The Art and Science of Weaning from Mechanical Ventilation

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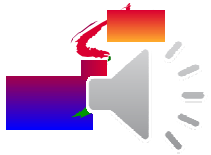
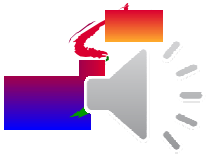


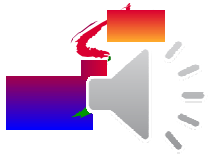
Some definitions

- Weaning
  - transition from ventilatory support to complete spontaneous breathing
  - reduction of mechanical ventilator support
  - the patient assumes the responsibility for effective gas exchange.
- Successful
  - when a patient maintains effective gas exchange with complete spontaneous breathing without any mechanical assistance
- Failure
  - when spontaneous efforts are incapable of sustaining effective gas exchange without mechanical ventilator support
- End of successful weaning
  - Liberation from mechanical ventilator support



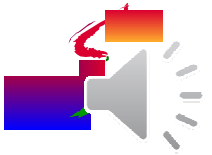
Some definitions

- Extubation
  - defined simply as the removal of an endotracheal tube
  - generally coincides with the end of weaning
- For the present discussion
  - Extubation performed at the End of weaning
  - Extubation to complete spontaneous breathing without any positive pressure support



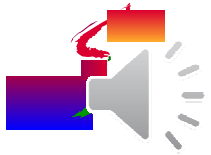
Why should we care about extubation?

- Premature extubation
  - Extubation before the patient is “ready”
  - Risk of emergent reintubation
  - Cardiovascular compromise
- Delayed extubation
  - Extubation delayed even though patient is “ready”
  - Risk of nosocomial infection
  - Risk of airway trauma



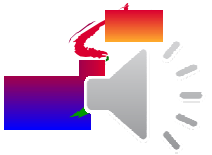
Why should we care about extubation at the end of weaning?

- Children who failed extubation and were re-intubated within 48 h had significantly higher mortality than those successfully extubated (20% versus 2%, p<0.001)
  - Esteban A, et al and the International Group of Mechanical Ventilation in Children (2001) An international study of mechanical ventilation in children. Am J Respir Crit Care Med 163:A30



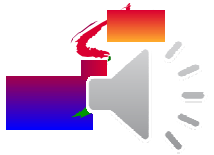
Important questions

- When should weaning start?
- When should weaning end?
- What is the optimal technique of weaning?
- What is the evidence in the literature?
- Are results from adults applicable?



When should weaning start?

- Underlying disease process is improving
  - Gas exchange is adequate
  - Adequate oxygenation
  - Adequate ventilation
- No conditions exist that imposes an undue burden on the respiratory muscles
  - Cardiac insufficiency
  - Severe hyperinflation
  - Severe malnutrition
  - Multiple organ system failure
- Patient is capable of sustaining spontaneous ventilation as ventilator support is decreased or removed

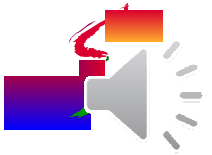


Specific criteria

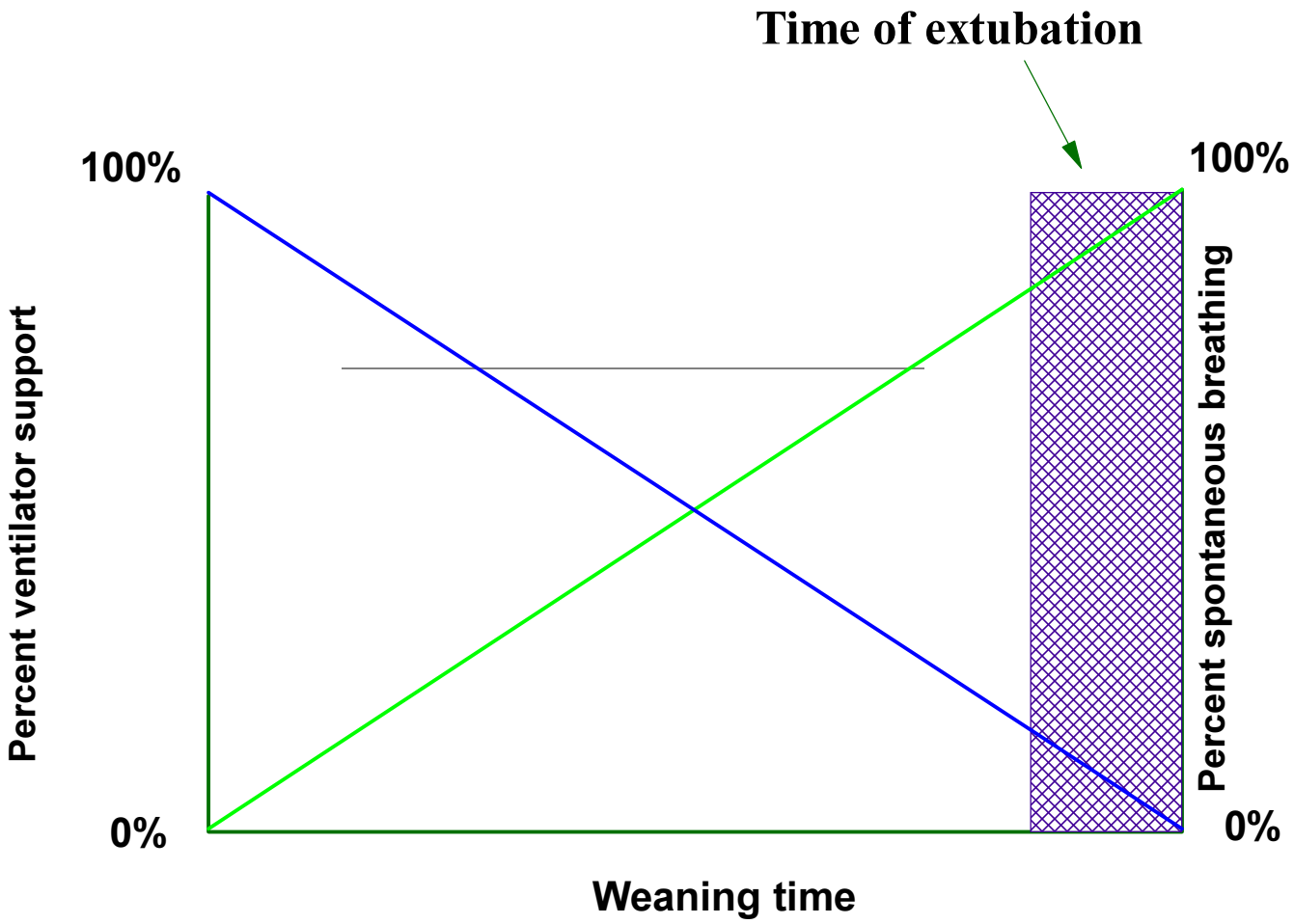
- Adequacy of oxygenation
  - PaO2/FIO2 >200
    - Esteban et al (N Engl J Med 1995;332:345-50)
  - FiO2 <0.4
    - Farias et al (Intensive Care Med 1998;24:1070-1075)
- Level of positive airway pressure
  - PEEP <7
    - Randolph et al JAMA 2002;288:2561-2568
  - PEEP <5
    - Farias et al (Intensive Care Med 1998;24:1070-1075)
- Ventilation
  - Physiological dead space < 50%
    - Cheifetz et al AJRCCM 2001
  - End-tidal-arterial CO2 difference < 20%
    - Extrapolated from the data above

Patient capable of sustaining spontaneous breathing

- Has adequate inspiratory drive
  - Reduce or stop all sedation
  - Patient is awake enough
  - Mean inspiratory flow of a spontaneous breath can provide an objective measure of inspiratory drive
  - Requires measurement of a spontaneous tidal volume and inspiratory time of a spontaneous breath without any pressure support (on CPAP)
- Has sufficient strength and endurance to breathe
  - NIF – Maximal Negative inspiratory force
    - Should be at least -30 cms H_2O

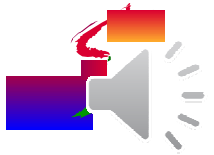


Current paradigm



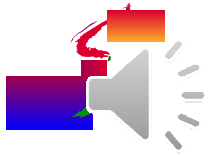
Operational definitions

- Readiness to Extubate Trial (RET)
  - defined as test to determine whether a patient can be extubated to complete spontaneous breathing
  - 3 ways currently performed
    - Minimal pressure support
    - CPAP
    - T-piece trials
- Spontaneous breathing trial (SBT)
  - defined as a test of the ability to maintain complete spontaneous breathing without any positive pressure assistance (Only CPAP and T-piece qualify)
- Extubation
  - defined simply as the removal of an endotracheal tube
- Extubation failure - need for reintubation within 48 hours of extubation.



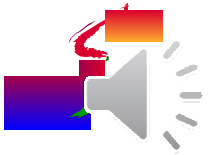
Should all patients be subjected to gradual withdrawal of mechanical ventilation?

- THE ANSWER IS NO!!!
- Pediatric studies
  - PALISI study - 42% of the patients initially tested with a minimal pressure-support trial passed the test and were extubated
    - Randolph AG et al JAMA 2002;27:2561
  - Farias study - 77.3% of patients who underwent SBT passed the test and were extubated and did not require any further weaning.
    - Farias JA et al Intensive Care Med 1998; 24:1070-5.



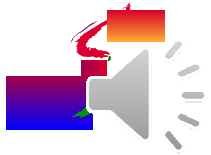
Trials of extubation readiness

- "Minimal" Pressure-support
  - Pressure support enough to overcome resistance of ventilator circuit
  - No in vivo data on the level of pressure support needed
  - Extrapolated from lab studies overestimates the pressure support
- CPAP
  - complete spontaneous breathing
  - concern about ventilator circuit resistance
  - flow through the circuit can be adjusted to meet demands
- T-piece trial
  - complete spontaneous breathing
  - concern about breathing through the endotracheal tube
  - inspiratory flow adjusted to overcome the resistance of ET tube



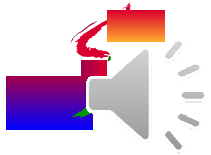
Criteria for terminating SBT or RET

- Respiratory rate
  - >60 breaths/min in patients aged 12 months or less
  - >50 breaths/min in patients aged 1-5years
  - >40 breaths/min in patients aged >5 years
- Hemodynamic instability
  - Hypotension for age
  - Increase in heart rate >20% from baseline
- Signs of increased respiratory work
  - Accessory muscle use
  - Retractions
  - Paradoxical breathing
- Blood gas
  - PaO2 <60 mmHg or SpO2 <92%
  - Arterial pH < 7.30
  - PaCO2 > 50 mmHg or an increase > 8 mmHg
- Spontaneous tidal volume <5mL/kg (if available)



Effect of Mechanical Ventilator Weaning Protocols on Resiratory Outcomes in Infants and Children

Randolph AG et al JAMA 2002;288:2561-2568

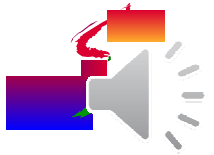


Weaning outcomes

Randolph AG et al JAMA 2002;27:2561

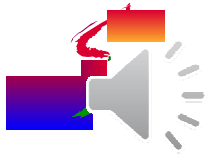
	Pressure support (n=61)	**Volume support (n=60)**	**No protocol (n=59)**	**P value**
Weaning failure n (%)	9 (15)	14 (24)	10 (17)	0.44
Median weaning times among successes (interquartile range) d	1.6 (0.9-4.1)	1.8 (1.0-3.2)	2.0 (0.9-2.9)	0.751

Extubation failure rate for patients who passed initial RET - 15.7%



"Breathing through a straw concept"

- Myth#1:
  - Children cannot breathe effectively through the narrow endotracheal tube without some level of support
  - Therefore, they should be extubated from a low level of support instead of weaning them to complete spontaneous breathing
- Myth#2:
  - Children cannot tolerate T-piece breathing
- Myth#3:
  - The resistance of the endotracheal tube should always be overcome with either pressure-support or other methods while evaluating readiness to extubate

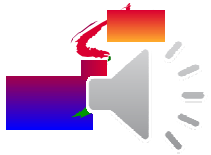


Intensive Care Med (2001) 27: 1649–1654
DOI 10.1007/s001340101035

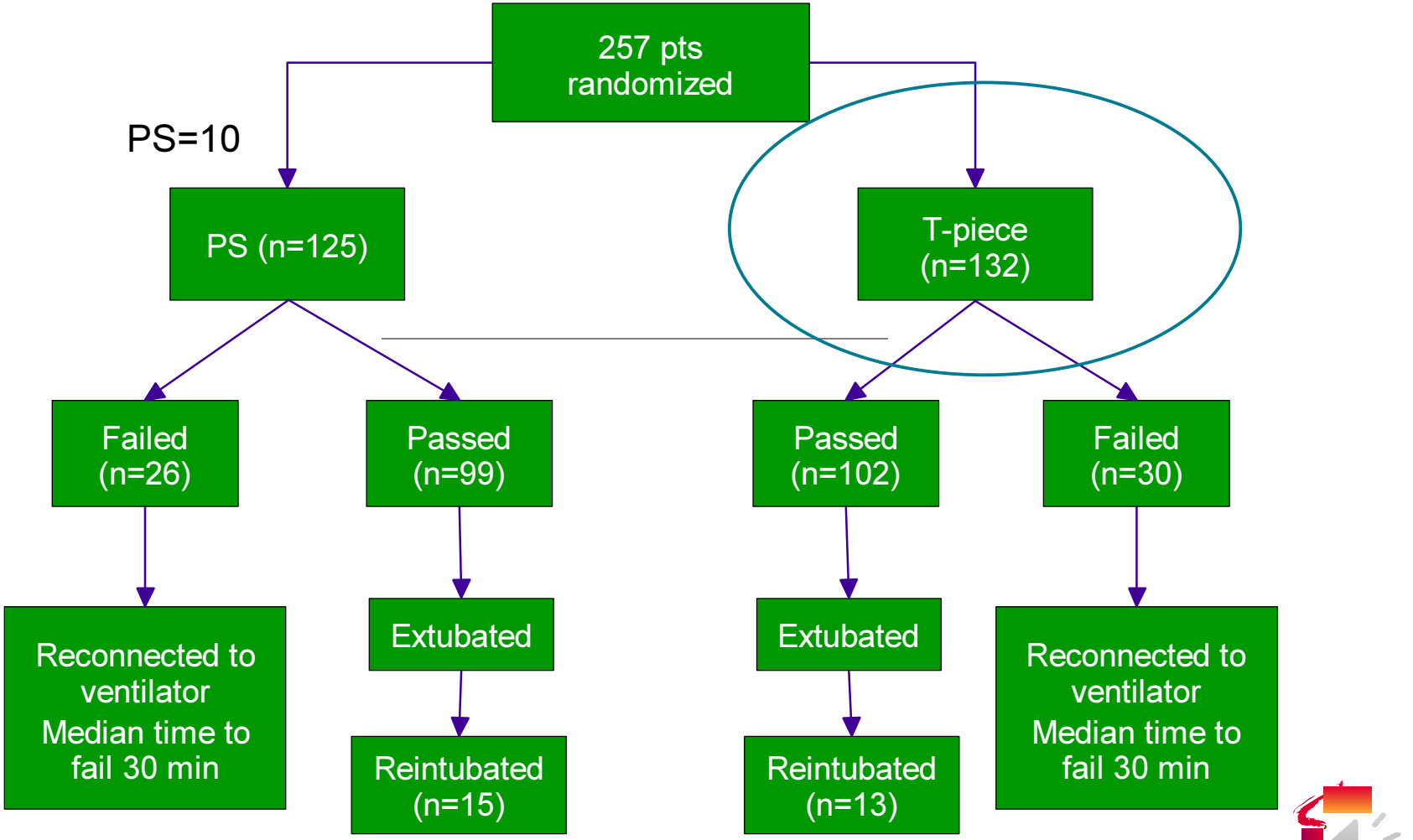
NEONATAL AND PEDIATRIC INTENSIVE CARE

J. A. Farias
A. Retta
I. Alía
F. Olazarri
A. Esteban
A. Golubicki
D. Allende
O. Maliarchuk
C. Peltzer
M. E. Ratto
R. Zalazar
M. Garea
E. G. Moreno

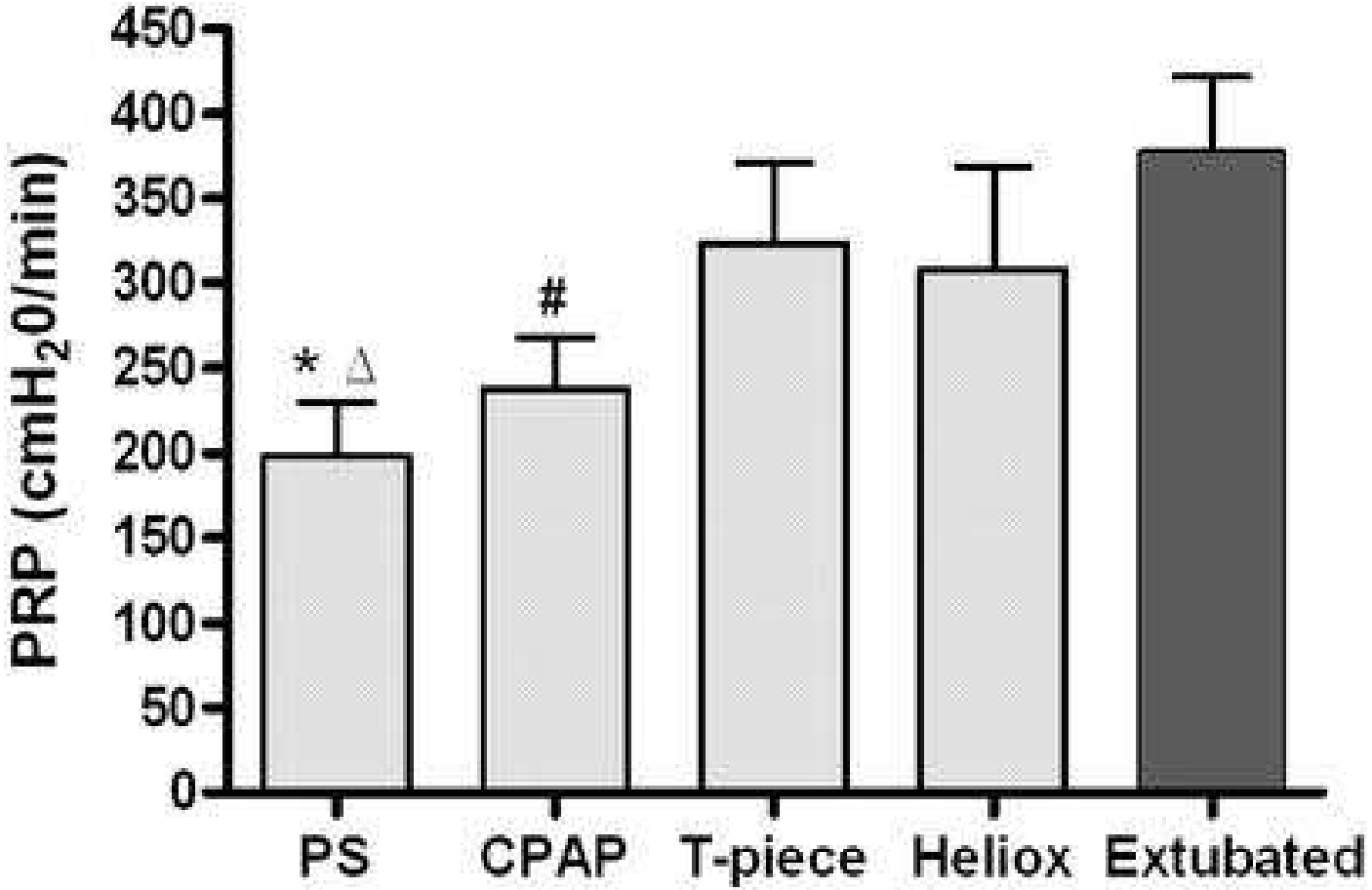
A comparison of two methods to perform a breathing trial before extubation in pediatric intensive care patients



Tolerance of a 2 hr T-piece trial



Does a T-piece trial increase work of breathing through the ET tube?

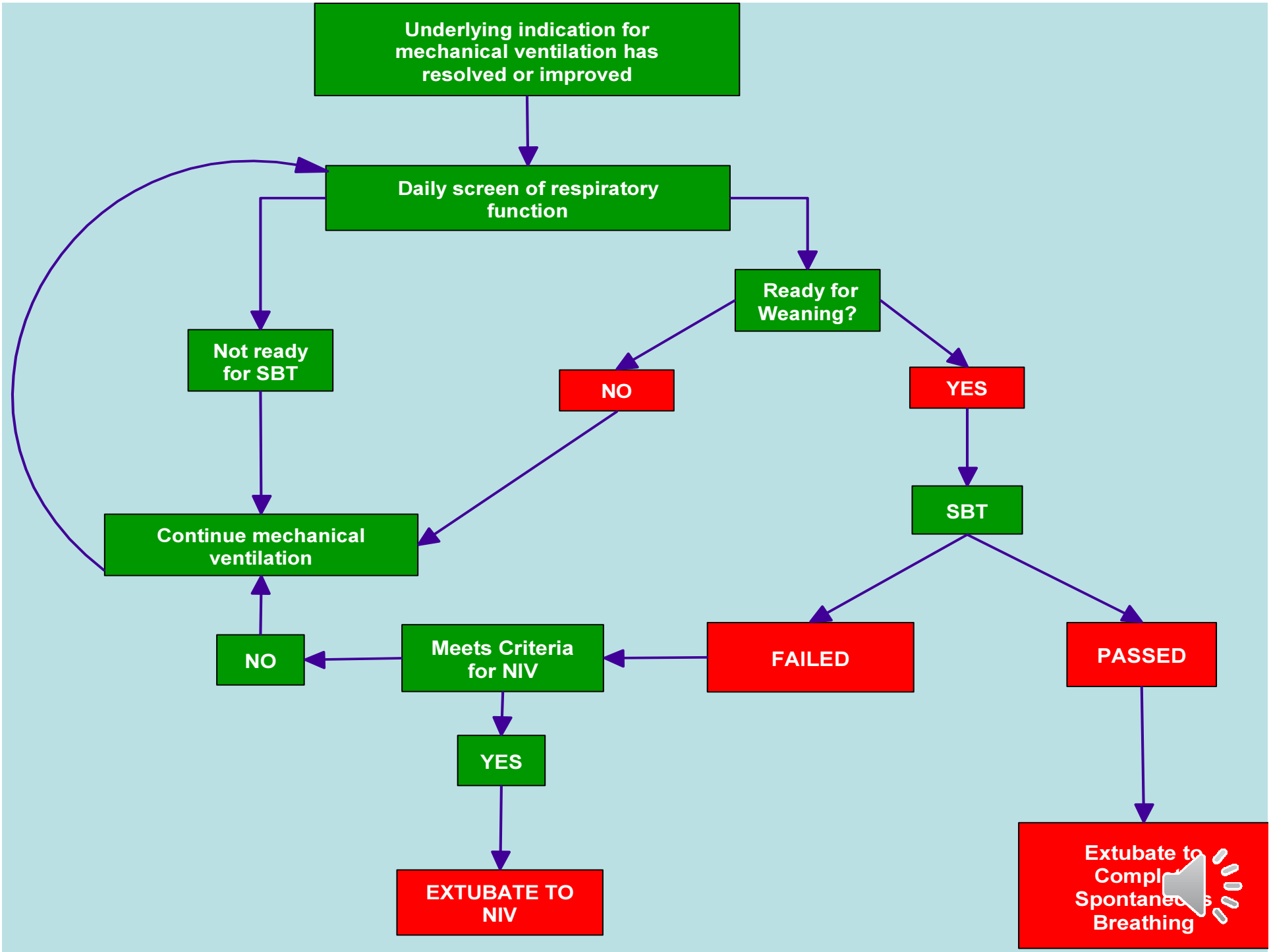


Willis BC et al Intensive Care Med 2005;12:1700-5

Threshold values for low and high risk of failure

Variable	<10%	10-25%	>25%
VTspont (ml/kg)	≥6.5	3.5 - 6.5	<3.5
FIO2	≤0.30	0.3-0.4	>0.4
Paw (cm H2O)	<5	5-8.5	>8.5
OI	≤1.4	1.4-4.5	>4.5
FrVe (%)	≤20	20-30	>30
PIP (cm H2O)	≤25	25-30	>30
Cdyn (ml/kg/cm H2O)	≥0.9	0.4-0.9	<0.4
Vt/Ti (ml/kg/sec)	≥14	8-14	<8

Khan et al CCM 1996


Underlying indication for mechanical ventilation has resolved or improved
Daily screen of respiratory function
Ready for Weaning?
Not ready for SBT
NO
YES
SBT
Continue mechanical ventilation
NO
Meets Criteria for NIV
FAILED
PASSED
YES
EXTUBATE TO NIV
Extubate to Compl Spontaneous Breathing

Dedicated to Dr. Farias for his contributions to the art and science of weaning in children