Singapore Med J 2000 Vol 41(7) : 331-334

# Chest Impedance: Characteristics of Local Patients

**F Lateef, S H Lim, V Anantharaman, C S Lim**

## ABSTRACT

**The Pre-hospital Defibrillation Program in Singapore has in some cases demonstrated a lower amplitude of Ventricular Fibrillation (VF) than considered the norm. The Electrode Skin Impedance (ESI) refers to the skin impedance determined between two electrodes placed at specific positions on the body surface.**

**The objective of this prospective study was to measure the ESI of patients at 5 Hz and 2 kHz frequencies, and assess its change with time from the application of electrodes, the difference between the ESI at two different sets of electrode placement positions and correlation with patient factors.**

**Patients who were 25 years or older and not critically ill had their ESI measured with a modified Heart-Save 911 defibrillator, using signal frequencies at 5 Hz and 2 kHz, at 10 seconds, 1 and 2 minutes after electrodes application. Two sets of positions were used; *Position I* where an electrode is placed in the right infra-clavicular region and another just lateral to the apex beat on the left and *Position 2*, which represents the mirror image of *Position I*.**

**36 each of male and female patients were studied. The mean age and weight were 59.9 ± 13.5 years and 56.8 ± 24.1 kg respectively. There was no significant correlation between the ESI and patients' body weight or sex. However, there was a significant decrease in the ESI with time from application of electrodes at both Positions ($p < 0.05$) with the two different frequencies. The ESI was lower when measured at lower frequencies and higher when taken at higher frequencies, but there was no statistically significant difference between the two mirror-image positions used. Thus, with lower frequency, the ECG amplitude of VF recorded on the automated external defibrillator could be enhanced.**

**Keywords: ventricular fibrillation, skin impedance, ECG amplitude**

*Singapore Med J 2000 Vol 41(7):331-334*

## INTRODUCTION

The Pre-hospital Defibrillation Program in Singapore has in some cases demonstrated a lower amplitude of ventricular fibrillation (VF) than considered the norm with respect to the time from collapse. If this is so, the algorithms as to whether direct current (DC) shock is required or not will be less sensitive if the amplitude of the electrocardiogram (ECG) becomes too low(1,2). There may be a potential link between this phenomenon and the electrical body impedance. The following factors generally affect the measured ECG amplitude(2,3);

1. The time from collapse to the time when the ECG is measured. The ECG amplitude of VF would normally decrease gradually over time with low remaining amplitude after 10 minutes.
2. The physiological differences between individuals will contribute to variations in the ECG amplitude. For example, Asians may have a different average from the Caucasian race.
3. The ECG signal can be shunted by wet skin surfaces or sweating.
4. A high electrode skin impedance (ESI) will make ECG artifacts more likely and with a high ESI, the input impedance of the ECG amplifier could attenuate the measured ECG.

Energy, voltage and impedance are predictive of the outcome for any given shock(4). To optimise the success of defibrillation, there will be a need to minimize impedance, select the appropriate energy levels, apply the correct interface, select the correct paddle size and deliver the shock at the earliest possible time(4-6). Skin impedance is generally high due to the high resistance of the strateum corneum and this may vary slightly with the technique used for measurement as well as the circumference of the body part concerned(7,8).

The electrical properties of tissue in the human body is generally measured by using electrodes attached to the skin and the voltages that develop between these electrodes are measured. This would give the conductivity distribution within the body(9-11).

**Department of Emergency Medicine**
**Singapore General Hospital**
**Outram Road**
**Singapore 169608**

F Lateef, MBBS (S'pore), FRCS (A&E) (Edin)
Associate Consultant

S H Lim, MBBS (S'pore), FRCS (A&E) (Edin)
Consultant

V Anantharaman, MBBS (S'pore), FRCP (Edin), FAMS
Senior Consultant/Head

**Nanyang Technological University**
**Mechanical and Production Engineering**
**Nanyang Ave**
**Singapore 639798**

C S Lim
Post-Doctoral Research Fellow

**Correspondence to:**
Dr Fatimah Lateef
International Fellow in Emergency Cardiac Care
Dept of Emergency Medicine
University of Cincinnati College of Medicine
231 Bethesda Ave,
PO Box 670769
Cincinnati, Ohio 45219

The ESI refers to the skin impedance determined between two disposable electrodes placed at specific positions on the chest wall(12-20).

At high frequencies, ESI would usually tend to have a lower value than at low frequencies. When the measurement of ESI is done at high frequencies, the results tend to approximate the trans-thoracic impedance (TTI). ESI measured at lower frequencies would also affect the amplitude of the ECG(16,18,21).

## OBJECTIVES

The aim of this study is to measure the ESI of local patients at 5 Hz and 2 kHz, ie. to study the change of ESI with time from the application of electrodes, the differences between the ESI at two different electrode placement positions and the correlation, if any, between ESI and demographic and anthropometric factors(21).

## METHODOLOGY

This prospective study was carried out at the Department of Emergency Medicine, Singapore General Hospital, over a period of a month (ie. July 1998). Patients, 25 years or older, not critically ill or requiring resuscitation were selected. They were excluded if found to have thick chest hair or dermatological diseases. The ESI was measured using a Heart-Save 911 defibrillator modified to measure ESI using signal frequencies at 5 Hz (lower frequency) and 2 kHz (the higher frequency, which is used in the electrode-conversion system of the Heart-Save 911), at 10 seconds, 1 and 2 minutes after application of the electrodes.

The ESI was taken at two different electrode placement positions:

- *Position 1*: an electrode in the right subclavicular region and another just lateral to the apex beat on the left.
- *Position 2*: one electrode in the left subclavicular region and the other over the mirror image site of the apex beat (ie. The mirror-image of the first set of electrodes).

The ambient temperature, humidity, patient demographic data and weight were also recorded. The measurement of the ESI did not in any case cause delays in the decision-making and treatment of critically ill patients.

**Table I. Electrode skin impedance at Positions 1 and 2.**

| | ESI at 5 Hz Position 1 | ESI at 2 Hz Position 1 | ESI at 5 kHz Position 2 | ESI at 2 kHz Position 2 |
|---|---|---|---|---|
| 10 seconds | 41.42 ± 20.59 | 62.0 ± 24.92 | 38.04 ± 18.17 | 59.62 ± 18.75 |
| 1 minute | 36.73 ± 18.46 | 57.04 ± 20.41 | 34.39 ± 17.27 | 55.27 ± 16.38 |
| 2 minutes | 31.96 ± 17.20 | 53.89 ± 19.08 | 29.24 ± 14.80 | 52.10 ± 19.08 |

## RESULTS

There were a total of 72 patients studied, 36 each of male and female patients. There were 60 Chinese, 8 Malays and 4 Indian patients and their ages ranged from 29 to 81 years, with a mean of 59.9 ± 13.5. The mean ambient temperature and humidity were 22.0 ± 1.0 degrees Celsius and 61.9 ± 18.6% respectively. The mean weight was 56.8 ± 24.1 kg.

It was noted that ESI decreased with time from the time of the initial application of the electrodes onto the chest wall. This decrease was statistically significant both at 1 and 2 minutes with either the 5 Hz and 2 kHz frequencies, at the two different electrode placement positions ($p < 0.05$) (Table I).

The ESI was lower at the lower frequency of 5 Hz and higher at the 2 kHz frequency (Table I). There was no statistically significant difference noted between the ESI at the two different electrode placement positions (ie. when comparing ESI at 5 Hz at Positions 1 and 2, $p=0.297$ and when comparing the mean ESI at 2 kHz at Positions 1 and 2, $p=0.073$ ). Neither was there any significant correlation found between the ESI and the sex (comparing male and female patients' data, $p=0.317$) or weight of this group of patients.

## CONCLUSIONS

From this preliminary study, the following observations can be made:

- there was a significant decrease of ESI with time from application of electrodes with both frequencies used
- there were significant differences in the ESI at the two frequencies used (5 Hz and 2 kHz)
- there was no significant difference noted in the ESI when comparing the two different electrode placement positions and
- no significant correlation was found between ESI and the sex or weight of this group of patients

## DISCUSSION

Ventricular fibrillation is the commonest rhythm in cardiac arrest, both in the pre-hospital and in-hospital settings(22). In order to optimise the success of defibrillation, the clinician needs to minimise impedance. Some of the determinants of this are modifiable whilst others may not be. The choice of the defibrillation current should be one that works well over a range of impedances. The peak current is the factor most correlated to defibrillation success. Defibrillation of patients with high impedance would require about the same peak current, but more energy than the defibrillation of low-impedance patients.

The ESI was seen to decrease with time from the initial placement of the electrodes on the patients' chest wall. The possible explanation for this would be a change in tissue properties, water, as well as electrolyte content(23, 24). It is also possible that given time, there is a change in the distribution of low skin impedance points(25-28). The skin has been depicted as a tissue with dynamic electrical properties from several studies(29,30). Tissue temperature may also have a role to play. However, in this study, ambient temperature was recorded and not the skin temperature. There have been studies which showed that altering the ambient temperature, significantly changes the resistance and impedance measurements(31,32).

In this study, there was no significant difference in the measured ESI between the two positions used, which were mirror-images of each other. Position 1 represented one of the American Heart Association's recommended electrode placements for trans-thoracic defibrillation(23,33). Position 2 was tested as a 'control' for each patient. It would thus be possible, during resuscitation or the treatment of critically ill patients, to use Position 2 for pad placement for monitoring or other purposes, now that the ESI has been shown to be not significantly different.

When considering chest wall impedance, it is important to realize that it is a reflection of the individual area local properties. The 'local impedance pathways' within the chest wall itself can change independently just as electrical impedance of biological tissue varies with water and electrolyte content. The other factor which could explain the variation in ESI at the different frequencies are the tissue or body fat distribution which affects the cross-sectional area and circumference of the particular body part. In this study, there was no definite correlation of the ESI with sex or weight, both known to affect body fat distribution.

The other consideration is the fact that with high frequencies, current tends to flow along the skin surface and does not tend to distribute into the deeper structures or tissue planes, thus seldom causing disturbance in innervation properties. This could result in a higher ESI value. With the lower frequencies, it tends to distribute only into the tissue layers of the skin (ie. skin, subcutaneous tissue and fat), thus, the lower ESI value. This could have some contribution in the explanation of the observed results where higher ESI was noted at higher frequencies.

The ECG amplitude is of importance in the use of the semi-automated or automated external defibrillators (AED). The reliable detection of Ventricular Fibrillation can only be expected above 200 microV peak to peak amplitude. Therefore, with higher frequency there would be a higher ESI, which could result in the ECG amplifier attenuating the measured ECG, causing lower ECG amplitude. With lower frequency and lower ESI, the ECG amplitude of VF, recorded on the AEDs, could be improved.

## REFERENCES

1. Watson AB, Ellis MS. Current and Energy in external cardiac defibrillation. Australas Phys Eng Sci Med 1994 Dec; 17(4):206-10.
2. Chapman F: Defibrillation Impedance: A current affair. Inservice Technical Support, Insync 1987 Winter; pp 20-21.
3. Lerman BB, Di Marco JP, Haines DE. Current-based versus energy-based Ventricular Defibrillation: A prospective study. J Am Coll Cardiol 1988; 12(5):1259-64.
4. Dalzell GW. Electrode pad size, trans-thoracic impedance and success of Ventricular Defibrillation. Am J Cardiol 1989 Oct; 64(12):741-4.
5. Rogove HJ, Hughes CM. Defibrillation and Cardioversion. Crit Care Clin 1992 Oct; 8(4):839-63.
6. Barnas GM. Total and local impedances of the chest wall. J Appl Physiol 1990 Apr; 68(4):1409-14.
7. Yamamoto Y. Measurement and analysis of skin electrical impedance. Acta Derm Venereol Suppl 1994; 185:34-8.
8. Panescu D. The mosaic electrical characteristics of the skin. IEEE Trans Biomed Eng 1993 May; 40(5):434-9.
9. Wu B, Hu X. Effect of increase and decrease of measurement voltage on skin impedance. Chen Tzu Yen Chiu 1993; 18(2):104-7.
10. Larsen FF. Trans-thoracic electrical impedance at 1 and 100 kHz – a means of separating thoracic fluid compartments? Clin Physiol 1987 Apr; 7(2): 105-13.
11. Smye SW, Sutcliffe J. A comparison of 4 commercial systems to measure electrical impedance. Physiol Meas 1993 Apr; 14(4):473-8.
12. Grimmes S. Impedance measurement of individual skin surface electrodes. Med Biol Eng Comput 1983 Nov; 21(6):750-5.
13. Yamamoto Y, Yamamoto T. Dispersion and correlation of the parameters for skin impedance. Med Biol Eng Comput 1978 Sep; 16(5):592-4.
14. Yamamoto Y, Yamamoto T. Dynamic system for measurement of electrical skin impedance. Med Biol Eng Comput 1979 Jan; 17(1):135-7.
15. Vransky VK, Emannuilov I. On the determination of electrical impedance of human skin. Med Biol Eng 1996 Nov; 4(6):605-9.
16. Yamamoto T, Yamamoto Y. Analysis for change of skin impedance. Med Biol Eng Comput 1977 May; 15(3):219-27.
17. Grimmes S. Skin impedance and electro-osmosis in human epidermis. Med Biol Eng Comput 1983 Nov; 21(6):739-49.
18. Liang MT. Effects of skin blood flow and temperature on bioelectrical impedance. Med Sci Sports Exerc 1993 Nov; 25(11):1231-9.
19. Cornish BH, Thomas BJ. Effect of temperature and sweating on bioimpedance measurements. Appl Radiat Isot 1998 May; 49(5-6): 475-6.
20. Gudivaka R, Schoeller D. Effect of skin temperature on multifrequency bioelectrical impedance. J Appl Physiol 1996 Aug; 81(2):838-45.
21. McKeown PP, Croal S. Anthropometric determinants of impedance. Acad Emerg Med 1995 Jan; 2(1):63-8.
22. Advanced Cardiac Life Support, American Heart Association 1997-1999. Emergency Medicine Cardiovascular Core Programme. Ed: Cummins RO. pp 1-4 to 1-16.
23. Sirna SJ, Kieso RA. Mechanism responsible for the decline in trans-thoracic impedance after DC shocks. Am J Physiol 1989 Oct; 257 (4 Pt 20): H 1180-3.
24. Kerber RE, Smith R. Is trans-thoracic impedance arrhythmia specific? Experimental Studies. Am Heart J 1994 Apr; 127(4 Pt 1):842-7.
25. Hu X, Wu B, Huang X, et al. Computerised plotting of low skin impedance points. J Tradit Chi Med 1992 Dec; 12(4):277-82.
26. Edic PM, Saulnier GJ. A real-time electrical impedance tomograph. IEEE Trans Biomed Eng 1995 Sep; 42(9):849-59.
27. Hu X, Wu B. Studies on the low skin impedance points and features of its distribution along channels by microcomputer. Chen Tzu Yen Chiu 1993; 18(2):163-7.

28. Hu X, Wu B. Studies on the low skin impedance points and features of its distribution along channels by microcomputer: observation on the reliability of the measurement. Chen Tzu Yen Chiu 1993; 15(3):232-8.
29. Shlunt VKH. The dynamic electrical properties of the skin. Med Tech 1997 Jul-Aug; (4):38-48.
30. Yamamoto T, Yamamoto Y. Analysis for the change of skin impedance. Med Biol Eng Comput 1977 May; 15(3):219-27.
31. Caton JR, Mole PA. Body composition analysis by bioelectrical impedance: Effect of skin temperature. Med Sci Sports Exerc 1988 Oct; 20(50):489-91.
32. Smith DC, Tan S, Follet DH. Effects of skin temperature on skin electrode impedance: Measurement at high direct current density. J Med Eng Technol 1992 Sep-Oct; 16(5):210-3.
33. Garcia LA, Kerber RE. Trans-thoracic defibrillation: does electrode adhesive pad position alter trans-thoracic impedance? Resuscitation 1998 Jun; 37(3):139-43.