Respiratory Effort Measurements During Polysomnography

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Conflicts of Interest

• Inspire Medical Systems
• No other conflicts
Learning Objectives

• Learn about available AASM approved tools for measurement of respiratory effort during polysomnography
• Discuss the history of Sleep Research and Belt Technology
• Discuss RIP belt technology
• Discuss PVDF belt technology
• Discuss Piezo-electric technology
• Discuss diaphragmatic EMG (dEMG) and intercostal EMG
Technological History – Research Driven

1913: French scientist Henri Pieron (1881–1964) publishes his work entitled “Le probleme ` physiologique du sommeil”.

1939: Nathaniel Kleitman (1895–1999) authors the seminal book: Sleep and Wakefulness. He is recognized as the father of American sleep research.

1952: William Dement (born 1928), made all-night, continuous recordings (EEG, EOG and movement channels) during sleep. He would later go on to found the American Sleep Disorders Association (now the AASM).

1967: A committee of investigators with experience in scoring sleep, led by Allan Rechtschaffen and Anthony Kales, developed a terminology and scoring system to be universally used by sleep specialists (the R&K Manual).

1990’s: Inductance plethysmography is adapted for human polysomnography (initially used only for pediatric and Asthma research).

2007: The AASM Manual for the Scoring of Sleep and Associated Events was published by the American Academy of Sleep Medicine (AASM).
How do you determine which respiratory effort tool to use?

• AASM Guidelines
• Quantitative versus qualitative measurements
• Patient comfort
• Cost
• Replacement frequency
• Susceptibility to artifact
• Hardware compatibility
• Industry driven
AASM Guidelines

• Chapter VIII. Respiratory Rules
  • Part 1: Rules for Adults

6. For monitoring respiratory effort, use one of the following:
   a. esophageal manometry  RECOMMENDED
   b. dual thoracoabdominal RIP belts (calibrated or uncalibrated)  RECOMMENDED
   c. dual thoracoabdominal PVDF belts  ACCEPTABLE
Esophageal Manometry

- Correct placement of the sensor is difficult and can cause patient discomfort and sleep disturbance
- Rarely used in sleep laboratories for routine diagnostic PSGs

Garrick W. Don, Karen A. Waters; Journal of Applied Physiology Published 1 June 2003 Vol. 94 no. 6, 2456-2464
Respiratory Inductance Plethysmography (RIP)

- RIP relies on the principle that a current applied through a loop of wire generates a magnetic field normal to the orientation of the loop (Faraday’s Law).\(^1\)
- A change in the area enclosed by the loop creates an opposing current within the loop directly proportional to the change in the area (Lenz’s Law).\(^1\)
- An elastic belt, with a zigzagging (coiled) wire sewn into, (to allow for expansion and contraction) is worn around the chest or abdomen.
- An alternating current (AC) is passed through the belt, generating a magnetic field.\(^1\)

\(^1\)Respiratory Inductance Plethysmography An Introduction Gandis G. Mazeika, MD Rick Swanson, RPSGT, CRTT
RIP Measurements

• The act of breathing changes the cross-sectional area of the patient’s body, and thus changes the shape of the magnetic field generated by the belt, “inducing” an opposing current that can be measured, most easily as a change in the frequency of the applied current.¹

• With RIP, no electrical current passes through the body (a weak magnetic field is present that does not affect the patient or any surrounding equipment).¹

• The signal is linear and is a fairly accurate representation of the change in cross-sectional area.¹

¹Respiratory Inductance Plethysmography An Introduction Gandis G. Mazeika, MD Rick Swanson, RPSGT, CRTT
RIP: Phase Shift and Paradoxical Breathing

1Respiratory Inductance Plethysmography An Introduction Gandis G. Mazeika, MD
Rick Swanson, RPSGT, CRTT
Polyvinylidene Fluoride (PVDF)

- Polyvinylidene difluoride (PVDF) is a highly non-reactive and pure thermoplastic fluoropolymer produced by the polymerization of vinylidene difluoride.

- PVDF has flexibility, low weight, low thermal conductivity, high chemical corrosion resistance, and heat resistance.
PVDF

• There are many commercial applications of PVDF
  • Insulation on electrical wires
  • Tactile sensor arrays
  • Strain gauges
  • Audio transducers
  • Measuring dust density in the solar system
  • Binder material in lithium ion batteries
  • Specialty fishing lines (fluorocarbon)
  • Sterilizing filter in biomedical science

Figure 2. PVDF film sample (left panel) and conductive fabric sheets sample (right panel).
PVDF Belts

- Provides linear, accurate effort signal and maintains polarity
- Infant, Pediatric, and Adult Sizes are available
- Sum Channel Option
- Compatible with most current PSG Systems
- Easy to clean with machine washable straps
- No Batteries to Change

On December 19, 2011 the AASM made changes to the Scoring Manual, effective immediately, to include Polyvinylidene Fluoride (PVDF) effort sensors using thoracoabdominal belts.
Piezoelectric Technology

• The sensing element, a piezo crystal, on a piezo effort belt is located only on a very small section of the belt’s length.
• The effort signal can be dampened, not detected (like when the patient is lying on the sensor), producing erroneous readings or unexplained changes in polarity (false paradoxing).
• Susceptible to trapping artifact.
• No longer recommended as an AASM standard.
Diaphragmatic EMG (dEMG) & Intercostal EMG


dEMG / Intercostals

- Diaphragm EMG can be recorded from the chest wall surface electrodes in most subjects and can be used to demonstrate the presence of respiratory effort during apnoea/hypopnea events.

dEMG / Intercostals

Notice the Intercostal Channel shows a lack of effort. Ballistocardiogram artifact can be seen in the RIP (abdomen) belt. Verification of central apnea.
Iatrogenic artifact still present in the leads. Intercostals can be helpful to determine artifact from true morphology.
Intercostals show a good decrease in EMG signal during an obstructive hypopnea. Notice the poor quality of the Abdomen.
Again, this shows the incremental increase during an obstructive event associated with snoring and increasing effort.
Strong intercostal signals help with identification of obstructive events.
Ambiguity from the chest and abdomen belt make this type of even difficult to differentiate between central and obstructive. The intercostals provide help here.
Summary

• The AASM gold standard for monitoring of respiratory effort is esophageal Manometry, but this technique is rarely used in commercial sleep laboratories today due to patient discomfort, technique difficulty and cost.
• RIP belts are the primary tool used to measure respiratory effort.
• PVDF are an AASM approved acceptable alternative to RIP belts.
• Piezoelectric belts are not recommended for measurement of respiratory effort.
• dEMG and intercostal EMG leads can be a helpful tool for monitoring respiratory effort, but more research is needed to determine accuracy and standardized placement procedures.