Estimating volumes of intra-abdominal blood using electrical impedance imaging

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***Abstract* - Electrical Impedance Imaging is a non-invasive method of imaging which we intend to apply to the problem of detecting intra-abdominal bleeding in Emergency Centre patients. Experiments performed using a cylindrical saline-gel phantom show that as little as 25 ml of free blood within the abdomen may be detected. We also find a strong linear correlation between the total resistivity change created by the anomaly and the volume of the equivalent blood anomaly; thus enabling us to easily quantify the volume of blood perfused into the abdomen over a period of time directly from a reconstructed image. The total resistivity change produced by an anomaly is also observed to be independent of its radial position within the phantom.**

I INTRODUCTION

Two thirds of patients who die unnecessarily following multiple injuries do so because of undetected intra-abdominal bleeding. Although abdominal lavage (see, for example, [4]) and CT scanning are capable of determining the amount of blood in the abdomen, neither are readily able to measure the rate of bleeding. Furthermore, these methods are invasive or complex and are not readily applied in a busy Emergency Centre. It is believed that a method which, using simple equipment, could rapidly and quantitatively determine the rate of intra-abdominal bleeding would be valuable in a variety of clinical situations. The aim of this study is to develop a set of criteria which will better enable surgeons to decide if surgery is necessary to control the internal bleeding. In an Emergency Centre application, it is proposed that the rate of internal bleeding may be monitored at regular intervals by maintaining a belt containing impedance imaging electrodes in position on a patient's abdomen. Data obtained after a monitoring period will be reconstructed relative to data collected at the beginning of the interval, and thus allow the bleeding rate to be estimated.

II METHOD

A Electronic Hardware

The measurements shown in this paper were made using the 16-electrode electrical impedance imaging system developed at the University of Western Australia. It is similar to several other impedance imaging devices, notably that devised by Barber and Brown [6]. It has a single current source and operates at frequencies between 5 and 78 kHz. Each electrode has a preamplifier incorporated to minimize the effect of electrical pickup on leads and measured differential voltages are demodulated using synchronous switched detection. Low-pass filtering of data is achieved using an integrator which can be set to operate over 10, 100 or 1000 cycles of the applied frequency.

B Phantom

The experiments were performed in a cylindrical phantom which had a volume similar to that of a human abdomen, being 30 cm in diameter and 34 cm high. Linear electrodes were used in order to simulate two-dimensional current flow.

Anomalies electrically equivalent to normal blood, which has a resistivity of approximately 1.5 Ωm, were prepared by setting an appropriate volume of saline solution with gelatine. Measurements were made relative to a background saline solution with a resistivity value of about 5 Ωm, the average resistivity of tissue [3]. Four anomalies equivalent to 25, 50, 100 and 150 ml of normal blood were prepared. Each anomaly was positioned by suspension from a radially marked perspex template positioned on top of the tank.

A reference set of data was obtained from the tank with no anomaly present. Each data set taken with an anomaly present was reconstructed relative to this according to the reconstruction method described previously by Barber and Brown [1] [3] [5], producing a two-dimensional (16 x 16) plot of log resistivity changes from the reference case. No post-reconstructive filter was applied to the data. The total change in log resistivity - equivalent to the integrated volume under a reconstructed anomaly - was calculated by adding all pixel values in an image together. This is similar to the procedure of Harris et al. [2] in their study relating

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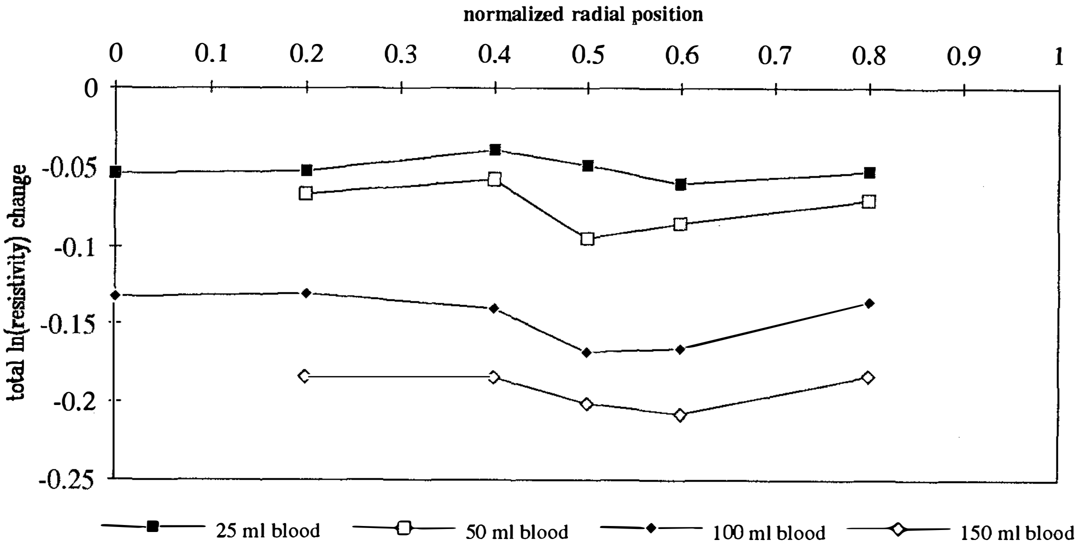

Fig. 1 Dependence of total measured log resistivity change on radial position inside the cylindrical tank

impedance tomography data to lung volume, except in that instance only changes in a particular area of the reconstruction corresponding to the active area of the lung of each subject are considered. Internal bleeding may occur anywhere within the abdomen, and it is important to find a quantity which is both characteristic of the volume of blood and independent of position.

III RESULTS

Fig. 1 shows the values obtained for the total change in log resistivity generated by each anomaly as it is moved from the centre of the phantom tank towards its perimeter. The values for the total log resistivity change are negative because the resistivity of blood is less than that of the background. In each case the value remains roughly constant. The average totals produced by each anomaly were used to construct Fig. 2 which relates the average total resistivity change produced by each anomaly to the volume of the blood equivalent. The relationship between the two is approximately linear with a correlation of about 0.98. This indicates that it may be possible to quantify the volume of blood within the abdomen directly from an impedance image, regardless of the location of the bleeding.

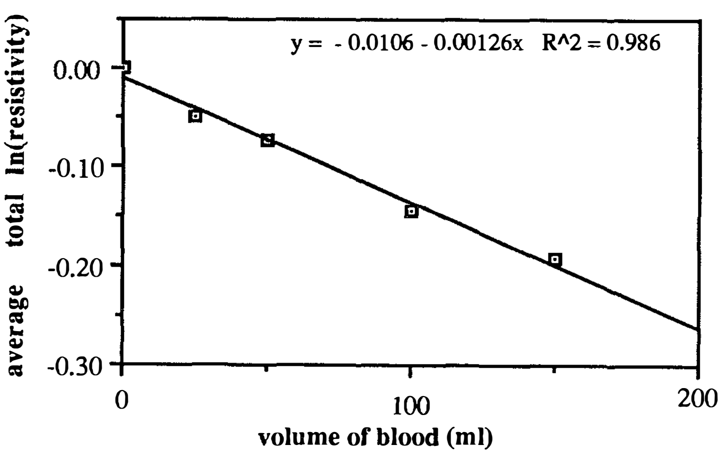

Fig. 2. Total log resistivity change as a function of blood volume

IV DISCUSSION

The data presented here indicate that quantification of blood volume inside the abdomen is possible using impedance imaging methods. However, the conditions of the experiment are far from those of *in-vivo* application. Further trials are necessary to establish the validity of this method when point electrodes are used and the cross sectional shape is altered.

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