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ECG movement artefacts can be greatly reduced with the aid of a movement absorbing device

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Abstract: Accurate ECG signal analysis can be confounded by electric lead, and/or electrode movements varying in origin from, for example, hiccups, tremor or patient restlessness. ECG signals recorded using either a conventional electrode holder, or with the aid of an electrode holder capable of absorbing movement artefacts, were measured on a healthy human subject. Results show a greatly improved stability of the ECG signal recorded using an electrode holder capable of absorbing movement artefacts during periods of lead disturbance, and highlight the movement artefacts that develop when the recording lead of a conventional ECG electrode holder is tugged or pulled during the period of monitoring. It is concluded that the new design of ECG electrode holder will not only enable clearer signal recordings for clinical assessment, but will reduce the ECG artefacts associated with the transportation of patients, and may also reduce the time spent by hospital personnel answering ECG alarms that are the result of patient movement.

Keywords: Electrocardiograph, surface electrode holder, lead disturbance

INTRODUCTION

It is well documented and accepted that lead and/or electrode movements, either of operator or patient origin, can give rise to temporal disruption or even loss of a recorded signal [1, 2, 3, 4, 5]. A common example of a movement related artefact is baseline wander or drift, perhaps as a result of a slight patient movement, hiccups, a tremor, or more severely a seizure. In a study involving computer-assisted analysis of an ECG signal in 708 subjects spanning the ages of 2 weeks to 27 years, either a baseline shift of 0.25 mV exceeding 7% of the data collected in a 6 s period, or a noise content greater than 15 mv RMS exceeding 6% of the data collected in a 6 s period, from 3 simultaneous leads were used as criteria to define traces as unacceptable for analysis on the basis of artefacts [6]. In the study by Arthur [6] these criteria led to the rejection of 68% of records from 0-4 year-old-subjects, and 31% of records from adults aged 19 years and over on the basis of technical quality. Furthermore, it was reported that ECG artefacts were primarily due to the actions of subjects, secondarily to technician error, and lastly as a result of equipment malfunction [6]. Whilst filters can be designed to remove this type of artefact, they will undoubtedly distort the low frequency components of the ECG signal, such as the TP-segment, the PR-segment, and most specifically the ST-segment [2]. Another problem with movement artefacts can be their resemblance to arrhythmias, and unless they are correctly identified as simply being an artefact, they may lead to serious errors of diagnosis and therapy [1, 4, 5, 8]. Moreover, changes in ECG signals, as perceived by monitoring equipment, can also give rise to a number of false call-outs where nursing or medical personnel are called to a patient to assess an abnormal ECG signal resulting from movement of the patient. To date, some steps have been taken to try and minimise movement artefacts associated with surface recording electrodes, namely, relocation of the lead connector to a less central site on the electrode holder, and use of materials that allow some movement of the connector, albeit limited in terms of direction. However, current commercial surface electrode holders still rely on a direct physical link between the recording electrode and the lead connector, a constant potential source of movement artefacts on an ECG trace. In a recent article in which were published results from the field of electromyography on isolated rat skeletal muscle, it was shown that use of a device capable of absorbing movement resulted in measurement of a stable compound action potential (M-wave) from deep within muscles contracting at frequencies of up to 90 Hz [7].

This study, as a consequence, addresses the question of whether incorporation of a device capable of absorbing movement into a commercially available ECG electrode holder can reduce the incidence of movement associated artefacts on a recorded ECG trace.

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METHOD AND MATERIALS

Standard commercial ECG electrodes (Blue Sensor type VL00S; Medicotest A/S, Ølstykke, Denmark) with or without the addition of a device capable of absorbing movement (Fig. 1, Patent No. PA 1998 01020), were applied to a healthy male human subject, aged 33 years. Although only one subject was used in this study, it is considered that the results more than adequately illustrate the potential of the device shown in Fig. 1 in terms of reducing ECG artefacts, which was the primary intention of the authors. A standard 5 lead ECG setup with

2 independent leads was used. Electrodes were connected to a TeleGuard MkII telemetry system (Danica BioMedical A/S, Rødovre, Denmark), which sent an ECG signal to a display monitor and to a personal computer from which the recorded signal could be printed. The subject was allowed to move freely over a period of 30 min continuous recording. During recordings, the subject made a number of movements, for instance circling movements of the arms, deep intakes of breath and coughing in order to simulate normal patient activity. Furthermore, in addition to the aforementioned activities, the recording leads attached to the ECG electrodes were subjected to short periods of approximately 4.0-7.5 s of movement disturbance in the form of rapid sequential pulls or tugs on the recording lead.

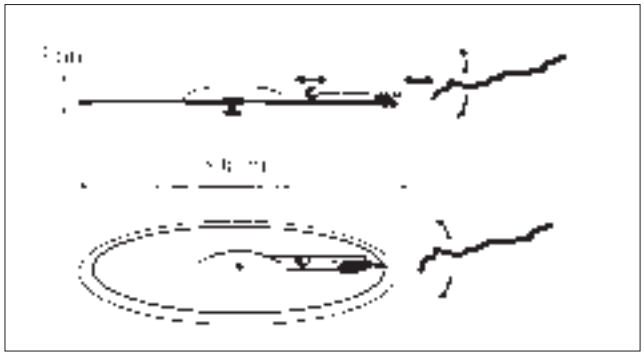

Figure 1 Line drawing of an ECG electrode modified to incorporate a device capable of absorbing movement, according to Patent No. PA 1998 01020. Note that the sensor in the centre of the ECG electrode, which is in contact with the patients skin, maintains a constant electrical contact *via* a 'silver piston' with the recording lead, by means of an electrolyte. The 'silver piston' and its holder are capable of absorbing movement in 3 different axes.

RESULTS

It was noted that subject movements often resulted in a noise content, which was of greater magnitude in the ECG electrode holder without, as opposed to fitted with a device capable of absorbing movement. In Figures 1 and 2, examples of just such noise in the data, which resulted in distortion of the P- and T-waves, was measured as be ing as little as 10% (0.20 mV), and as great as 28% (0.56 mV) of the recorded signal amplitude. However, deep respiratory movements or coughs gave no obvious change or disturbance to the recorded ECG signal in this particular instance. In stark contrast, however, signal disturbances were noted when the recording leads attached to the ECG electrodes were pulled or tugged, simulating patient-initiated movement of the recording leads.

In Fig. 2 an overview of part of the recorded ECG signal is presented so that a stable recorded signal is shown prior to movement disturbance artefacts from a commercial ECG electrode holder without (A) or with (B) the addition of a device capable of absorbing movement. This Figure shows that the addition of a device capable of absorbing movement to a commercial ECG electrode holder does not affect the amplitude or the shape of recorded ECG signals. It should be noted that for this trial one of the ECG recording leads only was fitted with a device capable of absorbing movement; the other electrodes remained un-modified, thus alternate pulls and tugs to either the standard electrode, or the 'improved' electrode produced the recording shown in Fig. 2, which accordingly shows no signs of electrode switching or exchange.

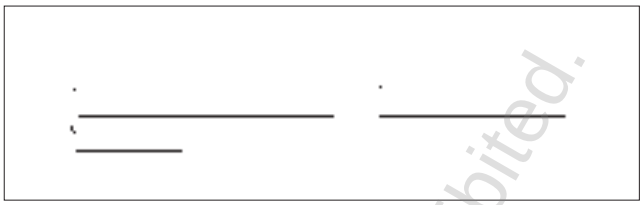

Figure 2 An overview of ECG signal recordings obtained using a commercial ECG electrode holder. The first line presents stable control ECG signals where no movement of the recording leads was undertaken. The regions labelled (A) present the ECG signal for a commercial ECG electrode holder during a period of repeated pulling and tugging of the recording leads; the region labelled (B), which lies between the (A) regions, presents the ECG signal for a commercial ECG electrode holder fitted with a device capable of absorbing movement during a similar period of lead disturbance.

In Fig. 3 the results of 3 separate movement disturbance tests are presented for a commercial ECG electrode holder without (A) or with (B) the addition of a device capable of absorbing movement. The results for the traces denoted (A) show quite clearly that rapid sequential tugs or pulls on the recording lead result in a disturbance and distortion of the ECG signal for the commercial ECG electrode holder. Signal disturbance in this test primarily affected the P and T regions of the ECG signal, the regions associated with depolarization of the atria and ventricular repolarization, respectively. In contrast, the results for the traces denoted (B) in which a device capable of absorbing movement was used, the recorded ECG signal appears much cleaner with little or no disturbance or distortion of the signal.

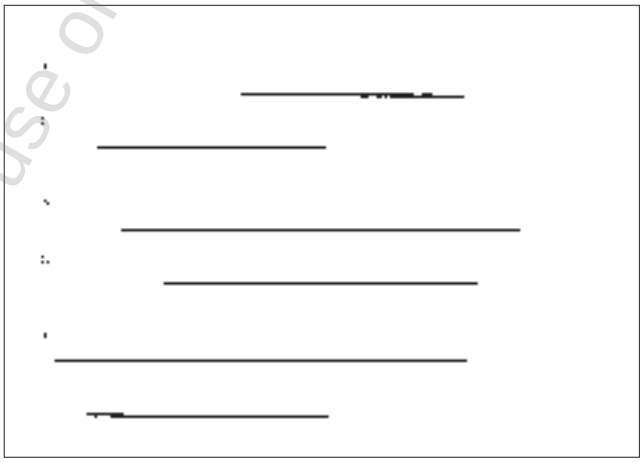

Figure 3 Comparison of ECG signal recordings obtained using a commercial ECG electrode holder without (A) or with (B) a device capable of absorbing movement. Solid black lines represent the period of time during which recording leads were repeatedly pulled or tugged. Scaling represents 25 mm/s trace speed on the horizontal axis and 1.0 mV/cm signal amplitude on the vertical axis.

The pulling and tugging tests performed in the present study gave rise to some baseline shifts. In commercial ECG electrode holders, changes in the baseline arising from lead disturbances ranged in amplitude from approximately 0.2-0.6 mV, whereas values for commercial ECG electrode holders fitted with a device capable of absorbing movement were approximately 0.2-0.4 mV, on those occasions when lead movements gave rise to a baseline shift.

DISCUSSION

This study confirms the results obtained by other researchers by showing that current commercial ECG electrode holders are prone to signal artefacts if the recording leads are exposed to movement [1, 7, 8]. While this study measured baseline shifts of the same magnitude as those reported by others [1, 3], the use of a device capable of absorbing movement in conjunction with a commercial ECG electrode holder gave an ECG signal that had a great deal less noise, and was much clearer in terms of analysis and interpretation than that given by a commercial ECG electrode holder alone. The majority of noise in the present study, caused by lead movement, was found to be associated with the P- and T-waves – regions of the ECG signal that are important for the clinical evaluation of, among others, atrial hypertrophy, hyperkalaemia, hyperacute myocardial infarction, pericarditis and electrolyte disturbances [8, 4]. The specific susceptibility of existing commercial ECG electrode holders to electrocardiography signal instability as a result of lead disturbance is likely to be a problem in diagnosis and therapy for: 1) neonates in intensive care units; 2) post-operative patients forced to shift position in bed for reasons of comfort; 3) recuperating patients attached to telemetry equipment, where electrode leads may be especially prone to disturbance; 4) patients in transit between operating theatre and ward, or en route in an ambulance to a medical centre or hospital; and 5) uncooperative patients. It is therefore concluded that incorporation of a device capable of absorbing movement into existing designs of commercial ECG electrode holders will not only result in ECG signals with minimal movement artefacts despite considerable agitation of the recording leads, but that it will also reduce the occurrence of false call-outs, where a nurse or a medic is called to the side of a patient after monitoring equipment has detected a change in the ECG signal arising from movement of the patient. Moreover, it is anticipated that the incorporation of such a device will enable the manufacture of smaller ECG electrode holders, since absorption of lead movement will reduce the need for extensive adhesive material as an anchor for a recording electrode. With regard to the later point, a reduction in ECG electrode holder size would be greatly advantageous in facilitating the monitoring of electrocardiographs in: 1) post-operative thoracic patients where availability of place for fixation of ECG electrodes is limited, and removal of large adhesive surfaces is especially painful; and 2) neonates and infants.

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