An improved right sided electrical impedance method to monitor pulmonary edema

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Abstract—**Currently commercial devices exist that monitor pulmonary edema by measuring the electrical impedance between a lead in the right ventricle (RV) and the device can. Studies have shown up to a 40% false alarm rate with these devices. We have published, using a computer model, about a three fold improvement in lung sensitivity to edema by measuring the impedance between a left ventricle lead in the coronary vein and can, which has been confirmed by others with animal experiments. New research has shown a further improvement with a new lead configuration requiring only right side heart measurements.**

An electrical impedance based finite difference model of the thorax with 3.8 million elements was constructed based on 43 MRI slices to study the impedance response to simulated lung edema. For the impedance measurements the excitation current was between the RV apex and the device can. The voltage sensing electrodes were in the superior vena cava (SVC) with spacing of 1.5, 5 and 7 cm. The lung resistivity was decreased from the normal value of 1400 ohm-cm to 200 ohm-cm in 200 ohm-cm steps reflecting increasing lung edema. The ventricles were increased in volume approximately 50% to simulate an enlarged heart. The decrease in impedance for lungs from 1400 to 400 ohm-cm, showed -39.9%, -37.4%, and -36% change for SVC spacings of 1.5, 5 and 7 cm respectively. In comparison, the decrease with the same condition for the RV to can was 8.9%. The simulated enlarged heart alone resulted in a significantly smaller impedance change for the SVC lead compared to the RV to can lead. The improved lead configuration shows an approximate fourfold improvement compared to the RV to can lead configuration and is less influenced by heart enlargement.

Keywords— **Impedance, FDM, modeling, edema, pulmonary.**

I. Introduction

Currently commercial devices exist (Medtronic's ICD and CRTD with OptiVol) that monitor pulmonary edema by measuring the electrical impedance between a lead in the right ventricle (RV) and the device can [1]. Studies have shown that with these devices there is up to a 40% false alarm rate [2]. We have published in the past, using a computer model, about a three fold improvement in lung sensitivity to edema by measuring the impedance between a left ventricle lead in the coronary vein and the can [3]. This has also been confirmed by others with animal experiments [4]. Our research now has shown a further improvement with a new lead configuration requiring only right side heart measurements.

II. Methods

An electrical impedance based finite difference model of the thorax was constructed based on 43 gated MRI slices from an adult human to study the impedance response to simulated lung edema. The model contained 3.8 million elements with a 1.5 x 1.5 x 5 mm resolution. For the impedance measurements the excitation current was between the RV apex electrode and the device can (ICD or pacemaker). The voltage sensing electrodes were in the superior vena cava (SVC) with spacing of 1.5, 5 and 7 cm. As the distance between the voltage sensing electrode was increased the upper was fixed and remained in the same location. The lower was moved closer to the heart as the distance was increase.

The lung resistivity was decreased from the normal value of 1400 ohm-cm to 200 ohm-cm in 200 ohm-cm steps reflecting increasing severity of lung edema. We have shown in the past that these values would be the approximate lung resistivities required to account for clinically reported impedance changes with pulmonary edema [3]. Also, the ventricles were increased in volume approximately 50% to simulate an enlarged heart in order to compare the magnitude of the change impedance due to lung edema with heart enlargement.

Along with the new right sided approach, two electrode measurements, RV to device can and SVC to device can were also modelled for comparison purposes.

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III. RESULTS

Figure 2 show the result of the study.

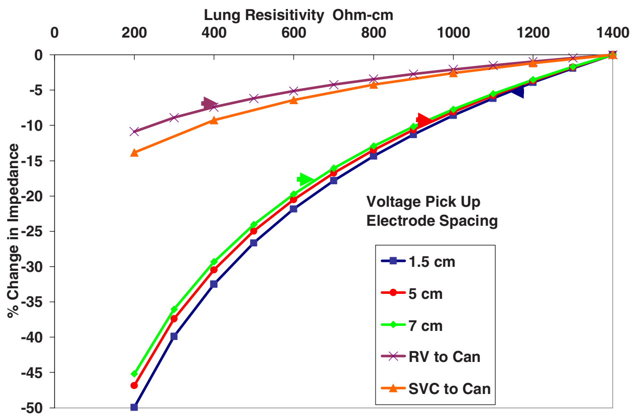

Figure 2 The blue, red ad green are traces using our right sided approach, which indicates the change in impedance caused by pulmonary edema. Pulmonary edema is simulated by reducing the electrical resistivity of the lung tissue The arrows on each trace show how much the impedance would change if only the heart enlarged, which is common in heart failure patients. The RV to Can trace is the change using a simulation of the method Medtronic currently uses. The SVC to Can impedance change is shown in orange

The decrease in impedance from 1400 ohm-cm to 400 ohm-cm, showed -39.9%, -37.4%, and -36% for a SVC spacing of 1.5, 5 and 7 cm respectively. In comparison the decrease for the same lung resistivity change for the RV to can impedance was -8.9%. The simulated enlarged heart alone resulted in an impedance change of 15% to 50% of the values for the 400 ohm-cm edema lung depending on SVC lead spacing, whereas the RV to can impedance values were 85% of the lung change.

IV. DISCUSION

The results, using the SVC voltage pick up leads, show an approximate four fold increase in sensitivity compared to the RV to can or SVC to can configurations. Surprisingly, the sensitivity, measured as a percentage change in the impedance, did not change significantly as the spacing of the electrodes in the SVC was increased. Although, as the spacing was increased, the possible contribution of the heart ventricles was increased. Using the four electrode approach as suggested by the SVC electrodes would also eliminate the device pocket problem, which results in impedance changes around the case of device. As a result data can not be taken for one month [2].

V. CONCLUSIONS

The improved lead configuration shows an approximate fourfold improvement compared to the RV to can lead configuration and is less influenced by heart enlargement.

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REFERENCES

1. Medtronic at http://www.medtronic.com/physician/hf/insync_sentry.html
2 Vollmann D, Nagele H, Schauerte P *et al.*, (2007) Clinical utility of intrathoracic impedance monitoring to alert patients with an implanted device of deteriorating chronic heart failure, Eur Heart J. 28:1835–1840
3 Belalcazar A., Patterson RP (2005) Monitoring lung edema using the pacemaker pulse and skin electrodes. Physiol Meas 26:S153-63
4 Khoury DS, Naware M, Siou J etal (2008) Usefulness of monitoring congestive heart failure by multiple impedance vectors. Conf Proc IEEE EMBS 1:5668-567Lock I, Jerov M, Scovith S (2003) Future of modeling and simulation, IFMBE Proc. vol. 4, World Congress on Med. Phys. & Biomed. Eng., Sydney, Australia, 2003, pp 789–792

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