et al.*, 1999). EEG recording machines are able to reject artifacts using the “common mode rejection” (Fisch, 1999b): electrical noise common to the active and the reference electrodes is automatically recognized and discarded by the amplifier. This implies that electrodes’ impendence have to be uniform to reject noise in a reliable fashion. Also, this ability depends on the ratio between the electrode’s impedance and the amplifier’s input impedance. While the latter is a fixed value, the skin impedance varies between patients and skull sites. If the skin impedance increases, the common mode rejection ability decrease and more noise is recorded (Kappenman and Luck, 2011). High impedances may in addition increase the artifact due to the skin potential (a natural electrical potential between the external and internal surface of the skin) (Kappenman and Luck, 2011). It has been suggested that good quality EEG can be performed with electrodes impedance around 40 kΩ (Ferree *et al.*, 2001) with modern high input impedance amplifier. However these amplifiers don’t decrease the amount of electrical noise associated with high impedances (Mahajan and Mcarthur, 2010) and the study was performed by a manufacturer providing EEG acquisition system avoiding skin preparation (which in turn represents an important step to decrease the impedance, see part 3.b). It seems therefore reasonable to recommend uniform impedances < 10 kΩ in daily practice with modern, digital acquisition machines.

3. Practical technical considerations for EEG in the ICU

a. Electrodes type

Many electrodes are available (cup, pad, cap with integrated electrodes, needle…), and each type offers its pros and cons. The ideal system in the ICU would be rapidly and easily set up, wouldn't required skilled technicians available 24/7, and would provide low and stable impedances for a prolonged period. Unfortunately this system doesn't exist. **Table 1** presents and summarizes the most widely used electrodes.

Cup electrodes glued on scalp represent probably the best alternative and are the most commonly applied. The electrode is highly flexible and can be placed in every patient (incl. with skull defects, or intracranial pressure monitoring…); it can be used for standard short EEGs but also provide stable impedances for prolonged cEEG, although after 10 days a period of 2-3 days without electrode are recommended in case of very prolonged recordings to avoid skin damages. Also, CT and MRI compatible plastic cup electrodes are available (Mirsattari *et al.*, 2004). Their only relative disadvantage is that they require a technician familiar with their application.

Sub dermal wire / needle electrodes provide a good alternative for comatose patients with stable impedances for prolonged cEEG. Less notch-related and large artifacts are observed as compared to classic cup electrodes glued with collodion (Young *et al.*, 2006); MRI compatible needle electrodes are also available. Because it crosses the skin barrier, this kind of electrodes does not require skin preparation, but due to their "invasive" nature and potentially painful application, those are only suitable for comatose patients and with a limited number of electrodes.

EEG cap systems are convenient for short term and urgent EEG recordings. Because of their fast set up they can give a rapid idea of brain activity, presence of encephalopathy or seizures. However they does not seem to be suitable for EEG recordings lasting more than 3 to 4 hours. Some manufacturer provides disposable and "easy to set up" systems (e.g., StatNet™ from HydroDot Inc. i.e), easily applicable by untrained medical staff. Unfortunately, only short term EEG are possible, impedances are fair, and full skull coverage is not possible. These devices

should therefore be reserved for situations when EEG information is needed immediately and alternative solutions are not possible.

b. Skin contact

One of the major components of the impedance is the skin, mostly the outermost layer made of dead cells (Eggins, 1993). In order to decrease it, it is important to abrade the skin with abrasive specific gel. Then, a conductive and adhesive paste (for cup electrodes) or a conductive gel (for EEG cap systems) should be used to insure contact between the skin and the electrodes. Of note, chloride-free and low-chloride gels have been shown to be unstable, resulting in a variation of electrodes potentials (Tallgren *et al.*, 2005). Chloride containing pastes/gels are thus recommended.

For cEEG, a strong, reliable and durable contact is needed. Collodion has been used in this setting to glue electrodes for decades; it is a solution of nitrocellulose in ether and alcohol. When applied on skin, the alcohol and the ether evaporate and thus a nitrocellulose film attaches the electrode on the scalp. Some concern has been raised regarding its toxicity, especially for EEG technologists. However, in a adequately ventilated environment the ether contained in the collodion never reaches toxic concentrations (Young *et al.*, 1993). The EC2® paste, a conductive medium with strong adhesive proprieties, may represent a cost effective alternative to collodion, and is not related to ether production. At the beginning and after 24hours of recording, impedances have been reported to be equivalent or better on EC2® as compared to collodion (Falco *et al.*, 2005).

c. Electrodes placement and montage

The international 10-20 system should be used the ICU, as for every other EEG. The International Federation of Clinical Neurophyiology (IFCN) has provided a detailed, step-by-step description for electrodes placement (Klem *et al.*, 1999). The montage depends from each EEG laboratory habits, and for example, the American Clinical Neurophysiology Society (ACNS) gives a list of different bipolar and referential montages (American Clinical Neurophysiology Society, 2006). The longitudinal bipolar montage (**figure 1**) represents a widely used and effective montage to screen EEG

traces in the ICU, with a good compromise between local and large-scale sensitivity.

Additional electrodes places near the eyes or on selected muscles may help to discriminate between cerebral and extra-cerebral activity or artifacts. Recently, intra-cranial electrodes have been used in the ICU (Claassen, Perotte, *et al.*, 2013) and shown to detect at times seizure activity missed on scalp cEEG. However, this approach needs further exploration before being considered for daily practice.

d. Filters

In the ICU, filters should be used the same way as for standard, routine EEG. Frequencies of interest being between 1 and 30 Hz, the low frequency filter (synonymous with high pass filter) should be set at 0.5 to 1 Hz, and the high frequency filter (or low pass filter) at 70 Hz. A notch filter of 50 or 60 Hz (depending of the country) for power-line artifacts should be used when needed. Of note, it is advisable to start the recording without the notch filter, as the electrodes with loose contact to the scalp will tend to show a prominent notch artifact.

e. Video

Video recording is nowadays highly recommended, as patients in the ICU require intensive nursing and are prone to many invasive procedures that can produce a huge variety of artifacts. Video information is essential in this setting. Also, clinical correlation with periodic or rhythmic patterns and seizures may be assessed. Framing should be set to capture patient's face, arms and the upper trunk at least. In selected cases, a focused frame on the region of interest should be discussed (e.g., face in patients with eyelid myoclonus). Of note, care providers frequently move EEG machine and/or camera around patients, so framing should be regularly checked and corrected.

f. EEG Softwares

Each EEG machines are provided with their own EEG software with all basic requirements (montage, filter setting, sensitivity, etc…). Software interfaces should be easy to use, so that untrained healthcare providers would be for example able to add some annotations in case of particular event.

Because cEEG is frequently used for comatose patients, additional software using quantitative EEG is useful and recommended. Many different analyses can be performed, such as compressed spectral array (CSA), rhythmicity index, asymmetry index, burst-suppression ratio, alpha-delta ratio, automatic seizure detections, and several more; these may be also customized according to the specific clinical question Recently, cEEG screening using CSA and page-by-page reading for selected epoch has been shown be very effective, as it reduced by 78% the time spent for analysis, with minimal loss in terms of seizure detection as compared to classical page-by-page reading (Moura *et al.*, 2014). Conversely, it is paramount to regularly check the raw trace in order to avoid false-positive and false-negative events; this has been recently reported to be trickier in patients with periodic discharges (Sierra-Marcos *et al.*, 2014).

g. "Bedside considerations"

i. Electrical environment

Acutely injured patients frequently require many devices including respiratory assistance, dialysis, external cardiac support, body temperature management, anti-bedsore mattresses, perfusion pumps, etc… Theses device can cause artifacts (Gaspard and Hirsch, 2012) and should be assessed separately if a recording proves difficult to be obtained.

ii. Body temperature

The temperature management is part of treatment of many patients with acute brain injury (Choi *et al.*, 2012). Even without any brain pathology, hypothermia leads progressively to brain activity slowing and then suppression (Mezrow *et al.*, 1994), (Stecker *et al.*, 2001). However no clinically relevant changes appear above 30°C. EEG can be performed during mild therapeutic hypothermia and is a reliable outcome predictor of outcome in particular settings (Rossetti *et al.*, 2012), but temperature at the time of recording should be noted.

iii. **Medication**

Sedatives, antipsychotics, and to a lesser extent anti-seizure drugs, opiates and antibiotics (mostly penicillins and cephalosporins) are frequently prescribed in critically ill patients and can produce EEG more or less changes (Bauer and Bauer, 2011). A list of all relevant medication should be available at time of EEG reading.

iv. **Skull defect**

A skull defect, as small as a burr hole or as big as a large craniotomy, can cause focal accentuation of fast activity and increased amplitude (called “breach rhythm). This can be misleading if the underlying defect is unknown (Gaspard and Hirsch, 2012).

v. **Muscular activity**

Critically ill patients may present different sorts of involuntary movements (myoclonus, clonus, shivering, shaking, tremor). These can produce artifacts and even render the trace non-interpretable. Short acting neuromuscular agents such as vecuronium can be considered to clear muscular artifacts (Chatrian *et al.*, 1996), under light sedation

vi. **Background EEG Reactivity assessment**

Reactivity should be assessed for every EEG performed on patients with disorders of consciousness unless there is a concern of raised intra-cranial pressure due to stimuli (Young, 2000); it is indeed an important predictor of clinical outcome, especially in brain anoxia (Rossetti *et al.*, 2010) and traumatic brain injury (Synek, 1990), (Gütling *et al.*, 1995). There is no consensus regarding the stimulation protocol. It is current practice to perform eye opening and auditory stimuli (voice and hand clapping far from the electrodes) first, and then, if no change in EEG, noxious stimuli. Painful stimulations over the trunk are preferred because temperature, focal compressive neuropathies, spinal cord lesions or stroke can all make stimuli applied on the limbs less reliable. Sternal rubbing, pressure on the supraorbital nerve above the eyebrow, and mandibular advancement will produce artifact and movement

artifacts may mask reactivity. We recommend border of axilla or nipple pinching over nasal septum stimulation (risk of nose bleeding). Stimulations have to be precisely specified on the trace.

vii. **Recommended length of recording**

This aspect is still an important matter of debate. cEEG for 24 hours for non-comatose patients and for 48 hours for the comatose ones may be required to detect most seizures (Claassen *et al.*, 2004). More recently, a study performed on more than 600 adult patients undergoing cEEG showed that most seizures were detected within the first 30 minutes and that the 72h-risk for seizures decays to <5% over 16 h without seizure in patients with epileptiform EEGs, and to <5% over 2h without seizure in patients without epileptiform EEG abnormalities (Westover *et al.*, 2014). For comatose survivors of cardiac arrest, repeated EEG seems to provide the same information as cEEG (Alvarez *et al.*, 2013), (Crepeau *et al.*, 2014). On the other side, cEEG has been proven to be important for the management of comatose patients with subarachnoid (Lindgren *et al.*, 2012) and intracerebral hemorrhage (Claassen *et al.*, 2007), or traumatic brain injury (Ronne-Engstrom and Winkler, 2006). Also cEEG is clearly recommended in case of refractory status epilepticus to guide treatment (Claassen, Taccone, *et al.*, 2013). EEG should be part of the management of every patient with unexplained altered consciousness (Claassen, Taccone, *et al.*, 2013) and its duration should be evaluated on a case-by-case and daily basis based in clinical setting and EEG availability.

4. Conclusion

EEG is highly valuable in the ICU; to fulfill its tasks, it has to be acquired under reliable and rigorous conditions. Adequate electrodes with skin preparation should be used; artifact sources and all confounding factors should be known and identified. **Table 2** provides a summary of technical aspect of EEG in the ICU and the recommended features.

References:

Alvarez V, Sierra-Marcos A, Oddo M, Rossetti AO. Yield of intermittent versus continuous EEG in comatose survivors of cardiac arrest treated with hypothermia. Crit. care 2013; 17: R190.

American Clinical Neurophysiology Society. Guideline 6: A Proposal for Standard Montages to Be Used in Clinical EEG. J Clin Neurophysiol 2006; 23: 111–117.

American Clinical Neurophysiology Society. Guideline 1: Minimum Technical Requirements for Performing Clinical Electroencephalography. J Clin Neurophysiol 2008; 23: 86–91.

Bauer G, Bauer R. EEG, Drug effects, and Central Nervous system poisoning. In: Schomer DL, Lopes da Silva FH, editor(s). Niedermeyer's Electroencephalography: Basic Principles, Clinical Applications, and Related Fields. Philadelphia: Lippincott Williams & Wilkins; 2011. p. 901–934.

Chatrian GE, Bergamasco B, Bricolo A, Frost JD, Prior PF. IFCN recommended standards for electrophysiologic monitoring in comatose and other unresponsive states. Report of an IFCN committee. Electroencephalogr Clin Neurophysiol 1996; 99: 103–122.

Choi HA, Badjatia N, Mayer SA. Hypothermia for acute brain injury — mechanisms and practical aspects. Nat rev neurol 2012; 8: 214–222.

Claassen J, Jetté N, Chum F, Green R, Schmidt M, Choi H, et al. Electrographic seizures and periodic discharges after intracerebral hemorrhage. Neurology 2007; 69: 1356–1365.

Claassen J, Mayer S a., Kowalski RG, Emerson RG, Hirsch LJ. Detection of electrographic seizures with continuous EEG monitoring in critically ill patients. Neurology 2004; 62: 1743–1748.

Claassen J, Perotte A, Albers D, Kleinberg S, Schmidt JM, Tu B, et al. Nonconvulsive seizures after subarachnoid hemorrhage: Multimodal detection and outcomes. Ann Neurol 2013; 74: 53–64.

Claassen J, Taccone FS, Horn P, Holtkamp M, Stocchetti N, Oddo M. Recommendations on the use of EEG monitoring in critically ill patients: consensus statement from the neurointensive care section of the ESICM. Intensive Care Med 2013; 39: 1337–1351.

Crepeau AZ, Fugate JE, Mandrekar J, White RD, Wijdicks EF, Rabinstein A a, et al. Value analysis of continuous EEG in patients during therapeutic hypothermia after cardiac arrest. Resuscitation 2014; 85: 785–789.

Eggins BR. Skin Contact Electrodes for Medical Applications. Analyst 1993; 118: 439–442.

Falco C, Sebastiano F, Cacciola L, Orabona F, Ponticelli R, Stirpe P, et al. Scalp electrode placement by EC2 adhesive paste in long-term video-EEG monitoring. Clin Neurophysiol 2005; 116: 1771–1773.

Ferree TC, Luu P, Russell GS, Tucker DM. Scalp electrode impedance, infection risk, and EEG data quality. Clin Neurophysiol 2001; 112: 536–544.

Fisch BJ. The Generator of the EEG. In: Fisch & Spehlmann's EEG Primer - Basic Principles of Digital and Analog EEG. Amsterdam: Elsevier ltd; 1999. a. p. 4–9.

Fisch BJ. Digital and Analog EEG Instruments: parts and functions. In: Fisch & Spehlmann's EEG Primer - Basic Principles of Digital and Analog EEG. Amsterdam: 1999. b. p. 35–72.

Gaspard N, Hirsch LJ. Pitfalls in ictal EEG interpretation: Critical care and intracranial recordings. Neurology 2012; 80: S26–S42.

Gütling E, Gonser a, Imhof HG, Landis T. EEG reactivity in the prognosis of severe head injury. Neurology 1995; 45: 915–918.

Kappenman ES, Luck SJ. The Effects of Electrode Impedance on Data Quality and Statistical Significance in ERP Recordings. Psychophysiology 2011; 47: 888–904.

Klem GH, Lüders HO, Jasper HH, Elger C. The ten-twenty electrode system of the International Federation. In: Deuschl G, Eisen A, editor(s). Recommendations for the Practice of Clinical Neurophysiology: Guidelines of the International Federation of Clinical Neurophysiology. Elsevier Science B.V.; 1999. p. 3–6.

Lindgren C, Nordh E, Naredi S, Olivecrona M. Frequency of Non-convulsive Seizures and Non-convulsive Status Epilepticus in Subarachnoid Hemorrhage Patients in Need of Controlled Ventilation and Sedation. Neurocrit Care 2012; 17: 367–373.

Mahajan Y, Mcarthur G. Does combing the scalp reduce scalp electrode impedances ? J Neurosci 2010; 188: 287–289.

Mezrow CK, Midulla PS, Sadeghi AM, Gandsas A, Wang W, Dapunt OE, et al. Evaluation of cerebral metabolism and quantitative electroencephalography after hypothermic circulatory arrest and low-flow cardiopulmonary bypass at different temperatures. J Thorac Cardiovasc Surg 1994; 107: 1006–1019.

Mirsattari SM, Lee DH, Jones D, Bihari F, Ives JR. MRI compatible EEG electrode system for routine use in the epilepsy monitoring unit and intensive care unit. Clin Neurophysiol 2004; 115: 2175–80.

Moura LMVR, Shafi MM, Ng M, Pati S, Cash SS, Cole AJ, et al. Spectrogram screening of adult EEGs is sensitive and efficient. Neurology 2014; 83: 56–64.

Nuwer MR, Comi G, Emerson R, Fuglsang-frederiksen A, Guérit J-M, Hinrichs H, et al. IFCN standards for digital recording of clinical EEG. In: Deuschl G, Eisen A, editor(s). Recommendations for the Practice of Clinical Neurophysiology: Guidelines

of the International Federation of Clinical Neurophysiology. Elsevier B.V.; 1999. p. 11–14.

Ronne-Engstrom E, Winkler T. Continuous EEG monitoring in patients with traumatic brain injury reveals a high incidence of epileptiform activity. Acta Neurol Scand 2006; 114: 47–53.

Rossetti AO, Carrera E, Oddo M. Early EEG correlates of neuronal injury after brain anoxia. Neurology 2012; 78: 796–862.

Rossetti AO, Oddo M, Logroscino G, Kaplan PW. Prognostication after cardiac arrest and hypothermia: a prospective study. Ann Neurol 2010; 67: 301–307.

Sierra-Marcos A, Scheuer ML, Rossetti AO. Seizure detection with automated EEG analysis: A validation study focusing on periodic patterns. Clin Neurophysiol 2014; 126: 456–462.

Stecker MM, Cheung a T, Pochettino A, Kent GP, Patterson T, Weiss SJ, et al. Deep hypothermic circulatory arrest: I. Effects of cooling on electroencephalogram and evoked potentials. Ann Thorac Surg 2001; 71: 14–21.

Sutter R, Stevens RD, Kaplan PW. Continuous electroencephalographic monitoring in critically ill patients: indications, limitations, and strategies. Crit Care Med 2013; 41: 1124–1132.

Synek VM. Revised EEG coma scale in diffuse acute head injuries in adults. Clin Exp Neurol 1990; 27: 99–111.

Tallgren P, Vanhatalo S, Kaila K, Voipio J. Evaluation of commercially available electrodes and gels for recording of slow EEG potentials. Clin Neurophysiol 2005; 116: 799–806.

Westover MB, Shafi MM, Bianchi MT, Moura LMVR, O'Rourke D, Rosenthal ES, et al. The probability of seizures during EEG monitoring in critically ill adults. Clin Neurophysiol 2014; 126: 463–471.

Young B, Blais R, Campbell V, Covacich D, Demelo J, Leitch G, et al. Vapors from collodion and acetone in an EEG laboratory. J Clin Neurophysiol 1993; 10: 108–110.

Young GB, Ives JR, Chapman MG, Mirsattari SM. A comparison of subdermal wire electrodes with collodion-applied disk electrodes in long-term EEG recordings in ICU. Clin Neurophysiol 2006; 117: 1376–1379.

Young GB. The EEG in Coma. J Clin Neurophysiol 2000; 17: 473–485.

Figure and Table:

Table 1: Electrodes type that can be used in the ICU with pros and cons.

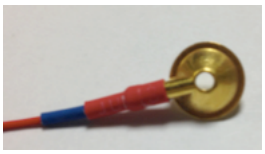
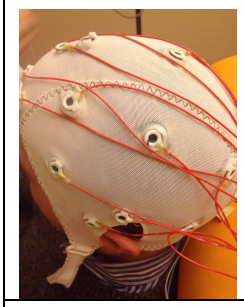
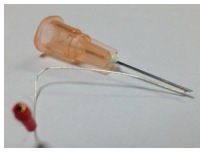
Electrode type	Pros	Cons
Cup electrodes (with conductive/adhesive paste) 	• Good impedance • Can be used for long term monitoring • Possible electrode placement modification if required (skull defects, skin scare, clip…) • Recommended by the IFCN • CT/MRI compatible plastic electrodes available	• Time consuming
Pad electrodes 	• Good impedance • May be used on patients minor skull defect • Possible electrode placement modification if required (skin scare, clip…)	• Only some hours of good recording • Not suitable for patient with important skull defect
EEG Cap system (with conductive gel) 	• Fast set up • Fair/good impedances (only for system with possible skin preparation)	• Only up to 4 hours of good recording • Some systems may be prone to high impedances • Prone to electrical bridge • Not suitable for patients with skull defects or intracranial monitoring devices
Needle electrodes 	• Fast set up • CT/MRI compatible plastic electrodes available • Provide stable recording condition	• May be prone to skin infection • Invasive • Only suitable for comatose patient
Disposable system and pre-gelled electrodes	• Fast set up • No risk of cross-contamination • Can be placed by any health care provider with minimal experience	• Full scalp coverage impossible • Fair/poor impedance • Short term recordings only

Table 2: Recommendation summary for EEG in the ICU

Features	**Recommendations:**

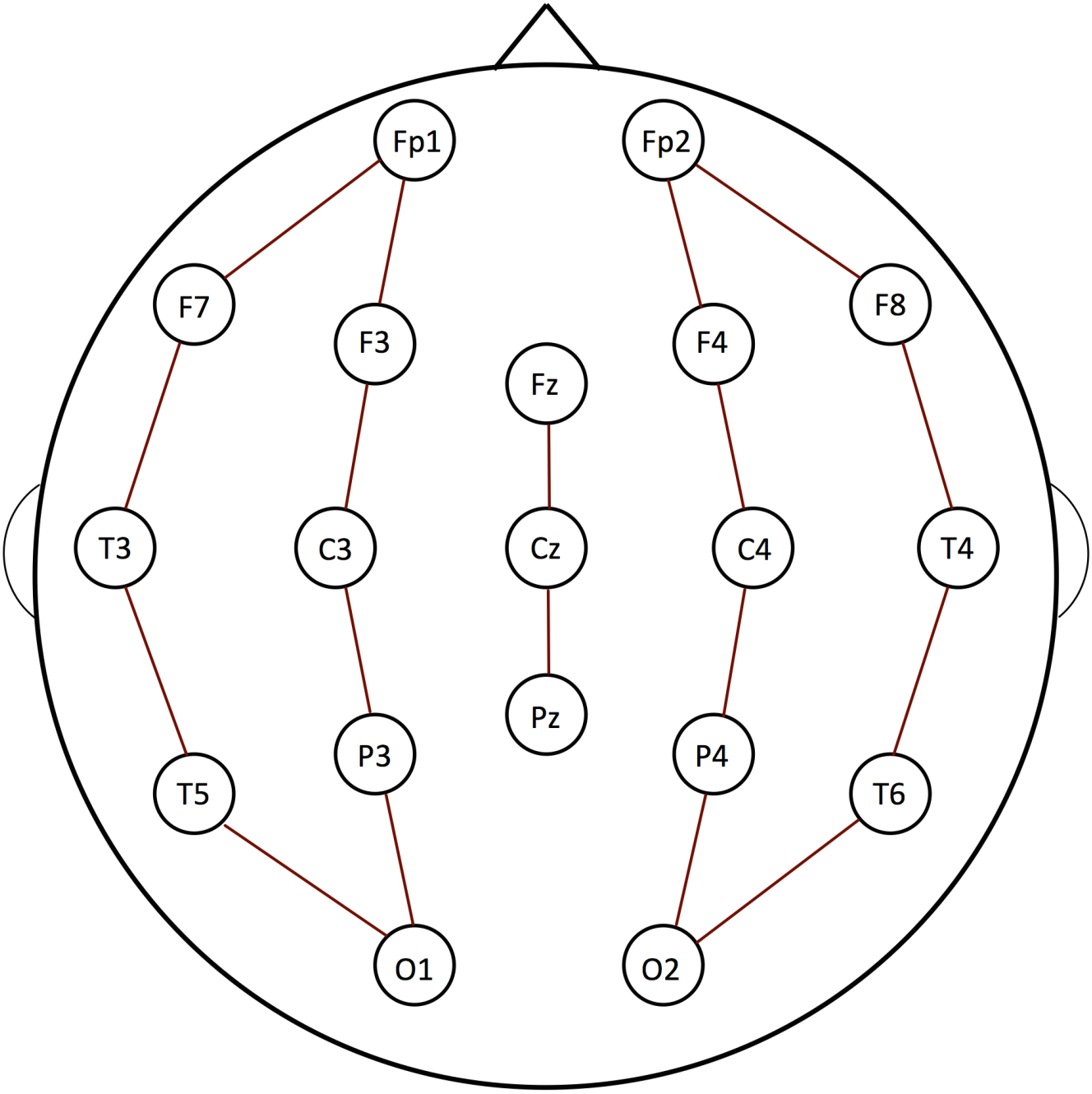
Electrodes	• Cup or needle electrodes (MRI/CT compatible if needed) placed according the 10-20 System
	  o 21 electrodes preferred
	  o Smaller number can be use for selected cases (very prolonged recordings, brain death determination)

Skin contact	• Preparation with an abrasive gel • Chloride containing adhesive paste/gel • Use EC2® paste or collodion to glue electrodes
Impedance	• < 10 kΩ for each electrodes • Homogenous values
Filter	• Low frequencies filter at 0.5 – 1 Hz; high frequencies filter at 70 Hz. • Notch filter applied if necessary
Video	• Always use it. Check and correct framing regularly

Duration	• Prolonged EEGs may be needed to detect most seizures or to guide treatment
	• Should be discussed based on clinical setting and EEG availability
	• To exclude the presence of seizures:
	  o 16-24 hours without seizures are probably sufficient for “epileptiform” recordings
	  o 2-5 hours without seizures are probably sufficient for “non-epileptiform” recordings

“Bedside EEG-requirements in the ICU”	Check for: • Body temperature • Medication (mostly sedative, anti-seizure drugs, antipsychotic, antibiotics and opiates) • Skull defects • Electrical devices • Involuntary muscles activity (i.e. myoclonus, shivering,…) o Short-acting neuro-muscular blockade can be considered in ventilated patient Always test for background reactivity (expect if raised ICP may be of concern) with sequential stimuli (stop if reactivity is demonstrated): • Eyes opening • Loud call • Hand claps • Painful stimuli (preferably on trunk)

Figure 1: The longitudinal bipolar montage using the International 10-20 system


Fp1
Fp2
F7
F3
Fz
F4
F8
T3
C3
Cz
C4
T4
Pz
P3
P4
T5
T6
O1
O2