# DESIGN OF A BREATHING SYNCHRONIZER TO ADDRESS RESPIRATORY DISTRESS IN PREMATURE BABIES

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## 2 Context

Preterm infants, especially those born before 34 weeks of gestation, are at high risk of developing Respiratory Distress Syndrome (RDS). RDS occurs due to insufficient surfactant, leading to difficulty in breathing and inadequate oxygenation of the blood. Surfactant is a substance that is critical for the proper function of the lungs, particularly in newborns. It is a mixture of lipids and proteins produced naturally in the lungs and works to lower surface tension within the alveoli, the tiny air sacs where gas exchange occurs. By reducing surface tension, surfactant prevents the alveoli from collapsing and allows them to remain open during exhalation, facilitating efficient gas exchange and making breathing easier [Fig.1].

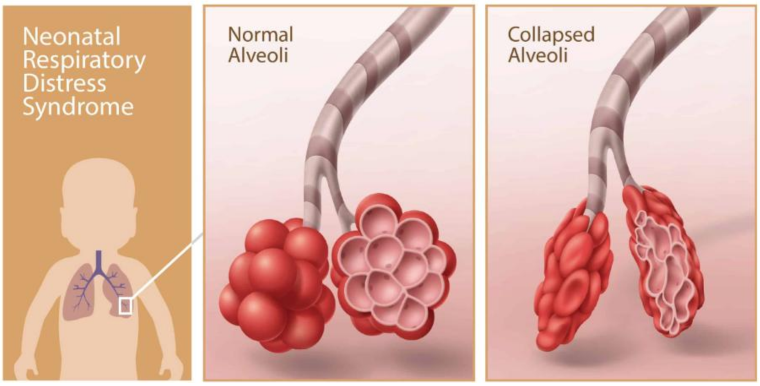


*Figure 1: Neonatal RDS showing normal and collapsed alveoli [1].*

Without enough surfactant, the alveoli tend to collapse after each breath, making it extremely hard for the infant to keep their lungs inflated. Administering surfactant helps keep the alveoli open, allowing for more efficient and less laborious breathing. The administration can be done soon after birth (prophylactic use) or when the symptoms of RDS become apparent (rescue therapy).

The classical technique to administer surfactant involves the insertion of an endotracheal tube by means of laryngoscope, followed by the insertion of a smaller catheter with the surfactant inside the tube. This technique called INSURE, which stands for INtubation, SURfactant administration, and Extubation, is invasive, requires sedation due to the discomfort and also brings risks of physical trauma to the airway such as laryngeal and tracheal injury, vocal cord damage, bleeding or rapid extubation failure [2]. Other techniques were developed to overcome these drawbacks [3], [4], [5], [6]: the LISA technique still uses a laryngoscope followed by administration with a dedicated catheter but can still be a source of pain, especially when performed without any anesthesia. A newly developed technique, called FAST [7] uses a less invasive approach by inserting a slim endoscope, as shown on Fig. 3, through the nose and delivering the surfactant at the laryngeal level by means of a sub millimeter catheter inserted through the working channel of the endoscope.

*Figure 2: Components involved in the INSURE technique; from top to bottom: laryngoscope and two types of endotracheal tubes.*

The FAST technique also brings the advantage of being able to keep the baby on CPAP (continuous positive airway pressure) while administering the surfactant.

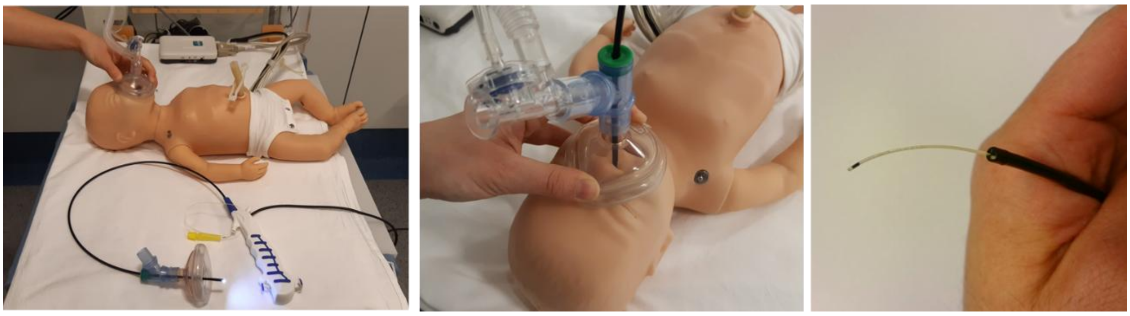

*Figure 3: FAST technique involving nasal endoscopy and delivery through a small catheter in the working channel* [source David Guevorkian, 2024].

Another approach would be to use nebulization. Surfactant delivery by nebulization would be even less invasive. Some tries have already been done [2][8], delivering nebulized surfactant at the CPAP mask level but surfactant delivery in the lungs is not effective, with a few percents of the volume reaching the target. Therefore, there is a need to go further and enhance the technique.

# 3 Work

This master thesis aims to study and design the breathing synchronizer part of a nebulization catheter with the following structure:

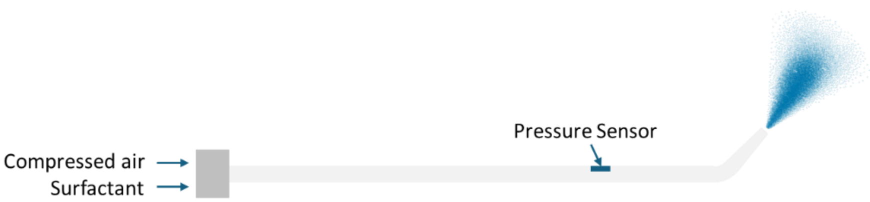


*Figure 4: Proposed nebulization catheter*

This nebulization catheter is designed to be inserted in the pharyngeal area without the need of endoscopy nor sedation. Nebulization is performed at the tip of the catheter by mixing compressed air and surfactant. As the catheter does not enter the trachea (entry going to the lungs), there is a need to synchronize the nebulization with the inspiration in order to enhance the amount of surfactant going to the lungs and optimize its delivery.

The main goal of this thesis is then to study and design the breathing synchronizer which can be coupled to the nebulization device. It will use a pressure or temperature sensor, either placed in the catheter or external to it (in the mask). The type of sensor and adequateness first needs to be reviewed and defined. Then, using the sensor, the student will develop an electronic board and associated embedded software: to amplify and filter the sensor signal, treat it, detect the breathing pattern and provide a digital control signal to the nebulizer, indicative of inspiration.

This work can also involve the overall management of the nebulization device, which is the goal of another MFE. In this case, it would require some collaboration with the other student.

# 4 References


[1] Onybiotech, “Onybiotech - what is RDS ?”

[2] D. G. Sweet *et al.*, “European Consensus Guidelines on the Management of Respiratory Distress Syndrome - 2019 Update,” *Neonatology*, vol. 115, no. 4. S. Karger AG, pp. 432–450, Jun. 01, 2019. doi: 10.1159/000499361.

[3] M. K. Sabzehei, B. Basiri, M. Shokouhi, S. Ghahremani, and A. Moradi, “Comparison of minimally invasive surfactant therapy with intubation surfactant administration and extubation for treating preterm infants with respiratory distress syndrome: a randomized clinical trial,” *Clin Exp Pediatr*, vol. 65, no. 4, pp. 188–193, Apr. 2022, doi: 10.3345/cep.2021.00297.

[4] G. H. Shim, “Update of minimally invasive surfactant therapy,” *Korean J Pediatr*, vol. 60, no. 9, pp. 273–281, Sep. 2017, doi: 10.3345/kjp.2017.60.9.273.

[5] “Verder et al_Surfactant Therapy & Nasal CPAP for Newborns with Respiratory Distress Syndrome_1994”.

[6] E. Herting, C. Härtel, and W. Göpel, “Less invasive surfactant administration: best practices and unanswered questions,” *Current Opinion in Pediatrics*, vol. 32, no. 2. Lippincott Williams and Wilkins, pp. 228–234, Apr. 01, 2020. doi: 10.1097/MOP.0000000000000878.

[7] D. Guevorkian *et al.*, “Pilot Study to Evaluate a New Method for Endotracheal Administration of Surfactant in Neonatal Respiratory Distress Syndrome: Fiberscope Assisted Surfactant Therapy (FAST),” *Neonatology*, vol. 119, no. 6, pp. 753–759, Dec. 2022, doi: 10.1159/000525848.

[8] J. J. Pillow and S. Minocchieri, “Innovation in surfactant therapy II: Surfactant administration by aerosolization,” *Neonatology*, vol. 101, no. 4. pp. 337–344, Jun. 2012. doi: 10.1159/000337354.

[9] A. Tronde, G. Baran, S. Eirefelt, H. Lennernäs, and U. H. Bengtsson, “Miniaturized Nebulization Catheters: A New Approach for Delivery of Defined Aerosol Doses to the Rat Lung,” 2002.

[10] “US20090107503A1_Nebulizing catheter system and methods of use and manufacture”