How to optimize timing of extubation?

Andrew JE Seely MD, PhD, FRCSC
Disclosure

• Therapeutic Monitoring Systems (TMS)
  • Founder and Chief Science Officer
  • TMS’ Aim: improve patient care through innovative variability-derived clinical decision support software
  • Issued patents re method and application of multiorgan variability monitoring
Why optimize timing of extubation?

• Prolonged ventilation harms patients


• Extubation failure harms patients

Optimize timing of extubation?

• Why?
  • Shorten duration of ventilation & length of stay.
  • Reduce incidence of extubation failure.
  • Improve patient care.
  • Reduce costs of care.

• How?
“If you can’t describe what you are doing as a process, you don’t know what you’re doing.”

~W. Edwards Deming
Summary of process to optimize timing of extubation

- Best practice weaning, preparing for extubation.
- Plan in place for the event of failed extubation.
- Repeatedly re-assess readiness for extubation.
- Evaluate risk & consequences of failed extubation.
- Assist the Decision to Extubate?
- Mitigate risk of extubation failure.

Extubate!
Best Practice Weaning

• Use protocols attempting to minimize sedation
• Protocolized rehabilitation, early mobilization
  • Schmidt et al, ATS/ACCP Guidelines, AJRCCM 2017
• Wean to partial support ventilation asap
  • Assuming absence of strong effort, severe ARDS
Establish plans if failed extubation prior to extubation

• Extubation failure is rapid & unpredictable, and may indicate need for tracheostomy

• Need to know what action is indicated in event of failure, prior to extubation
  • Many patients do not want re-intubation, tracheostomy, prolonged ventilation and rehab

• Ideal opportunity exists for establishing goals of care prior to extubation
Repeatedly reassess readiness for extubation

• How? Spontaneous Breathing trial (SBT)
  • Mimic and thus predict ability to tolerate unassisted breathing

• SBT as soon as “SBT readiness criteria” met:
  • resolution of initial reason for intubation, cardiovascular stability (minimal or no vasopressors), adequate mentation, adequate respiratory function (F<35, MIP < 20-25, Vt > 5ml/kg, VC > 10ml/kg, f/Vt < 105), adequate oxygenation defined as PaO2/FiO2 ≥ 150 mm Hg with PEEP up to 8 cm H2O.

• Boles JM et al. *Eur Respir J* 2007

• Once daily screening will shorten LOS & costs
Evaluating SBT Success?

“Criteria for passing SBT include respiratory pattern, adequate gas exchange, haemodynamic stability and subject comfort.”


- Pass SBT if absence of agitation, anxiety, diaphoresis, worsened hypoxemia, tachypnea, arrhythmia, rapid shallow breathing, hypotension

- No strict thresholds of success vs. failure
SBT Technique Controversy

• No Support (T-piece) vs PS support?
  • T-Piece: greater specificity (higher true negative rate)
  • PS support: higher readiness, no evidence of more failure

• SBT Duration: 30 - 120 min

• ATS/ACCP Guidelines, AJRCCM, Jan 2017
  • If vented>24 hrs, initial SBT should be with inspiratory pressure augmentation (5–8cm H2O) rather than without.

• FAST Trial underway (PI Karen Burns)
  • 2x2 RCT: SBT technique & frequency, 250/750 pts enrolled
Assess risk factors for extubation failure

<table>
<thead>
<tr>
<th>Airway</th>
<th>Non-Airway</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Airway obstruction</td>
<td>• Congestive heart failure</td>
</tr>
<tr>
<td>• Excessive secretions</td>
<td>• hypoxemia</td>
</tr>
<tr>
<td>• Impaired cough</td>
<td>• hypoventilation</td>
</tr>
<tr>
<td>• Aspiration</td>
<td>• Pulmonary disease</td>
</tr>
<tr>
<td>• Decreased LOC</td>
<td>• Decreased LOC</td>
</tr>
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</table>

Can’t breathe without ET tube
Can’t breathe without vent support

Epstein SK et al, AJRCCM 1998
Large Multicenter study


Airway failure
Non-airway failure

- SOFA ≥ 8 before extubation
- Cough -
- Secretions +
- Length of intubation > 8 days
- Resp failure
- Coma
- BMI < 30 Kg/m²
- Female sex

1514 patients; 157 EF (10.4%)
45% airway, 50% breathing; 5% mixed
2013-2015 (26 ICUs)
Risk Factors for Extubation Failure

• Non-modifiable factors: age, cardiorespiratory disease, APACHE II, pneumonia as indication for intubation

• During SBT: high f/Vt>105 (>60?), PCO$_2$>44, increase in BNP

• Potentially modifiable: +’ve fluid balance last 24 hrs, GCS<8 (?), PaO$_2$/FiO$_2$<200, peak exp flow <60 L/min, ++ secretions, weak cough, Hg<100

  • F Frutos Vivar et al Chest 2006; A Thille et al, AJRCCM 2013
Estimate risk of failed extubation / time

- Assess risk factors of extubation failure
- Identify modifiable risk factors; reduce them if possible, prior to extubation

“Clinicians should be more vigilant in identifying who is at high risk for extubation failure ... one can recommend delaying extubation if the risk factor can be substantially corrected in 1–3 days.”

Assess consequences of extubation failure

- Overall frailty, potential for myocardial ischemia, mild organ dysfunction – all augment risk of harm due to extubation failure
- Etiology of extubation failure (non-airway worse than airway) and time to re-intubation are independent predictors of poor outcome
- Epstein SK et al, AJRCCM 1998
Individualized process of assessment?

- First SBT: with 5-8 cm H$_2$O support
- Subsequent SBT technique modified by perceived consequences of failed extubation

“T-piece test results may be too conservative if the clinicians are very cautious and/or if the prevalence of extubation failure is low (e.g., in postoperative patients). On the other hand, the low-PS test may underestimate the risk of extubation failure, especially if the clinician is overoptimistic or if the prevalence of extubation failure is high”

A Thille, JC Richard, L Brochard, AJRCCM 2013
Mitigate risk of Extubation Failure

- **Pre-extubation:**
  - Consider diuresis, afterload control, inotropic support as required
  - Absence of cuff leak: consider systemic steroids at least 4 hrs before extubation

- **Post-extubation**
  - Impaired ability to expectorate, dead space ventilation, impaired oxygenation, consider high flow high humidity (HFH) O₂
  - Poor LV fxn, COPD, weakness, hypercapnea, consider non-invasive ventilation (NINV)
  - Multiple factors, high risk, consider intermittent NINV & HFH
Assist clinicians with extubation decision making?

- What might be beneficial?
  - Complete holistic patient evaluation
  - Optimal prediction extubation outcomes
  - Standardized patient assessment
Weaning and Variability Evaluation (WAVE) study

Do heart and respiratory rate variability improve prediction of extubation outcomes in critically ill patients?

- Multicenter observational study (721 pts, 12 sites, 434 high quality data)
- Observed a 12% extubation failure (EF) rate (re-intubation <48 hours)
- **Statistical analysis**: 1 heart rate variability (HRV), 9 respiratory rate variability (RRV) metrics associated with EF (p-values 0.00004 - 0.001)
- **Predictive modelling**: WAVE score (ave of 5 univariate RRV logistic regression models) was **best predictor** of EF, superior to AND complementary with RSBI, RR, or clinical judgement
WAVE score

- WAVE score correlates with probability of extubation failure
- Goal: Identify low risk and high risk patients
- Provide clinical decision support, not decision-making

![Graph showing WAVE Score Quartiles](image)
RSBI

Clinical impression

WAVE score:
Complementary Value

PPV 36%
ROC AUC 0.87

RSBI<105
Risk of failing extubation

351 Passed, 45 Failed

RSBI≥105
Risk of failing extubation

20 Passed, 6 Failed

Low/Average risk
Risk of failing extubation

298 Passed, 32 Failed

High risk
Risk of failing extubation

33 Passed, 12 Failed

PPV 42%
ROC AUC 0.82
Extubation Advisor™

Optimal prediction extubation outcomes

- Respiratory rate variability AND best current practice

Standardized multidisciplinary assessment

- Summary (one-page) “synoptic” report

Assist & improve extubation decision making
Extubation Advisor
Input Screens

### SBT:

#### SBT Start
- Date of SBT
- Start time of SBT
- RASS Score:

#### SBT End
- Completed as planned?: Yes / No
- End time of SBT: HH:MM
- Average RR: (breaths/min)
- Average TV: (L)
- SBT Outcome: Pass / Equivocal / Fall
- Rate the expected risk of extubation failure:
  - High (i.e. expect risk is > 15%)
  - Average (i.e. expected risk is 5-15%)
  - Low (i.e. expected risk is < 5%)

#### Extubation Readiness Checklist

Generate Report and Send Feedback Link
## Extubation Advisor

**Phase I Single center study**  
**Co-PI A Sarti**

**June 2017 to Oct 2018:**

- Enrolled 117 patients  
- Entered 240 SBT forms  
- Generated 231 SBT reports  
- Recorded 78 extubations  
- Completed 52 questionnaires  
- Conducted 15 interviews

Results pending.

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### Extubation Advisor™

**SBT Synoptic Report - 2016-10-20**

<table>
<thead>
<tr>
<th>Name: Anstee, Caitlin</th>
<th>Bed Number: ICU 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOB: 1982-07-25 (34)</td>
<td>Days in ICU: 2</td>
</tr>
<tr>
<td>MRN: 888888888</td>
<td>Days on Ventilator: 5</td>
</tr>
<tr>
<td>Sex: F</td>
<td></td>
</tr>
</tbody>
</table>

### Overall Assessment of Extubation Failure Risk:

<table>
<thead>
<tr>
<th>Standard (RSBI):</th>
<th>Wave Score:</th>
<th>RT Impression:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Risk</td>
<td>Low Risk</td>
<td>Low Risk</td>
</tr>
</tbody>
</table>

### Patient Information:

- **Comorbidities:** Major Cardiac Illness, Diabetes  
- **Reason for Admission:** Shock - Septic - Lung

### SBT Information:

- **Start:** 2016-10-20 12:30  
- **End:** 2016-10-20 13:00  
- **Completed as planned?** Yes  
- **Possible Last SBT?** No  
- **RASS Score:** +1  
- **PS:** 1 cmH₂O  
- **PEEP:** 1 cmH₂O

### Measured Vitals during SBT:

- **Average BP:** 103/52.6  
- **Average HR:** 67.8 beats/min  
- **Average RR:** 14.3 breaths/min  
- **Average O₂ Sat:** 95.9 %  
- **MAP:** 70.6 mmHg

### Exubation Readiness Checklist:

- Improved from admission  
- Cuff Leak Present  
- Strong Cough  
- Spontaneous Cough  
- Gag Present  
- No or Intermittent Sedatives  
- able to lift head off pillow for > 5 sec

- High Dose Pressors Required  
- No Cuff Leak Present  
- SpO₂ < 90%  
- FiO₂ > 40%  
- on PEEP > 5cm H₂O  
- Does Not Obey Commands  
- Weak Hand Grip  
- Positive Fluid Balance Last 24H  
- Poor Urine Output

### Respiratory Therapist Impression:

**SBT Outcome:** Pass  
**RT Perception of Risk of Extubation Failure:** Low

### Exubation Advisor™ Decision Support:

- **Wave Score™:** 0.41 (Based on respiratory rate variability. Low variability = high score and a high probability of extubation failure.)  
- **Risk of Extubation Failure:** LOW  
- **Fold Increase:** 40% of normal risk.

**Note:** The Wave Score™ provides an estimate of the risk of extubation failure based on respiratory rate variability. This risk estimate is based on a model incorporating measurements of the patient’s heart rate and respiratory rate variability. The decision to extubate a patient from mechanical ventilation must incorporate all available medical information. Please refer to the Extubation Advisor™ Instructions for Use.

**Report Generated:** 2016-10-20T14:30:04-04:00  
**Respiratory Therapist:** Caitlin Anstee
Summary

1. Best practice weaning, preparing for extubation.
   - Spontaneous breathing, protocolized sedation, early mobilization

2. Plan in place in the event of failed extubation.
   - Opportunity to understand patient’s goals of care & limits to care

3. Repeatedly re-assess readiness for extubation.
   - Perform SBTs as soon as possible and daily, look to extubate if success

4. Evaluate risk & consequences of failed extubation.
   - Identify & correct risk factors, modify SBT if potential harm from EF

5. Assist the decision to extubate?
   - Offer optimal prediction and standardized assessment

   - Selective non-invasive ventilation, High flow High humidity O₂, steroids
Thank you.

aseely@ohri.ca
Understanding variation is the key to success in quality and business.

Uncontrolled variation is the enemy of quality.

W. Edwards Deming
Lack of Standardized Practice

- No universal SBT performance or reporting
- Analysis of 931 SBTs in 680 pts (8 NA centers)
  - Inter-institutional variation in SBT performance, including ventilator settings, sedation, oxygenation and SBT reporting (checklists, MD communication)

Research Article

Practice Variation in Spontaneous Breathing Trial Performance and Reporting

Canadian Respiratory Journal
Volume 2016, Article ID 9848942

Stephanie Godard, Christophe Herry, Paul Westergaard, Nathan Scales, Samuel M. Brown, Karen Burns, Sangeeta Mehta, Frank J. Jacono, Dalibor Kubelik, Donna E. Maziak, John Marshall, Claudio Martin, and Andrew J. E. Seely
# Acknowledgements

## Canadian Critical Care Trials Group

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## Clinical research coordinators
A Fazekas, C Anstee, E Delic I Watpool, R Porteous, B Gomes, ...

## Therapeutic Monitoring Systems
D Longbottom, W Threader, D McNair

## Funding
### Why optimize timing of extubation?

Prolonged ventilation harms patients

- Ventilation causes muscle atrophy, weakness, VAP, ...
- Prolonged ventilation after cardiac surgery increases mortality 6x and costs 8x.
- Delayed extubation after brain injury associated with increased mortality, LOS and VAP
  - Coplin WM et al, *AJRCCM* 2000
- Prolonged ventilation (>21d) spent longer in hosp post ICU (17 vs 7 days) & increased mortality (40% vs 34%)
  - Lone NI, Walsh TS, *Crit Care* 2011
Why optimize timing of extubation?

Extubation failure harms patients

- Extubation failure: incidence 15%

- Extubation failure associated with increased mortality, duration of ventilation, length of stay, rehab, independent of illness severity

- Extubation failure costs additional $34,000/pt
How should we seek to improve care by influencing clinical decision making?

<table>
<thead>
<tr>
<th>Thinking Fast: System One</th>
<th>Thinking Slow: System Two</th>
</tr>
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<tbody>
<tr>
<td>Fast, instinctive, emotional</td>
<td>Slow, learned, deliberate</td>
</tr>
<tr>
<td>Prone to repeated mistakes:</td>
<td>Able to correct System I errors</td>
</tr>
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**Examples:**

- Loss aversion: give more weight to potential losses than gains

Status quo bias: prefer status quo

Endowment effect: overestimation of what we already have

Thus, goals in introducing CDS are to:

- Aim to standardize processes of assessment & decision making
- Aim to systematically support & augment System Two thinking

Daniel Kahneman

Amos Tversky
Weaning and Variability Evaluation (Wave)

- **Hypothesis:** Decreased HRV and/or RRV during SBT is associated with and predicts extubation failure.

- **Design:** Multicenter, waived consent, observational study, record HRV & RRV during last SBT prior to extubation.

- **Aims:** (1) Determine if altered HRV and/or RRV are associated with extubation failure; (2) develop a predictive model to predict extubation outcomes; (3) determine if variability offers added value to traditional predictors of extubation outcomes.
Reduced RRV = reduced adaptability

Dyspnea and Decreased Variability of Breathing in Patients with Restrictive Lung Disease

Thomas Brack, Amal Jubran, and Martin J. Tobin

Division of Pulmonary and Critical Care Medicine, Edward Hines Jr., Veterans Affairs Hospital; and Loyola University of Chicago, Stritch School of Medicine, Hines, Illinois

Restrictive Lung Disease

Controls

Diminished variability = diminished adaptability = decreased capacity to tolerate increased workload.
E.g. reduced respiratory variability

Reduced breathing variability as a predictor of unsuccessful patient separation from mechanical ventilation*  

Marc Wysocki, MD; Christophe Cracco, MD; Antonio Teixeira, MD, MSci Biostat; Alain Mercat, MD; Jean-Luc Diehl, MD; Yannick Lefort, MD; Jean-Philippe Derenne, MD; Thomas Similowski, MD, PhD

- First multicenter study (4 units). $N=51$ (“extubation success”, 14 “failure”)
- “Breathing variability is greater in patients successfully separated from ET tube”.

Example of reduced variability predicting poor outcome
Variability and Extubation

**Pattern of spontaneous breathing: potential marker for weaning outcome**
Spontaneous breathing pattern and weaning from mechanical ventilation

**Changes of Heart Rate Variability During Ventilator Weaning**
Hsiu-Nien Shen, Lian-Yu Lin, Kuan-Yu Chen, Ping-Hung Kuo, Chong-Jen Yu, Huey-Dong Wu and Pan-Chyr Yang
*Chest* 2003;123:1222-1228
DOI 10.1378/chest.123.4.1222

**Reduced breathing variability as a predictor of unsuccessful patient separation from mechanical ventilation**
Crit Care Med 2006 Vol. 34, No. 8
Marc Wysocki, MD; Christophe Cracco, MD; Antonio Teixeira, MD, MSc Biostat; Alain Mercat, MD; Jean-Luc Diehl, MD; Yannick Lefort, MD; Jean-Philippe Derenne, MD; Thomas Similowski, MD, PhD

**Lower Interbreath Interval Complexity Is Associated With Extubation Failure in Mechanically Ventilated Patients During Spontaneous Breathing Trials**
The Journal of TRAUMA® Injury, Infection, and Critical Care • Volume 68, Number 6, June 2010
Christopher E. White, MD, MSc, Andryi I. Batchinsky, MD, Corinna Necsoiu, MD, Ruth Nguyen, MD, Kerfoot P. Walker, III, MS, Kevin K. Chung, MD, Steven E. Wolf, MD, and Leopoldo C. Cancio, MD

**Biosignal analysis techniques for weaning outcome assessment**
Vasilios Papaioannou*, Christos Dragoumanis, Ioannis Pneumatikos
Extubation Decision Making?

• “Will the patient be able to sustain spontaneous ventilation following tube removal, and protect his or her airway after extubation?”
  
  • Tobin M, Am J Resp Crit Care Med 2012

• “Clinicians should be more vigilant in identifying who is at high risk for extubation failure ... one can recommend delaying extubation if the risk factor can be substantially corrected in 1–3 days.”
  