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Improving the clinical physiological examination environment - Avoiding EMD on medical equipment used for detecting biological signals -

***Abstract**: Shimane University Hospital constructed an electromagnetic shielded room to do electromyogram examinations. However, the quality of physiological examinations to detect weak biosignals was not acceptable. To create a safer environment, we re-installed the electric grounding and shortened the power cable to the minimum. And, we covered the power cable using electromagnetic shielding material. Also, we used an electromagnetic shielded mesh tent with shielding capacity of 20-30 dB. As a result, the electromagnetic noise was much reduced*

***Streszczenie.** Szpital Uniwersytecki Shimane zbudował ekranowane elektromagnetycznie pomieszczenie do badań elektromiograficznych. Jednak jakość badań fizjologicznych podczas detekcji słabych biosygnałów nie była zadowalająca. W celu poprawy środowiska badań zainstalowano uziom, skrócono i zaekranowano przewody zasilające oraz zastosowano namiot z siatki ekranującej o skuteczności ekranowania 20-30 dB. W rezultacie znacznie zredukowano szum elektromagnetyczny. (**Poprawa środowiska elektromagnetycznego klinicznych badań fizjologicznych – Unikanie wpływu zaburzeń elektromagnetycznych na urządzenia medyczne do detekcji sygnałów biologicznych**).*

Keywords: Medical Devices, EMG, Electromagnetic Environment, Shielding Mesh Tent.
Słowa kluczowe: urządzenia medyczne, EMG, środowisko elektromagnetyczne, namiot z siatki ekranującej.

Introduction

Shimane University Hospital (hereafter, SUH) constructed a room with electromagnetic shielding in which to do electromyogram examinations (hereafter, the target room) in 1979. When using electromyogram (EMG) [1], noise reduction has been a serious problem for decades because the voltage is of micro-volt order. Many problems and solutions for dealing with noises related to EMG have been proposed [2]. Noises are categorized by their frequency, and most are filtered or have calculations done when processing waveforms. Reducing environmental electromagnetic noise is essential for insuring accurate biosignal tracking examinations.

For low frequency noise, the commercial frequencies (50/60Hz), are well-known for their problematic noise on EMG. Such noise can be reduced by grounding (earth), use of filters, or noise reduction circuitry [2].

For high frequency noise, the necessary requirement for shielding performance when constructing a safe environment for the use of an EMG has been proposed to be not less than 40 dB to electromagnetic noise of 500 kHz or higher frequency [3].

However, for the target room, questions about its shielding capability arose from the beginning. An electric power source wire was simply laid in the room and no noise reduction filter for the power supply or air conditioner had been installed when the room was built (see Fig. 1). Furthermore, the shielding performance of the door had decreased because of long years of use without maintenance (see Fig. 2). Because of these weaknesses, physiological examinations to detect weak biological signals, such as somatosensory evoked potential, were difficult to do in this room. In order to detect the signals, examinations took much longer than would have been necessary under good conditions.

Therefore, we attempted to improve the condition of the target room by re-constructing it with shielding against noise so that high quality, reproducible EMG examinations could be done.

However, reconstruction to improve the shielding capacity of the walls and doors was cost prohibitive. Also, examinations would have to be stopped during re-construction. Vibration from extensive construction would have been problematic and would have interfered with examinations in the next room, which houses an electroencephalogram (for identifying high order functional disorders) and the rooms directly under the target room, which are used for radiology. Radiological images could be influenced by vibration at the time images were taken.

Thus, we decided not to reconstruct the walls or ceilings, but to re-arrange the room and to add shielding materials. Herein, we report the details of this project.

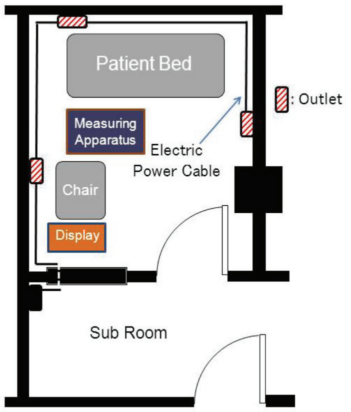

Fig. 1. The target room before improvement

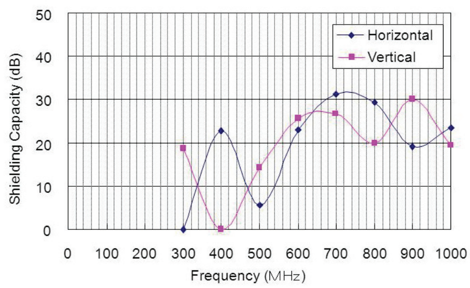

Fig. 2. Shielding capacities of the target room before improvement

Materials and Methods

It was necessary to add shielding materials against both low and high frequency noise. For low frequency noise, we re-did the electric grounding (earth), but this did not improve the quality to the required level.

We then re-arranged the location of the bed and examination apparatus. Also, the power cable was shortened to the minimum possible length and the electric sockets re-arranged. In addition, we covered the power cable and electric sockets using electromagnetic shielding materials. We used aluminum sheeting and shielding mesh (Fig. 3). To determine the effect of each shielding material, we recorded biological signals using an EMG, which can be seen in the right side of each of the Fig. 3 pictures.

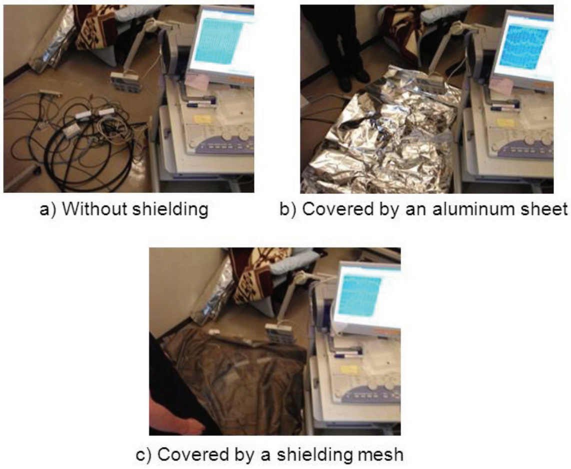

Fig. 3. Shielding method taken for power line

To protect against high frequency noise, we installed a tent made from an electromagnetic shielding mesh, and placed the bed for the examination inside the tent. The tent mesh has an electromagnetic shielding capacity of 20-30 dB and can be hung easily on metal frames (see Fig. 4 and 5). All materials with metals were equipotential bonded.

Fig. 4. Mesh tent type shielding in the target room

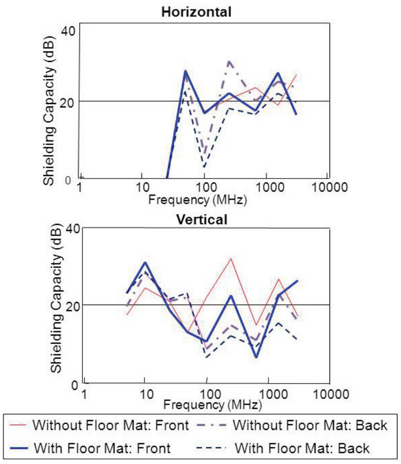

Fig. 5. Shielding capacities of the mesh tent

Finally, for both types of noise, we re-examined the arrangement of the EMG, which consists of a main body, a display, and an electrode box that connects to the wiring of electrodes that are attached to the surface of the patient’s body for signal extraction. The electrode box is connected to the main body using a 50cm arm, as seen in Fig. 4. The main body and the display are placed on a wagon. It was decided to place the electrode box inside the shield mesh tent and the body of the equipment on the outside. One side of the tent can be opened from the center, like a curtain. When closed, the mesh is positioned so that shielding performance can be maintained. The electrode box is placed inside the tent through the opening.

Results

As a result of taking these measures, the electromagnetic noise was much reduced and we have produced an environment in which examination results are always quickly reproducible.

Improvement in somatosensory-evoked-potential extraction (nervus medianus) was measured for various physiological examinations done in the target room. For this experiment, each driven normal wave form is multiplied hundreds of times and the consumption is considered the result, while the wave forms that appear as noise are rejected [4,5].

In order to determine the improvement, the number of rejected waveforms in a somatosensory-evoked-potential extraction were counted and compared.

For lower frequency noise protection, examples of the waveform taken for each test condition are shown in Fig. 6. Figure b) seems to be a good waveform, but 2 of the 4 waveforms (top and bottom) are inappropriate. For c), all waveforms seem good.

In the former environment, 1,500 or more wave forms were rejected when the normal wave form was increased by 500 times. After installation of the shielding tent, only 23 waveforms were rejected before taking normal waveforms upto 200. This result means that the total number of measurements were reduced 70% or more.

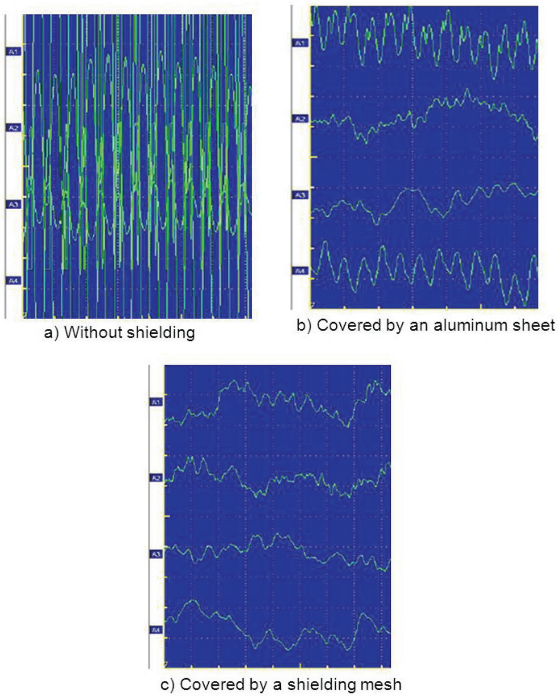

Fig. 6. Signals were taken from the power line for each shielding method

Discussion

Reducing rejection for this type of examination means that the precision of the examinations was improved. Also, the patient's burden from the examination was eased and an environment was created in which more patients were able to undergo examination. The time necessary for the measurement was also reduced. The changes were effective from the perspective of both the patients and staff.

Before the remodeling of the target room, the electric power source line was drawn in from outside and no noise rejection filters had been installed for the power supply or air-conditioning. In addition, the shielding performance of the door had deteriorated with age. Because of the above, it was difficult to carry out accurate physical examinations in the target room. This was probably caused by problems with communication between the construction company and the hospital staff at the time of construction of the building. In many cases, the staff of large hospitals sees the building for the first time only after completion. Because the administrative processes for constructing hospitals have changed little over the past many years, the possibility that such situations will continue to occur is great. When constructing or repairing hospital buildings, a process should be in place that allows the users to communicate their specific needs to the persons responsible for construction.

The target room had had problems with both low and high frequency noise for more than 30 years. Before we found the sources of the noise, almost no one in the clinical laboratory knew about it. This was not a problem of a lack of knowledge of the clinical laboratory technologists They were simply much too busy and did not have adequate time to consider corrective measures and to negotiate with the building maintenance section.

Based on information gathered from our interviews with the laboratory staff, we chose not to observe the frequency spectrum of noise in this study. Because there were many noise sources and the position of the measurement device changes with the type of examination, we could not determine a fixed point to measure. Also, because noise always varies in the results of biosignal measurement, we could not determine which value should be used, even if it could be measured. For these reasons, we compared the measurement results as evaluation of noise reduction.

For many years, noise reduction when using the EMG was a serious problem because the target biosignal is so weak. Filters are usually used, and they are effective as written above. The electromagnetic environment for using the appratus is much more important. The electromagnetic environment in a clinical setting has many components such as electromagnetic fields, the electric power supply, grounding (earth), surge (thunder, static electricity), and the static magnetic field [6]. In this study, we only focused on the electromagnetic field and grounding.

The electromagnetic environment of any area changes with time and for many reasons. For example, if there is degradation of the shielding performance because of age, as in our case. Increases in electromagnetic noise in the surroundings also must be considered. In addition, there can also be increases of low frequency noise caused by the amount of current increasing due to increased usage of operating electric energy. Other than the above, noise superimposed on the power supply can sometimes happen. This results in changes of voltage, which leads to incorrect examination values being recorded, in particular in the tracking of biomedical signals.

From an economic viewpoint, our measures were cost effective. The cost of reconstruction to SUH, cost was estimated to be at least 4 million yen (50,000 U.S. Dollars). Even though we used a custom-made tent frame, our scheme was realized at half that cost. If the tent frame could be replaced by a less expensive product, a further half of the cost could be reduced.

There are many kinds of shielding mesh currently for sale. The frequency characteristics of the shielding capacity of a mesh differ depending on the size of the mesh [7]. As the shielding capacity for high frequency waves becomes higher, the mesh size becomes smaller. However, if the mesh size of the mesh used were too small, the patient would have to be examined in a dark environment, because the transparency would be reduced. The mesh size must be selected considering the environment around the patient.

Conclusions

We were able to reduce the electromagnetic interference in the target room by use of an electromagnetic shielding mesh tent. This allowed us to create a good environment for examinations that use weak biopotential signals.

In many cases such as this, remodeling the whole room must be done, which necessitates the suspension of examinations throughout the long construction period. In addition, vibration that occurs when reconstructing walls, floors, and ceilings can interfere with work in other areas. The electromagnetic shielded mesh tent used was effective in reducing environmental artifacts. Also, electromagnetic interference was reduced and a good examination environment that derives weak potential was built. The tent greatly reduced the cost of remodeling and installation was very simple.

It might be adventagious to use this procedure in rooms with respirators and continuous infusion and for examinations in wards where life support systems are used.

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REFERENCES

[1] Merletti R., Botter A., Troiano A., et al. Technology and instrumentation for detection of the surface electromyographic signal: State of the art. Clinical Biomechanics 24, 2009, pp. 122-134.

[2] Clancy E.A., Morin E.L., Merletti R. Sampling, noise-reduction and amplitude estimation issues in surface electromyography. Journal of Electromyography and Kinesiology 12, 2002, pp.1-16.

[3] MauguieÁre F., Allison T., Babilon C. Somatosensory evoked potentials. Recommendations for the Practice of Clinical Neurophysiology: Guidelines of the IFCN, Chapter 2.4, Elsevia Science, 1999, pp.79-90.

[4] Vincent A. Methods for improving the signal-to-noise ratio of endogenous-evoked potentials. Integrative Physiological and Behavioral Science 27(1), 1992, pp.54-65

[5] Nuwer MR. Aminoff M., Desmedt J. et al, IFCN recommended standards for short latency somatosensory evoked potentials. Report of an IFCN committee. Electroencephalography and Clinical Neurophysiology, 1994, 91(1), pp.6-11.

[6] Hanada E. The electromagnetic environment of hospitals: how it is affected by the strength of electromagnetic fields generated both inside and outside the hospital. Ann Ist Super Sanità 2007, 43(3), pp.208-217

[7] Hanada E., Takano K., Antoku Y., et al. Electromagnetic shielding capacity of stainless-steel fiber mesh. IEEE EMC Society Newsletter, 2003, 196, pp.21-26

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