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Respiratory Sensor Continuously Attached on the Abdomen

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Abstract

A respiratory sensor is studied measuring the capacitance constructed by the attached electrodes on the abdomen. The skin thickness change caused by the respiration gives the cyclic capacitance signal. The contact condition of the electrode is stabilized using the 7μm-thick dressing film. Such stabilized electrodes can give not only the respiration but also the body volume signals. As the demonstration, the respiration is measured during the exercise and the 6-minute walk.

1. Introduction

Recently, the sensors suitable for continuous monitoring of the patient's vital sign gather the attentions from the medical and healthcare fields. Daily monitoring of the subject's health and activity information is considered to lead to the detection of a change in the physical condition and to the early detection of the disease. Now, there are some wearable sensors in market (e.g, Silmee™ from Toshiba, Hitoe™ from NTT). Many products measure the heart rate and the temperature, but not the respiration.

Although the respiration is recognized as one of the important vital signs, it is said as the most neglected one[1] because of the lack of sensing method under the natural condition. Since the respiration is consciously controllable, keeping natural condition is important. The conventional spirometer uses the mask and the tube tethered to the equipment, and disturbs the subjects' natural activity[2]. The piezoresistive fabric sensors are studied[3]. The inner garment surrounding the body gives the stress. This stress is big for baby / elder people, and also usual people when sensing period is long.

In this study, based on our previous finding that the capacitance signal gives the skin condition changed by the respiration[4, 5], the electrodes are closely attached on the skin for obtaining the pure signal.

2. Experimental Setup

Figure 1(a) shows the skin model. The capacitance is constructed between one electrode attached outside and another of the inside electrolyte. Figure 1(b) shows the condition under the exhalation. The body volume decreases, and the skin thickness shrinks. The gap between two electrodes will increase. The capacitance decreases. Figure 1(c) shows the condition under the inhalation.

For obtaining the pure signal as much as possible, the electrode is attached on the skin not inside the wear. Three attaching tapes in Table 1 are tested. The sports tape suffers from the drift noise. The silicone gel sticks to the skin stabilizing the signal but the signal magnitude decreases. The dressing film (Airwall™) stabilizes the signal keeping the signal magnitude because it is thin. There are the tiny holes for the breathability.

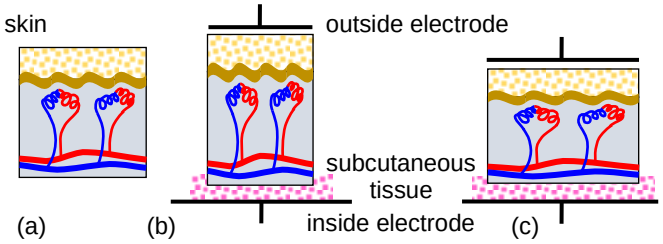


Fig. 1. (a) Skin structure. The model of the electrodes constructing the capacitance across the skin at (b) the exhaled and (c) the inhaled conditions.

Table 1: List of the tapes tested for sticking the electrode.

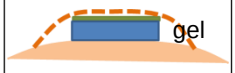
Sports tape	Silicone gel	Dressing film
for taping	for artificial scab	for fixing needle of a drip infusion
t0.4mm tape (under-layer and cover).	t2mm plate (under-layer). Cover is sports tape.	t7μm film (under-layer and cover).
		
Drift occurs. X	Signal is stable but decreases. X	Signal is stable and large. O

Figure 2 shows 4×4-cm^2 electrodes attached on the abdomen. The distance between electrode centers is 7 cm. The longitudinal position is the middle between a navel and an epigastric fossa. The capacitance between these two electrodes is measured by the impedance analyzer (Hioki IM3570) at a frequency of 400 kHz. The holes in the conductive textile are for fixing using the cover film.

3. Results

Signal for Daytime

Normal respiration is measured lying on the mat for making the posture same. The electrodes are continuously attached for measurements at 10:00, before/during/after lunch, 15:00, and 16:00. Figure 3 shows the measured capacitance. The capacitance increases at inhaled, and decreases at exhaled conditions. The amplitude due to respiration is almost same to be about 10 pF. The baseline reduces and increases at hungry and satiated conditions, respectively. The satiated condition gives 14-22% larger baseline compared to that in hungry condition in several experiments.

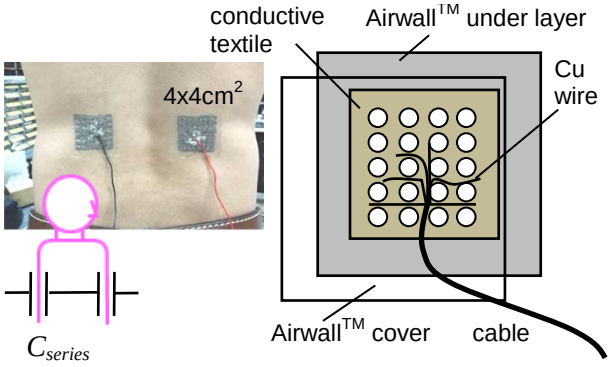


Fig. 2. Typical electrodes attached on the skin. The conductive textiles are used. Two capacitances are considered to connect in series inside the body.

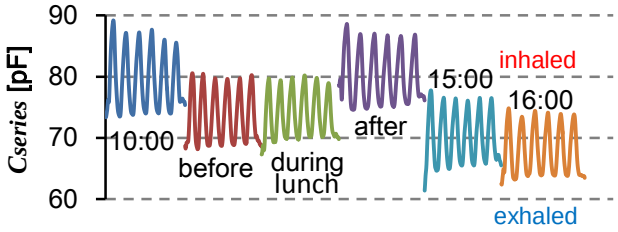


Fig. 3. Signal change during day time pasting electrodes on the skin continuously.

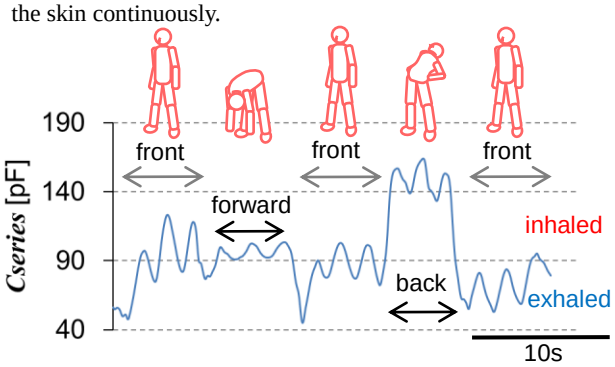


Fig. 4. Abdomen capacitance signal during the exercise of bending the upper body forward and backward.

Singal during Bending Upperbody Forward/Backward

Figure 4 shows the capacitance when the upper body bends about 90° forward and backward. Three times normal respiration is done keeping each posture. Three peaks correspond to the respiration. Although the postures with the skin sag or stretch decrease the signal ratio caused by the respiration, the respiration can be counted. Even with such large body movement, the maximum value of the capacitance is 4 times of the minimum value. This will not be a problem of the dynamic range for the sensor.

Signal during Slow Walking for 6 min

Figure 5 shows the data during 6-min walk, which is the standard test in the medical diagnosis for checking the lung activity. The wireless unit is used for allowing free walking. The capacitance is measured using the inverter circuit. The vertical value is arbitral unit. The larger capacitance gives the smaller output. On the periodic capacitance change of

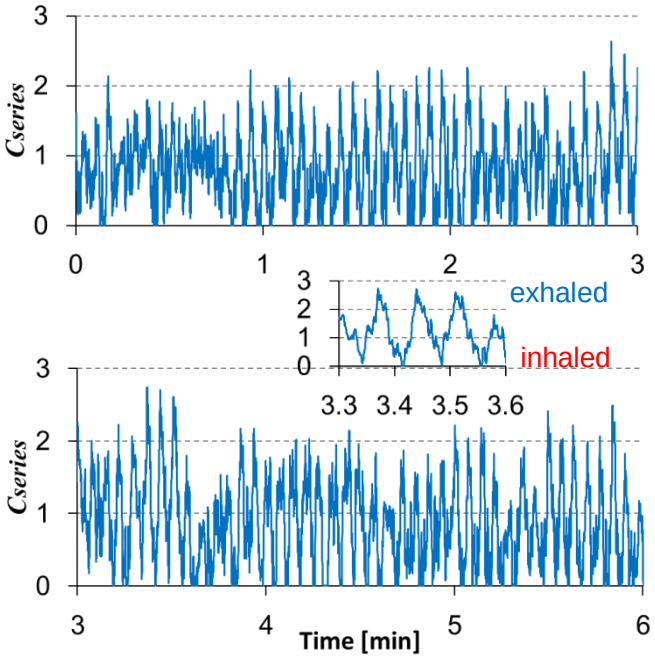


Fig. 5. Abdomen capacitance signal during slow walking for 6 minutes.

the respiration signal having the magnitude of about 2, there are smaller peaks corresponding to the stepping motion.

4. Conclusions

Based on the understanding that the capacitive signal comes from the electrical skin thickness, the stable respiration signal is obtained when the electrodes attached on the skin being compliant against the body movement. The minute body expansion caused by having the meal also can be detected by the baseline increase. Sensing respiration during the activity with the body movement is demonstrated.

Acknowledgements

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