Letter to the Editor "On the feasibility of noncontact ECG measurements"

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Letter to the Editor "On the Feasibility of Noncontact ECG Measurements"

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The article by Kranjec *et al.* [1], "Novel methods of noncontact heart rate measurement: A feasibility study" is interesting and informative as it compares different contactless methods for heart rate detection. Nevertheless, the use of the term "capacitively coupled ECG" (CCECG) in the article is confusing and may mislead readers.

That article studies the feasibility of four noncontact methods for heart rate measurement, which are classified in two groups: "the methods measuring electromagnetic energy generated by the bioelectrical activity within the cardiac muscle (referred to as direct methods), and the methods measuring displacement of a part of the subject's body caused by the periodic physical contractions of the heart (referred to as indirect methods). The first group is represented by a measuring device which detects changes in surrounding electric field..." [sic]. Later on, this device is described in [1] as being based on "capacitively coupled electrodes" and hence termed "CCECG Measuring Device." The electrodes are two 48-cm^2 metal plates placed side by side (see [1, Fig. 3]) placed at distances from 5 to 60 cm from the chest.

Capacitive electrodes for biopotentials were proposed long ago. The two first types were based on small anodized aluminum plates [2] and ceramic material [3]. The first yielded typical ECG signals with clearly identifiable waves, particularly the QRS complex and T wave. Their use required a differential amplifier with high enough input impedance compared with that of the electrodes in the 0.5–40 Hz frequency range. This was not very demanding because the capacitance of the electrodes exceeded 100 pF due to the thin dielectric used and to the mechanical contact between electrode and skin.

Contactless capacitive electrodes are feasible but air is a very poor dielectric, which makes electrode capacitance C_e to rapidly decrease with increasing body distance. If that capacitance is estimated using [1, eq. (3)], for 48-cm^2 plates at 5 cm from the body, C_e would be about 0.85 pF and decrease to 0.07 pF for a plate at 60 cm from the body. These capacitances attenuate the signal because of the voltage divider effect due to the equivalent differential input capacitance (C_in) of the measuring device. C_in cannot be easily reduced as it comprises amplifier capacitance C_d, (more than 3–4 pF in electrometer-grade instrumentation amplifiers such as INA116 used in [1]) and electrode-to-electrode capacitance C_ee, which depends on their area and separation. At 10 Hz, where the maximal power spectral density of the ECG is, the impedance of 1 pF is about 16 GΩ, and therefore, extremely high input resistances cannot avoid signal attenuation because the impedance of input capacitances is smaller. Anyway, if that voltage divider effect were the only problem, ECG waves could still be visible for electrodes very close to the body surface, say less than 2–3 mm, because the ECG would be attenuated only by about 20%. It turns out, however, that body surface movements, very prominent in the chest, make the electrode-body distance C_e to change. As a result, signal attenuation becomes dependent on any physiological activity that produces body surface movements, mainly respiration and cardiac-induced vibrations. Further, electrostatic surface charges yield variable potentials that reflect those displacements, as reported in [4].

Therefore, it should not be a surprise that if a strong electric field is created nearby the body (a 1 kV source was used in [1]), variable potential differences can be detected that reflect respiratory and cardiac activity. But these are not the "contactless ECG" at all. In fact, the peak-to-valley amplitude of the so-called CCECG in [1, Fig. 11] is about 900 mV, much larger than the surface ECG measured with contact electrodes, in spite of measuring at 5 cm from the thorax. At 15 cm, the amplitude of the "CCECG" is about 40 mV [1, Fig. 12]. That is, tripling the separation reduces the signal by a factor larger than 20, which suggests that C_e cannot be simply modeled as a parallel-plate capacitor as in [1, eq. (3)].

Consequently, the so-called CCECG Measuring Device is not a "passive method with no need for electromagnetic radiation" as claimed in [1, Section V]. It is an active method that relies on an external dc electric field that is distorted by body surface movements the same as methods based on radar or ultrasound. The "electric field applied in the close proximity of the measuring electrodes" did not "enhance the sensitivity of the sensors" because these did not detect the ECG, as no ECG waves were visible in any of the recordings. Instead, the signal recorded is the distortion of that external field because of the mechanical activity of the heart and respiration reflected on the chest surface. In other words, what was measured was the variable C_e.

Noncontact ECG measurement needs electrodes whose impedance is, at most, comparable with the equivalent differential input impedance of the measuring device and remains constant. In practical terms, electrode capacitance should not be smaller than, say, 1 pF, which seems unfeasible for electrodes at more than 2–3 mm from the body. As for keeping

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electrode distance constant, it is not easy to achieve that without resourcing to a mechanical contact and hence the noncontact advantage would be lost.

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