PhD Thesis title: 'Total Iron Overload Measurement in the Human Liver Region by the Susceptometer Magnetic Iron Detector (MID)'

Author: Barbara Gianesin
Email: gianesin@ge.infn.it
Institution: Department of Physics, University of Genoa
Supervisors: Prof. Mauro Marinelli (University of Genoa, Italy), Dott. Gian Luca Forni (Galliera Hospital, Genoa, Italy)
Graduation Date: 26th March 2010
Available on line:
http://www.fisica.unige.it/~dottorato/images/stories/Tesi/XXII/PHD_XXII_Gianesin.pdf

ABSTRACT:
An accurate assessment of body iron accumulation is essential for the diagnosis and therapy of iron overload in diseases such as hereditary hemochromatosis, thalassemia and other forms of severe congenital or acquired anaemia. Being toxic, the iron in excess must be removed by a tuned therapy (phlebotomy or chemation).
The susceptometer Magnetic Iron Detector (MID) is a room-temperature susceptometer which performs the non-invasive measurements of the total iron overload in the liver. This apparatus obtains the amount of iron in the liver region by measuring the susceptibility of the human body. To perform the measure, a low frequency magnetic field is applied to the body and the small change of the magnetic field (~1 ppm) generated by the magnetization of the body is measured by a pickup coil and a lock-in amplifier. The iron overload is then obtained by making the difference between the measured magnetization signal of the patient and its background signal. The latter is the magnetization signal that the patient would generate with a normal iron content.
About 150 healthy volunteers have been measured and several models have been developed to solve the problem of calculating the background signal of patients from their anthropometric characteristics. The first model was developed extracting the relevance of each anthropometric feature using the correlation coefficient between the measured magnetization signal and the anthropometric variables. Another approach, based on statistical learning techniques, was applied to generate a more accurate model.
As an alternative, the background signal can be also calculated directly, knowing the shape of the body, the contribution of a unitary volume of matter to the magnetization signal and the susceptibility distribution of the body. For this purpose, a laser system was used to precisely measure the 3D shape of the body. A first direct model is then constructed, assuming a uniform distribution of the susceptibility, equal to that of water (whence the name waterman). Then, the model is updated, in order to take into account the empty regions inside the body (i.e. the lungs) and outside it (i.e. the cavity of the body that the laser system is unable to detect). This model was tested on about 80 volunteers, who were measured both with MID and with the laser system.

The present MID sensitivity is about 1 g (1std) and the reproducibility of the iron overload measurement of the same patients is better than 0.5 g. As a comparison, a healthy liver contains an average of about 0.4 g of iron. Between February 2005 and February 2010, the MID has been used by the Galliera Hospital of Genoa and about 750 patients have been measured, thus avoiding biopsies. The MID measurements were correlated with the results of liver biopsies, SQUID susceptometer, MRI and blood serum ferritin concentration measurements, as well as with the results of phlebotomy therapy in hemochromatosis patients.
The description of the apparatus and of the method used to acquire the magnetization signal of the patient is the object of Chapter 1. The method used to obtain the iron overload and the clinical results are presented respectively in Chapter 2 and 3. Finally, Chapter 4 is devoted to the analysis of the models based on statistical learning technique and on waterman.

References to author publications that are specifically relates to the dissertation:

[1] M. Marinelli, B. Gianesin, M. Balocco, P. Beruto, C. Bruzzone et al., "Total iron overload measurement in the human liver region by the magnetic iron detector (mid)," IEEE Trans. Biom. Eng., VOL. 57, NO. 9, SEPTEMBER 2010 pp 2295-2303.

[2] Iron overload detection in rats by means of a susceptometer operating at room temperature Marinelli M, Gianesin B, Avignolo C, Minganti V and Parodi S Phys. Med. Biol. 53 6849–60 2008.

[3] B. Gianesin, L. Baldassarre "Computational Models for Estimating Liver Iron Overload with the Magnetic Iron Detector". The Fourth International Conference on Advanced Engineering Computing and Applications in Sciences (IARIA Journals ADVCOMP 2010, pp 59-64).

[4] L. Baldassarre, A. Barla, B. Gianesin, M. Marinelli "Vector Valued Regression for Iron Overload estimation" , ICPR 2008. 19th International Conference on Pattern Recognition, 2008 (ICPR 2008)**.**