Transcutaneous electromyography of the diaphragm

Monitoring breathing and the effect of respiratory support in preterm infants

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Chapter 11

Summary

In this thesis, the use of transcutaneous electromyography of the diaphragm (dEMG) is investigated in daily clinical care of preterm infants suffering from common respiratory diagnoses. In **chapter 1,** a general introduction is provided on respiratory physiology after preterm birth, common respiratory diagnoses in preterm infants and treatment options for these respiratory conditions.

Monitoring of spontaneous breathing is important to continuously assess the clinical respiratory condition of preterm infants. Transcutaneous dEMG provides information on the electrical activity of the diaphragm, the main respiratory muscle, and neural breathing effort. Four different applications of transcutaneous dEMG in neonatal intensive care are investigated in this thesis: 1) monitoring of breathing patterns, 2) monitoring the effect of pharmacological treatments for common respiratory diagnoses on diaphragmatic activity, 3) monitoring the effect of non-invasive respiratory support on diaphragmatic activity and 4) breath detection for future synchronization of ventilation.

Monitoring breathing patterns

Preterm infants often suffer from apnea of prematurity (AOP) and correct classification into central, obstructive and mixed apnea is important because these types of apnea require different treatments. In **chapter 2** apnea classification is compared based on transcutaneous dEMG recordings with standard chest impedance monitoring, testing the hypothesis that the use of transcutaneous dEMG will improve apnea classification. It is shown that apnea classification is more accurate based on transcutaneous dEMG tracings in different groups of assessors. Based on these findings, transcutaneous dEMG seems to be a promising technique for future respiratory monitoring systems providing information on spontaneous breathing and breathing patterns in preterm infants.

Monitoring the effect of pharmacological treatments

Transcutaneous dEMG is used in **chapter 3** and **chapter 4** to investigate the effect of pharmacological treatment with exogenous surfactant and doxapram, respectively, on diaphragmatic activity and neural breathing effort.

Minimally invasive surfactant therapy (MIST) is used to administer exogenous surfactant to preterm infants suffering from the respiratory distress syndrome (RDS). Neural breathing effort is measured with transcutaneous dEMG before and after MIST. The majority of infants included in the study show a decrease in diaphragmatic activity one hour after MIST, although the response is highly variable. Clinically, a rapid decrease in extra oxygen demand is observed. It is concluded that exogenous surfactant administration via the MIST procedure leads to a reduction in neural breathing effort in most preterm infants. However, it has to be taken into account that the variability in response to MIST might indicate that establishing a new balance in the respiratory system might take more than one hour after treatment.

Doxapram is an analeptic drug used to treat preterm infants suffering from severe AOP. A pilot study is conducted to investigate if doxapram alters diaphragmatic activity. Transcutaneous dEMG measurements are conducted to achieve information on diaphragmatic activity before and after doxapram treatment in eleven preterm infants. Overall, no effect of doxapram is seen on diaphragmatic activity despite a clear reduction of apneic events. Therefore, doxapram seems to establish a more constant respiratory drive and does not seem to have a direct effect on respiratory muscle activity.

Monitoring the effect of non-invasive respiratory support

Different modalities of non-invasive respiratory support are available in daily clinical care and the effect of some of these modalities on neural breathing effort are assessed. In **chapter 5**, the effect of weaning from nasal continuous positive airway pressure (nCPAP) to low flow nasal cannula (LFNC), a less supportive mode of respiratory support, is investigated by measuring diaphragmatic activity before and after weaning to LFNC. In line with our hypothesis, neural breathing effort increases in infants weaned from nCPAP to LFNC. The increase in neural breathing effort is most prominent in infants failing the weaning attempt. These results indicate that transcutaneous dEMG is able to detect changes in neural breathing effort when the level of respiratory support alters. In addition, the higher neural breathing effort in preterm infants failing the weaning attempt is an important observation indicating the potential of transcutaneous dEMG to guide weaning from respiratory support in preterm infants.

Transcutaneous dEMG is used to compare the amount of support delivered by nCPAP and high flow nasal cannula (HFNC) in **chapter 6**. HFNC is a relatively new mode of non-invasive respiratory support which increases in popularity despite inconsistent data on the level of support it provides. To get insight in neural breathing effort on HFNC compared to nCPAP, transcutaneous dEMG measurements are conducted during the transition from nCPAP to HFNC. The parameters of neural breathing effort measured and the clinical parameters registered, remain stable over the three-hour measurement period. These results indicate that nCPAP and HFNC provide a similar level of respiratory support in these first few hours on HFNC in stable preterm infants.

The most advanced mode of non-invasive respiratory support studied in this thesis, nasal intermittent positive pressure ventilation (nIPPV), provides peak inflation pressures on top of a positive end-expiratory pressure. The ventilator inflations are often not synchronized with spontaneous breathing and most likely lead to patient-ventilator asynchrony. Using transcutaneous dEMG to measure spontaneous breathing, it is shown in **chapter 7** that patient-ventilator asynchrony is present when preterm infants are supported with nIPPV in over two-thirds of inflations, both during inspiration and expiration. This high level of patient-ventilator asynchrony in preterm infants on nIPPV underlines the need to develop techniques to synchronize ventilator inflations with spontaneous breathing.

Breath detection for future synchronization of ventilation

Transcutaneous dEMG might be a candidate to synchronize ventilator inflations with spontaneous breathing. Adequate and fast breath detection is an essential step towards synchronization and this is investigated in **chapter 8**. Breath detection in the transcutaneous dEMG signal is compared to breath detection in the signal of a Graseby capsule, a pneumatic sensor placed on the abdominal wall. The accuracy of an already existing breath detection algorithm, based on the Graseby capsule signal, is tested and leads to suboptimal breath detection in both the Graseby capsule and transcutaneous dEMG signal. New algorithms are developed and allow for much better breath detection rates. Furthermore, the timing of breath detection is much faster when based on the transcutaneous dEMG signal. The results of this study support the possible role for transcutaneous dEMG in synchronization of non-invasive ventilation.

The results, implications and limitations of the research presented in this thesis are further discussed in **chapter 9** and three main clinical applications of transcutaneous dEMG are brought forward**:** 1) monitoring of spontaneous breathing, 2) guiding of respiratory treatment, and 3) synchronization of respiratory support with spontaneous breathing. Recommendations for future research to answer clinical research questions as well as to improve the data acquisition and data analysis of transcutaneous dEMG, are presented in **chapter 10**.

Conclusion

Transcutaneous dEMG can be used to monitor breathing and provides objective information on the effect of pharmacological treatments for common respiratory diagnoses and respiratory support on diaphragmatic activity in spontaneously breathing preterm infants. Based on these results, transcutaneous dEMG seems to be a promising tool to individualize the respiratory treatment of preterm infants in the future.