Title : HIGH ELECTRODE IMPEDANCE AS A CAUSE OF EKG DISTORTION

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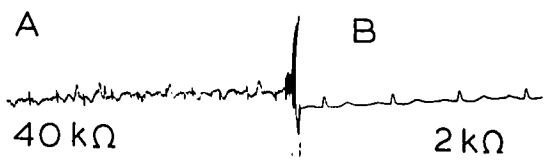
Introduction. The availability of an undistorted electrocardiograph tracing is an essential requirement for the appropriate management of cardiac arrhythmia. Haslam and Bruner[1] studied the epidemiology of failure in cardiac monitoring systems used at the bedside. They found that 40% of all problems were due to malfunction of the electrodes, the lead wire, or the patient cable. In our operating rooms, with an average of 1,400 cases per month (all of which are EKG monitored) the laboratory receives about 50 system failure calls of which approximately 30% are due to electrode or cable malfunction.

With modern high input impedance physiological signal amplifiers, the most common sources of electrical interference are the numerous electrical fields set up by line operated equipment used in the operating room. Since most modern differential input amplifiers have extremely high common mode rejection, most interference is rejected if the electrode to electrode impedance is low. When the electrodes are unbalanced, the voltages induced by stray electric fields are not rejected by the amplifiers and cannot be eliminated by selective filtering. As the frequencies of the interference signals span across the bandpass of the EKG, marked distortion of the EKG will then result.

Since most of the equipment is not in use during the immediate preoperative period, there is no visual indication that the electrode impedance may be great enough to render the EKG useless later in the case, when, for sterility reasons, the electrodes cannot be readily replaced. During the critical transition period from cardiopulmonary bypass to normal cardiac function, the EKG is essential for diagnosis and treatment. Furthermore, the EKG signal may be required to synchronize intra-aortic balloon pump support with the patient's heart activity.

An example of distortion of the EKG tracing due to an electrode with a high impedance is shown below:



The EKG taken prior to induction of anesthesia was free of electrical interference. At the end of cardiopulmonary bypass, the EKG was difficult to interpret (A). Electrode impedance was 1.5 and 40 KΩ. Replacement of the 40 KΩ electrode restored the readability of the EKG despite the continued presence of the disturbing electrical field (B).

In this study, we have documented the magnitude of the impedance of electrodes of various makes with and without skin preparation.

Methods. In those operating rooms where ECG is monitored telemetrically through 2 electrodes, 2 sets were used. One set was applied without preparation, the other set was placed nearby after cleaning the skin with a solvent (Freon) followed by abrasion with an abrasor provided with the electrodes. A current of 8 μA at 30 Hz was passed through the electrodes and the impedance measured. The values were recorded immediately after application, 5 minutes, and 1 hour later for each of the electrodes.

In the open heart operating rooms where a 4 lead wire system is used, the current was passed through 1 electrode to the other 3 electrodes which were connected in parallel. In this way, a representative value for each electrode was found. If the impedance measured more than 20 KΩ, the electrode was replaced. Measurements were made after application and at the end of the open heart procedure.

Results. In those operating rooms where 2 electrodes were used, the average impedance of 45 electrodes without any skin preparation was 68 KΩ (SD 20). After 5 minutes, the impedance had decreased to 50 KΩ (SD 23.6), while 1 hour after application, the impedance diminished to 34 KΩ (SD 20.7). In the same patients, the impedance after abrasion and cleaning with a solvent immediately after application, 5 minutes later, and 1 hour later were respectively 11 KΩ (SD 15.9), 9 KΩ (SD 12.5), and 7.5 KΩ (SD 9.3). The decrease was statistically highly significant if compared to those without preparation and measured at the same time.

In the open heart operating room, all electrodes were applied after careful skin preparation. Of 204 electrodes, 18 were replaced because of a measurement of over 20 KΩ. The preoperative impedance was 4.7 KΩ (SD 4.7). At the end of the open heart procedure, the value was 3.2 KΩ (SD 3.2) and only 2 electrodes had an unacceptable rating.

Discussion. Most EKG tracings were of reasonable quality throughout the operation, regardless of the measured electrode impedance if a telemetric system was used. Only when the impedance was unusually high did the EKG become diagnostically unusable, especially after various electrical apparatus were added. During open heart surgery, where as in most operating rooms, direct wiring of the EKG was used, provision of low impedance electrodes was critical to preserve an undistorted EKG tracing. We concluded that 1) Cleaning and abrading of the skin prior to EKG electrode placement decreases the impedance markedly. 2) The readability of the EKG will be better maintained if the impedance of the electrodes is low. 3) Measurement of the electrode impedance is advisable prior to operations, where many electrical instruments are used (e.g., cardiopulmonary bypass).

References.

1. Haslam KR, Bruner JMR: The epidemiology of failure in cardiac monitoring systems. Medical Instrumentation 7:293-296, 1973.