

OPTIMISATION OF PREPARING AND UTILISING SINTERED Ag/AgCl-ELECTRODES FOR LOW DRIFT DC-EEG MEASUREMENTS

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Abstract: Recent measurements of Full-band EEG numerously use DC-capable amplifiers. To reduce the low frequency noise and especially for obtaining low drift values, special preparation of the electrodes is of crucial importance. In this study activation alternatives for sintered Ag/AgCl circular electrodes were investigated using different kinds of salt solutions and electrode pastes at varying concentration and temperature. The study shows that the activation of electrodes in a salt solution at concentrations more than 0.9% reduces the stabilisation time of the electrode potential significantly. A common salt solution can be utilised as well as pure NaCl solution or KCl solution. Heated solutions or electrode pastes do not enhance significantly the results.

Recording the electrode potential during temperature changes shows that a rapid rise of the temperature leads to an immense increase of the electrode potential. Independent of the temperature value a stabile electrode potential could be received if the temperature remains constant or changes less than 1°C per minute.

Thus, a simple method for checking the functional efficiency of electrodes for DC measurements based on the drift assessment has been developed.

Introduction

By advancement of direct current (DC)-capable amplifiers, measurements of Full-band EEG (FbEEG, between 0 Hz and the maximum of bioelectric signal frequency) gain importance [1]. The electrode-electrolyte interface harms these measurements due to the junction from electrode conduction to ion conduction. Slow spontaneous changes in electrode polarisation can cause drift in the DC recordings. Drift changes are usually termed as low-frequency noise. The applicability of different types of commercially available electrodes and electrode gels or pastes for recording slow EEG potentials was tested in [2].

The object of this study was to investigate different preparation methods for sintered Silver / Silver chloride (Ag/AgCl) circular electrodes in order to reduce initial electrode drifts in DC-EEG measurements. Therefore different kinds of salt solutions at varying concentrations and temperatures and two

electrode pastes were compared. Applying the measurement results a simple functional test for electrodes, which are used in DC-EEG recordings, has to be found.

Further, the influence of temperature changes on the electrode potential caused by the electrode paste has been examined.

Materials and Methods

In all tests sintered Ag/AgCl circular electrodes (outer diameter 12 mm, inner diameter 6 mm) were used as active electrode and neutral electrode as well. The time continuous electrode potentials were recorded by a multichannel DC-capable biosignal acquisition system (eldith GmbH, Germany) with MATLAB™ interface (The MathWorks Inc., USA). The used sample rate was 128 sps.

For analysis of the differences in stabilisation time in pure NaCl solutions, KCl solutions and common salt (“ja-Speisesalz”, not iodized, not fluoridated) solutions at concentrations of 0.9%, 4% and 10%, the electrodes were placed at different positions within the solutions and the electrode potential has been measured. The maximum distance between the neutral electrode and the active electrodes was 10 cm.

In continuative measurements the electrodes were activated in common salt solution at concentrations of 0.9%, 4%, 6%, 8% and 10%, in the electrode paste Ten20 (D. O. Weaver and Co, Aurora, CO, USA) and in Abralyt HiCl (Falk Minow Services, High Chloride (10%), Abrasive Electrode-gel, in the following called electrode paste) for 10 minutes. “Activation” is a procedure to prepare the electrodes before the measurement will be started. The concentration of chloride ions is increased by the use of a special substance containing chloride ions in order to accelerate the initial transients at the electrode-electrolyte interface.

Then the electrodes were positioned inside the electrode pastes not contacting one another so that the active surfaces of the active electrodes and the neutral electrode pointed to each other. The stabilisation of the electrode potential in the electrode pastes was recorded.

Furthermore, it was investigated whether heating the solution or the electrode paste to 37°C before starting the measurement would reduce the initial electrode drift. Therefore the electrodes were activated for 10 minutes

in common salt solution at a concentration of 10% for Ten20 and 6% for Abralyt HiCl, respectively. Accordingly they were placed in the electrode paste and the electrode potential was recorded.

The combinations of solution temperatures and of electrode paste temperatures are shown in Table 1.

Table 1: Analysed combinations of temperature of common salt solution (step 1) and electrode paste (step 2).

Measurement	Temperature salt solution	Temperature electrode paste
A	20°C	20°C
B	20°C	37°C
C	37°C	37°C
D	20°C	Slow warming from 20°C to 37°C

For additional tests Ten20, Abralyt HiCl and common salt solution at a concentration of 10% at a volume of 20 ml each were used. A stabilisation time of 30 minutes in the electrode paste and the salt solution itself leads to largely stable electrode potentials. In the following the electrodes were heated from 20°C to 45°C inside the paste and the solution, respectively. Reaching the temperature of 45°C the heat addition was stopped. The electrode potential was measured while heating and during the following 25 minutes as well.

In Ten20 and Abralyt HiCl a slow warming as it could occur on the patient's head was tested, too. Activated for 10 minutes in common salt solution at a concentration of 10% and 6%, respectively, the electrodes were positioned inside glass reservoirs filled with 20 ml of the pastes and put into a water bath at a temperature of 37°C.

Altogether 80 measurements were carried out recording the potential of four electrodes each. Utilising 25 Ag/AgCl circular electrodes only two of them were employed as neutral electrode. All post-processing was done using MATLAB™. The data were filtered, averaged and the drift values were calculated.

Results

The comparison of electrode potential and drift shows no significant difference of using KCl solution, pure NaCl solution or common salt solution. As expected and mentioned in [3] the concentration of chloride ions is important. The shortest time in electrode potential stabilisation and the lowest value of drift were conceived by a salt solution at a concentration of 10%.

If the distance between the neutral electrode and the active electrodes is less than 10 cm the electrode position within the solution or electrode paste does not affect the potential or drift.

Activating the electrodes in common salt solution at a concentration of 10% before using Ten20 electrode paste leads to the lowest values of electrode potential drift and the shortest time of stabilisation as shown in Figure 1. After five minutes a stable electrode potential was obtained.

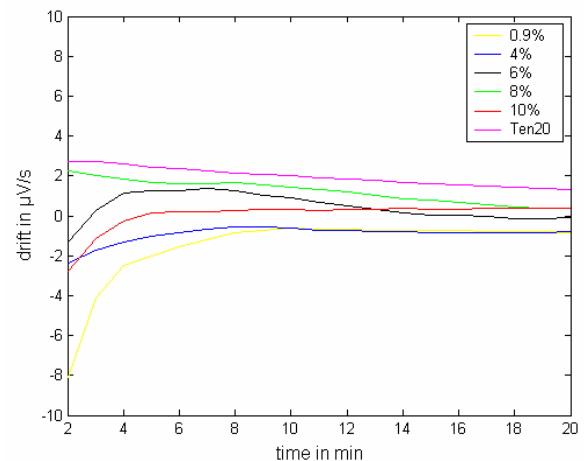


Figure 1: Values of drift of the initial electrode potential in Ten20 electrode paste after activating the electrodes in common salt solution at a concentration of 0.9%, 4%, 6%, 8%, 10% and in Ten20 itself.

For measurements using Abralyt HiCl lowest values of drift can be achieved activating the electrodes in common salt solution at a concentration of 6% or in Abralyt HiCl itself (cf. Figure 2). This is confirmed by contemplating the values of the electrode potential.

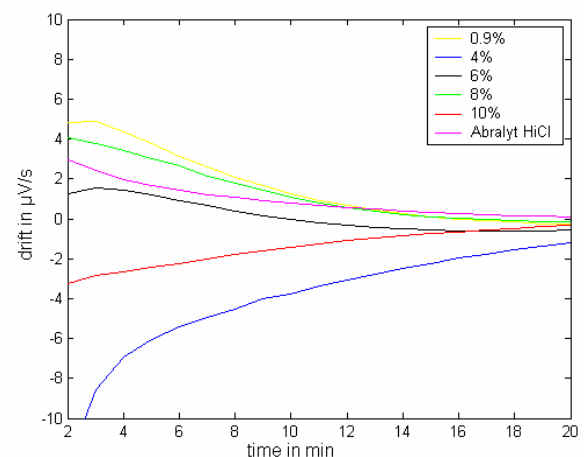


Figure 2: Values of drift of the initial electrode potential in Abralyt HiCl electrode paste after activating the electrodes in common salt solution at a concentration of 0.9%, 4%, 6%, 8%, 10% and in Abralyt HiCl itself.

Comparing Figure 1 and Figure 2 shorter time of stabilisation and lower values of drift were achieved using Ten20 electrode paste, even though the varieties are not significant.

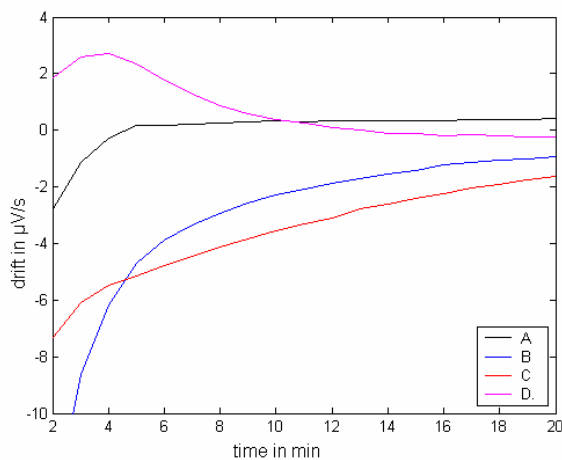


Figure 3: Values of drift of the initial electrode potential in Ten20 electrode paste at different temperatures after activating the electrodes in common salt solution at different temperatures (cf. Table 1)

Heating the solution or electrode paste to 37°C before starting the measurement does not reduce the initial electrode drift, cf. Figure 3. Keeping the temperature of the electrode paste constant at 20°C during EEG measurements is not possible because of the human body temperature. Thus, activation in common salt solution at 20°C and a slow warming, as it occurs on the patient's head, result in the fastest stabilisation of the electrode potential.

Exactly identical results were achieved in these tests with Abralyt HiCl electrode paste.

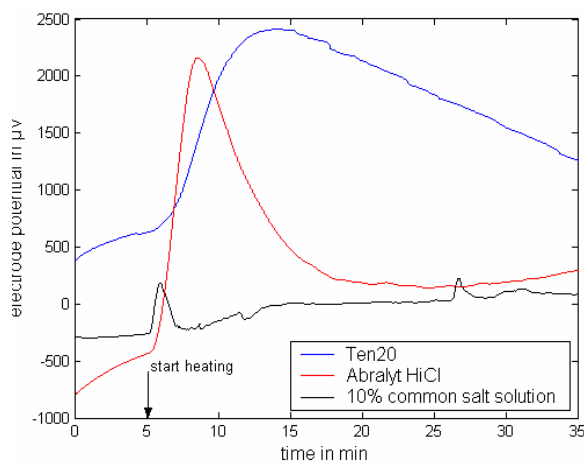


Figure 4: Electrode potential while temperature rises from 20°C to 45°C after heating starts at 5 minutes

At a temperature rise from 20°C to 45°C the electrode potential varies significantly as demonstrated in Figure 4. After 5 minutes recording the stabilising electrode potential heating was started. As soon as the temperature grows, the electrode potential increases

rapidly. A temperature of 45°C was reached in the common salt solution after 4 minutes, in Ten20 and Abralyt HiCl electrode paste after about 7 minutes. After having stopped the heat supply the temperature remained constant at the highest stage for 5 minutes in the salt solution and 7-8 minutes in the electrode pastes. Subsequently it declined slowly (< 1°C per minute). The electrode potential of both common salt solution and Abralyt HiCl reaches a small and stable value when the temperature, independent of its amount, changes less than 1°C per minute. Following, the drift will have a small amount.

In Ten20 electrode paste a slight rising or decreasing of the electrode potential and therefore more drift was detected even at constant temperature and little temperature changes. An advancement of the warming method induced the obtained results of the next tests, presented in Figure 5.

A gradual warming up from 20°C to 37°C shows no fundamental difference between Abralyt HiCl und Ten20 electrode pastes concerning their behaviour of potential and drift. Reaching high drift values when the temperature increases rapidly, the electrode potential remains constant and the values of drift are small having changes of the temperature less than 1°C per minute. It confirms the results attained in the tests before. In Abralyt HiCl a faster rise of the temperature was detectable and the drift reaches higher amounts, but the disparity to Ten20 electrode paste is not significant.

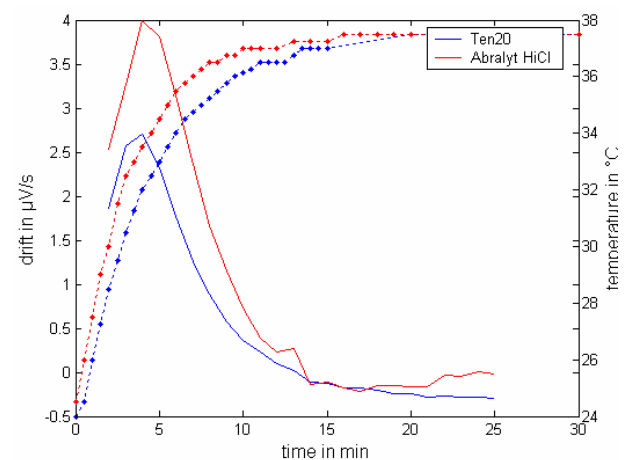


Figure 5: Values of drift (solid line) of the electrode potential in Ten20 and Abralyt HiCl electrode paste while warming up from 20°C to 37°C (dotted line)

Approximately 10 minutes after placing the electrodes inside the pastes into the water bath the electrode potential in Ten20 and Abralyt HiCl as well remains almost constant, so the DC-EEG measurement could be started.

Discussion

The concentration of NaCl in Abralyt HiCl is about 10%. It was expected that activation in common salt solution at a concentration of 10% would lead to the shortest stabilisation time of the electrode potential. As

the results of the measurements show, most expeditious stabilisation was achieved when the electrodes were activated in common salt solution at a concentration of 6% or in Abralyt HiCl itself. The reason for this occurrence remains unclear.

Checking out salt solutions at concentrations higher than 10% was set aside because skin irritation on the patient's head was provoked using 10% solutions, already.

In this study few tests on the influence of temperature were carried out. More and other extreme conditions like quicker controlled heating and cooling as well as excursive temperature changes should be the object of further measurements.

So far all tests were done in vitro. To optimise further research in this field, the temperature development in the electrode paste and near the electrode, respectively during EEG measurements should be analysed.

Conclusions

As no difference using pure NaCl solution, KCl solution or common salt solution was detectable, it is possible to realise specific measurements and the activation of electrodes by application of solutions made of common salt. It has to be not iodized and not fluoridated otherwise the electrodes will get damaged.

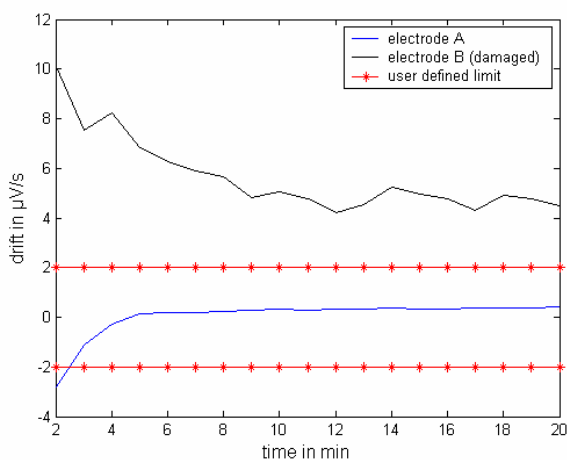


Figure 6: Possible result of the functional efficiency check of electrodes for DC-EEG measurements.

By applying the results of the first tests, a simple method to check functional efficiency of electrodes for DC measurements was found. For this purpose the electrodes have to be positioned in a salt solution (e.g. common salt solution at a concentration of 10%) so that they do not contact each other. After recording the electrode potential with a DC-capable amplifier for each electrode the values of drift must be calculated.

If the drift values are not within user defined limits after a certain time, the further application of these electrodes should be avoided. In Figure 6 one possibility of representing the results is demonstrated. Utilising a

multi-channel amplifier numerous electrodes can be checked simultaneously.

Activation of the electrodes in common salt solution at a concentration of 10% instead of using solution at a concentration of 0.9%, as it has been customary to now, reduces the stabilization time of the electrode potential significantly. Attaining a stable potential after 10 minutes applying 0.9% solution, this could be achieved after 5 minutes utilizing a solution at a concentration of 10%. This comes up to a reduction of the time at 50%. For Abralyt HiCl electrode paste related conclusions could be compassed. Shorter stabilisation time entails shortening of the measurement period and diminishment of the stress of the patients during EEG measurements.

Warming the salt solution before activating and the electrode paste before placing on the head, respectively, up to body temperature is not required and does not reduce initial electrode potential drift.

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