AN ENHANCED ELECTRICAL IMPEDANCE IMAGING TECHNIQUE IN TWO AND THREE DIMENSIONS

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Abstract: A new configuration utilising twenty electrodes is employed. Four electrodes are used to inject the same current simultaneously. Current is injected at the four corners of the circle (i.e. equally spaced electrodes). The gradients collected at the rest of electrodes along with those extrapolated between the injection electrodes and their adjacent neighbours are all back projected along the equipotential lines. This has improved the resolution and accuracy at central area of the circle. However, it is argued that back projecting the gradient collected between any two electrodes along half the equipotential line yields better results since any voltage gradient is more affected by impedance variation in the quarter closer to its electrodes, or at least adding the effect of this gradient by a certain weight. On the other hand the gradient corresponding to the two electrodes in the middle between any two injecting points of the current also needs further processing before being back projected or else increase/decrease the number of electrodes by four. When used in three dimension two rings each of 20 electrodes (transmitter and receiver) enclose the area to be imaged and this new configuration eliminates the need to correct the back projection.

Introduction

Electrical impedance imaging has been a useful technique in monitoring a number of physiological variables in the human body[6]. Various data collection systems has been introduced [4] and evaluated for many apllications[3]. An enhanced technique is proposed which improves the resolution and accuracy of the inner areas of the area to be monitored in two and three dimensions[2].

Materials and Methods

The suggested technique employs 20 electrodes where at any instance two identical currents are simultaneously applied at four electrodes equally spaced around the circumference of the circle as Figure 1-a shows[2]. The figure shows the distribution of the equipotential lines. Voltage gradients are collected at the remaining electrodes [V_{2-3}, V_{3-4}, V_{4-5}, V_{7-8}, V_{8-9}, V_{9-10}, V_{12-13}, V_{13-14} , V_{14-15} , V_{17-18} , V_{18-19}] while gradients [V_{1-2} , V_{5-6} , V_{6-7} , V_{10-11} , V_{11-12} , V_{15-16} , V_{16-17} , V_{19-20}] are extrapolated. The whole set is stored in an array. The current sources are then rotated simultaneously to the adjacent four electrodes and another set of gradient potentials are collected and stored. Only ten sets of gradients are collected in this case, since after that duplication starts to happen. These sets of voltage readings are then back projected along the equipotential lines.

The choice of 20 electrodes introduce a problem of back projecting the gradients V_{3-4} , V_{8-9} V_{13-14} V_{18-19}. Since each of these gradients is to be back projected along two equipotential line as Figure 1-b shows. We have the choice of splitting this gradient into two gradients $\mathbf{V_{3-4-a}}$ and $\mathbf{V_{3-4-b}}$. This problem is related to the chioce of the number of electrodes. If we had chosen 16 electrodes or 24 electrodes, this problem will disapper. But having only 16 electrodes will reduce the number of measurements. On the other hand, having 24 electrodes improves further the resolution and solves this problem but makes the electrodes crowded which is not such a great inconvenience.

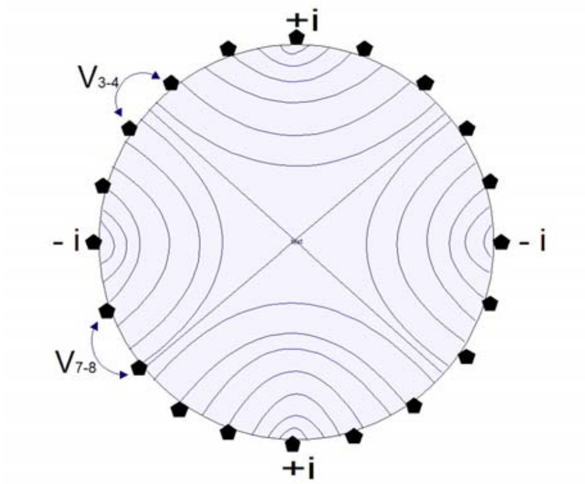

Figure 1-a : Shows the four electrodes where the same currents are applied simultaneously, and voltage gradients are collected.

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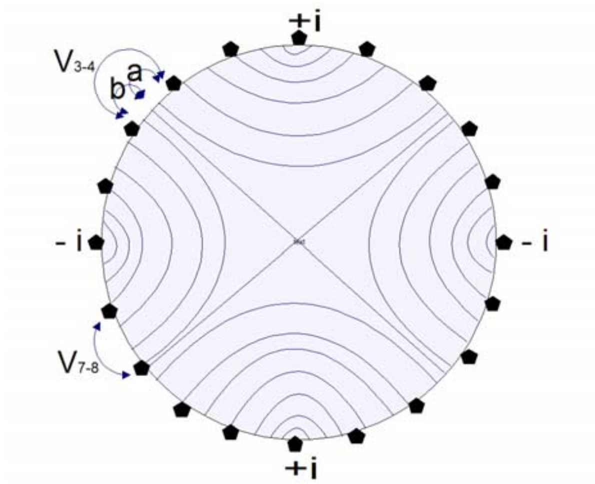

Figure 1-b : Shows the gradient V_{3-4} split into two parts V_{3-4-a} and V_{3-4-b} each to back projected on the corresponding equipotential line.

Conformal mapping ($w=z^2$) is used to transform the complicated potential problem into a simpler area as Figure 2 shows[1]. The area resulting is divided into equal steps in the ***u*** and ***v*** coordinates. The processing is easier since there is no weights to be given to each block as was needed in the previous current injection scheme between two adjacent electrodes[1],[5].

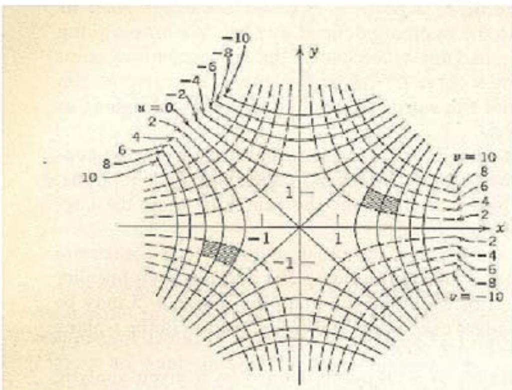

Fig. 2-a : Shows the equipotential lines in ***x*** and **y** coordinates.

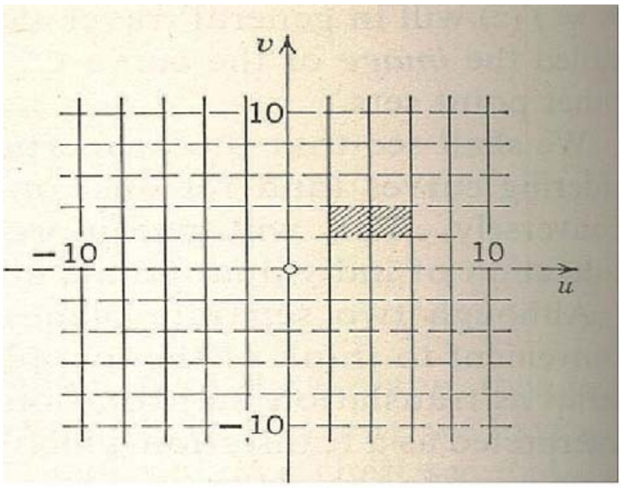

Figure 2-b : Shows the conformal mapping into ***u*** and ***v*** coordinates.

In three dimensions, two rings of electrodes, each of 20 electrodes, are employed around the body and spaced from each other to enclose the volume whose impedance is to be imaged and monitored as shown in Figure 3. This is, particularly, useful in application where monitring the volume change in impedance, such as heart and lung monitoring or stomach embtying. This is, also, very useful in application where the temperature of some organs are to be monitored while being heated by some external applicator (mircowave or radiofrequency, or ultrasonic), where it is not advisable to place the ring of electrodes under the heating applicator since it will introduce additional errors and great amount of discomfort to the patient especially if metal electrodes are being used.

As we can see in Figure 4-a, if the currents are injected in two electrodes only on the first ring while the voltage gradients are collected on the other ring. One source of error in this configuration is the case where the equipotential lines distribution vary from one slice to the next. The virtual current source starts to spread and distant from each other as a function of the slice distance from the original source ring as Figures 4-b shows. Backprojecting the gradients collected at the transmitter ring need no correction but is not of much usefullness since the volume to imaged lies betwwen the transmitter ring and the receiver ring. So, building the image from gradients collected on the receiver ring only will contain much of the information resulting from the interaction of the current with the volume to be imaged. If we try to back project across the same equipotential lines as on the trasmitter ring, this will introduce some error since the distribution on the receiver ring is no

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longer the same as it is on the transmitter ring (with or without impedance variations to the volume). In this case, every slice has its own distribution depending on its distance from the transmitter ring [3].

In the new configuration, the equipotential lines distribution is the same at the transmitter ring and at the reciever ring; no matter how far the receiver ring is from the transmitter ring. This eliminates the need to apply any kind of correction to the gradients collected at the receiver ring before being backprojected along the equipotential lines as used to be the case when injecting current between two adjacent electrodes only.

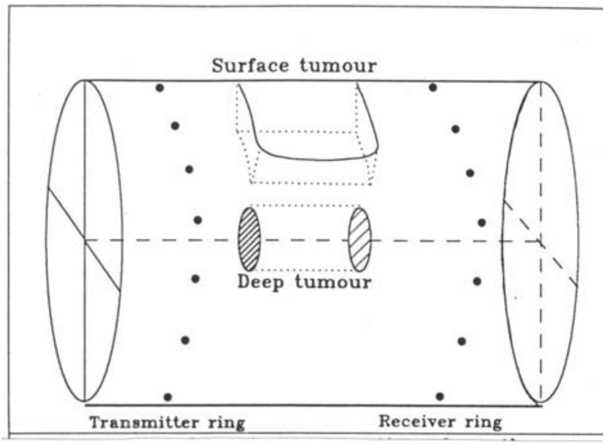

Fig. 3 : Shows the three dimensional configuration.

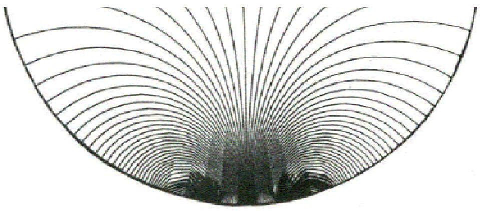

Figure 4-a : The distribution of equipotential line at the transmitter ring.

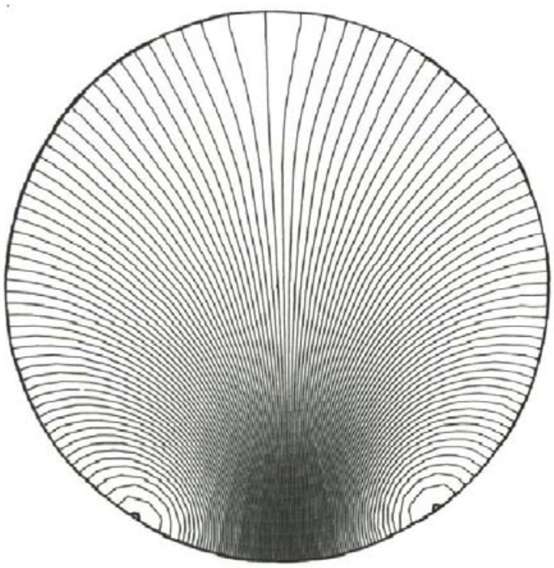

Figure 4-b : The distribution of equipotential line at the receiver ring.

Results

Combining the back projection of the gradients both along the whole equipotential line and along the first half of the equipotential line lying in the quarter close the electrodes on which the gradient is collected has further improved the results. This is because the effect of any impedance variation is mostly apparent in the quarter where it happens to occur which reflects most on the distribution of the equipotential line in that quarter.

Discussion

Different scenarios for back projecting the gradients along parts of or the whole of the equipotential line will be further investigated.

On the other hand, the choice between having 24 electrodes to overcome the need to interpolate at the middle gradients and between having 20 electrodes while interpolating the gradient in the middle two electrodes before back projection each half onto the corresponding equipotential line is yet to be further investigated.

Conclusions

This configuration has improved the accuracy and resolution especially at the central areas. This is not merely due to the increased number of electrodes, but due to the configuration itself.

In the three dimensional case where two rings of electrodes are employed, there is no need to make any correction before back projecting the gradients collected at any receiver ring enclosing the imaged area.

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