Intrathoracic fluid changes from preconception to postpartum as measured by bio-impedance monitoring

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Intrathoracic Fluid Changes from Preconception to Postpartum as measured by Bio-Impedance Monitoring

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ABSTRACT

Background: The OptiVol fluid status monitoring system of implantable cardioverter defibrillators (ICD) continuously measures intrathoracic impedance, which strongly relates to intrathoracic fluid content and allows timely diagnosis of intrathoracic fluid retention. Postconceptional maternal systemic vasodilatation is reported, triggering a cascade of cardiovascular adaptive changes.

Case presentation: Intrathoracic impedance was remotely monitored from preconception to postpartum in a woman with an ICD. At 6 and 20 weeks, 2 significant changes were recorded, suggestive for thoracic fluid accumulation. After normal outcome, postpartum intrathoracic impedance returned to preconception values.

Conclusions: Intrathoracic impedance monitoring allows remote follow-up of gestational changes in maternal body fluid status. The obtained results from this case report show that these measurements can be obtained with an implanted device. Current devices for measuring cardiac output by impedance technique allow evaluating thoracic fluid changes non-invasively. As such, non-invasive impedance monitoring may be a potential new method for continuous monitoring of maternal vascular changes during any time window between preconception and postpartum, to be assessed in a large cross sectional observational study.

KEYWORDS

Intrathoracic impedance, remote monitoring, maternal hemodynamic changes in pregnancy

BACKGROUND

The case of a pregnant woman with an implantable cardioverter defibrillator (ICD, Evera™ XT DR, Medtronic, Brussels, Belgium) and second generation fluid build-up detection algorithm, implanted for the presence of the Long QT Syndrome, is presented. She had written the informed consent from for the publication of this case report and any accompanying images. The patient was included in two remote monitoring follow-up programs, a cardiac remote monitoring program for her ICD device and an obstetric remote monitoring program for the early detection of hypertension in high risk pregnancies. In contrast to first generation implantable electronic cardiac device, modern ICD devices also enable device-based diagnostic remote monitoring[1]. The OptiVol® fluid status monitoring system continuously measures intrathoracic impedance which strongly relates to intrathoracic fluid content and allows for timely diagnosis of thoracic fluid retention. Using the broad concept of Ohm's law, intrathoracic impedance can be measured by delivering a small alternating current between the defibrillator's right ventricular coil and the device, meanwhile measuring the corresponding voltage drop and hence the electrical resistance. There is an inverse relation between intrathoracic impedance and thoracic fluid content [1]. Important intrathoracic impedance changes are remotely signaled to clinicians by automated alerts. The OptiVol® system takes into account a dynamic reference intrathoracic impedance value and constantly adjusts for newly measured bioimpedance values. The OptiVol fluid index measure indicates the accumulation of the difference between the daily (raw) impedance and dynamic reference impedance and therefore increases gradually. It triggers an alarm when a predefined threshold is crossed, by default set at 60Ω. In the current study, the default OptiVol threshold setting was used. The reference impedance works as the patient's own control and the fluid index immediately resets when a new (raw) bioimpedance measure crosses the reference line. The raw intrathoracic impedance measurements give an estimation of changes in a patient's thoracic fluid content. It is known that important cardiovascular adaptations occur during pregnancy to accommodate for fetal requirements [2]. Vasodilatation has been observed within the first weeks after conception, before placentation is complete, and triggers

a cascade of cardiovascular adaptive changes throughout pregnancy until postpartum [2]. In addition, several research groups reported an early gestational increase of thoracic fluid content, especially the extracellular component [3,4]. However, these groups only performed bioimpedance measurements at specific moments during and after the gestational period. This is the first case report showing longitudinal and semi-continuous thoracic bioimpedance measurements before, during and after an uncomplicated pregnancy.

CASE PRESENTATION

The case of a 31-year-old female patient who experienced a thoracic impedance alert twice during gestation, is presented. This was observed via an implantable cardioverter defibrillator (ICD, Evera™ XT DR, Medtronic, Brussels, Belgium) with second generation fluid build-up detection algorithm (OptiVol® 2.0), implanted in 2003 after an episode of sudden cardiac arrest related to the Long QT Syndrome type intrathoracic impedance [5]. She has been in routine follow-up since and was included in a cardiac remote monitoring follow-up program since February 2015, prior to conception. Five weeks before conception, the patient developed an OptiVol 2.0 fluid index crossing (Event 1) (

Figure **1**). This crossing triggered an alert that was handled by specialized cardiac remote monitoring nurses, who assessed technical aspects and other cardiovascular measurements associated with this event. Because these were all normal, the patient was contacted by phone to identify possible causes of the fluid buildup alert. An interview was taken, consisting of a structured questionnaire towards identification of (early) signs of fluid retention, including shortness of breath and the presence of edema. The patient mentioned having a flu since a couple of days, for which NSAIDs were taken. It is reported that infectious intrathoracic processes, such as pneumonia or a flu, can affect intrathoracic impedance measurements [1]. The OptiVol 2.0 fluid index crossing recovered a few days later. In the early phase of gestation, at 6 $^{2/7}$ weeks, the patient developed a second OptiVol 2.0 fluid index crossing, the first one during pregnancy (Event 2) (Figure 1). The very first signs of this signal already started at 4 $^{4/7}$ weeks. She was again contacted by phone, but confirmed being asymptomatic and responded negative to all questions. At 20 $^{2/7}$ weeks of gestation, the patient developed a third OptiVol 2.0 fluid index crossing (Event 3) (Figure 1). Again, she was asymptomatic and responded negative to all questions. The alert disappeared at 28 $^{1/7}$ weeks of gestation, despite a continuing decrease of thoracic impedance (i.e. fluid accumulation) until delivery. Thoracic impedance values pre-, per- and post- pregnancy were significantly different (Figure 2). The patient was also included in an obstetric remote monitoring follow-up program for pregnant women who are at risk for the

development of gestation-induced hypertensive disorders (GHD). Because of the presence of the Long QT Syndrome, the patient was invited to participate in this program from 15 $^{6/7}$ weeks of pregnancy. In this follow-up program, two blood pressure measurements and one weight measurement a day are communicated wirelessly to the clinical call center. A team of obstetricians and midwives monitor all measured parameters remotely, and initiate interventions when necessary. There were no blood pressure values recorded above 140/90 mm Hg, and gestational weight gain was 11 kg, which is within the normal range. No phone contact was triggered based on the transmitted data. At 27 $^{2/7}$ weeks of gestation, a maternal cardiovascular assessment was performed as reported elsewhere [4, 6]. During this examination, maternal cardiac, arterial and venous function are evaluated using ICG and ECG- Doppler ultrasonography, to assess maternal hemodynamic function non-invasively. All cardiovascular parameters were normal. At 40 $^{6/7}$ weeks of gestation, she delivered a girl of 3295 grams with normal Apgar score. There were no maternal or neonatal complications. At 6 weeks of age, the neonate was also diagnosed with Long QT Syndrome type II .

CONCLUSIONS

A decrease in thoracic impedance, indicating an increase in thoracic fluid content, started already shortly after fertilization (i.e. 4 $^{4/7}$ weeks of pregnancy). This increase in thoracic fluid content persisted during the course of pregnancy and immediately recovered to initial pre-pregnancy values after delivery. This clearly demonstrates the presence of a higher thoracic fluid content during pregnancy, which already starts at the early beginning of gestation [2]. Women with the Long QT Syndrome are known to have a reduced risk for cardiac events during pregnancy, but have increased risk during the 9-month postpartum period [5]. In our case, no severe cardiac events were recorded during pregnancy. Nevertheless, two events of OptiVol fluid index crossing were observed during gestation. Both crossing alerts can be explained by well-known physiological cardiovascular changes during the corresponding gestational stages. The event at 6 weeks is observed during the gestational window where maternal systemic vasodilation is reported which could result in a higher blood volume and lower intrathoracic impedance [2], one of the earliest observed changes in the body of the pregnant women. This vasodilatation causes a fall in systemic vascular resistance and triggers physiological changes in the cardiovascular and renal systems. In early pregnancy, osmoregulation is 'reset' at a lower osmolality around a new steady state which facilitates water retention [2]. The second gestational OptiVol fluid index is observed around the moment previous research reported a maximum increase in cardiac output [7]. This is associated with increased flow in the pulmonary circulation. Pulmonary vascular resistance is reduced and the increase in plasma volume is accompanied by a decrease in plasma colloid osmotic pressure of about 10-15%. Consequently, the colloid osmotic pressure/pulmonary capillary wedge pressure gradient falls by about 30%, increasing susceptibility to pulmonary edema in pregnant women [8]. Since the patient was not experiencing any symptoms related to fluid overload, these events can be attributed to normal cardiovascular changes during pregnancy. From data received through the obstetric remote follow-up program, the maternal cardiovascular profile at 27 weeks and the normal clinical outcome, we conclude that maternal hemodynamic changes in our case can be labeled as "normal".

This case report is the first one in which the earliest maternal cardiovascular changes are detected and registered longitudinally until full recovery in postpartum. Our observation illustrates the feasibility to use the bioimpedance technology for continuous monitoring of gestational cardiovascular changes. Our observations were made using the remote monitoring technique of an implanted cardioverter defibrillator. Today, innovative research is producing more and more devices to evaluate cardiovascular function by non-invasive mode, including external bioimpedance patches[7]. When these new devices would allow cardiovascular monitoring at similar quality, the way is open towards exploring periconceptional cardiovascular monitoring as a new tool to discriminate normal from abnormal maternal cardiovascular adaptations and identify pregnancies at risk for GHD already at the very first post-implantation stages.

LIST OF ABBREVIATIONS

ICD = Implantable Cardioverter Defibrillators

NSAID = Non Steroid Anti-Inflammationary Drug

GHD = Gestation-induced Hypertensive Disorders

DECLARATIONS

Ethics approval and consent to participate

This report has ethical acceptance of the Medical Ethics Committee of Ziekenhuis Oost-Limburg (o. characteristic number 14/078U and eudract/B-nr B371201422731).

Consent for publication

We have the written consent of the patient to potentially publish their case.

Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

There are no sources of funding to be reported.

Authors' contributions

DL and WG analyzed and interpreted the data regarding the obstetric remote monitoring program for the early detection of hypertension in high risk pregnancies. CJPS, LG and PV analyzed and interpreted the data regarding the cardiac remote monitoring program for her ICD device. DL and CJPS were involved in drafting the manuscript; PV, LG and WG revised it critically and gave their final approval of the version to be published. All authors agreed to be accountable for all aspects in this work and ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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FIGURE LEGENDS

Figure 1: Overview of the OptiVol® 2.0 information from an implantable cardioverter defibrillator. Blue-marked areas: gestational period; Red-marked areas: period of fluid index crossing; Event 1: OptiVol crossing which triggered the fluid built up alert for the first time due to an episode of flu; Event 2: OptiVol crossing which triggered the fluid built up alert for the second time at 6 $^{2/7}$ weeks. Event 3: OptiVol crossing which triggered the fluid built up alert for the second time at 20 $^{2/7}$ weeks.

Figure 2: Thoracic impedance (ohms) values from an implantable cardioverter defibrillator pre-, per- and post pregnancy. Differences in means (± SD) were tested using Paired Student's two sampled *t*-test, at nominal level $\alpha = 0.05$. Of the 319 thoracic impedance values, 34 were pre-pregnancy, 82 were in the first trimester (1 – 12 weeks of pregnancy), 105 were in the second trimester (13 – 26 weeks of pregnancy), 55 were in the third trimester (27 – 40 weeks of pregnancy) and were 43 post-pregnancy.