Pro-Con Debate:

Mechanically Assisted Insufflation-Exsufflation (MIE) in Neuromuscular Disease

Aaron St-Laurent

Cross Canada Rounds, Jan. 2017

MIE Debate - Contents

- Cough primer
  - Purpose and physiology
  - Cough in neuromuscular disease (NMD)
  - Peak cough flow
  - Assisted cough & mechanical insufflation-exsufflation
- Pro-Side
  - Effect on peak cough
  - Effect on physiologic measures
  - Effect on outcomes
  - Safety and Acceptability
- Con-Side
- Recommendations
- Discussion

Cough

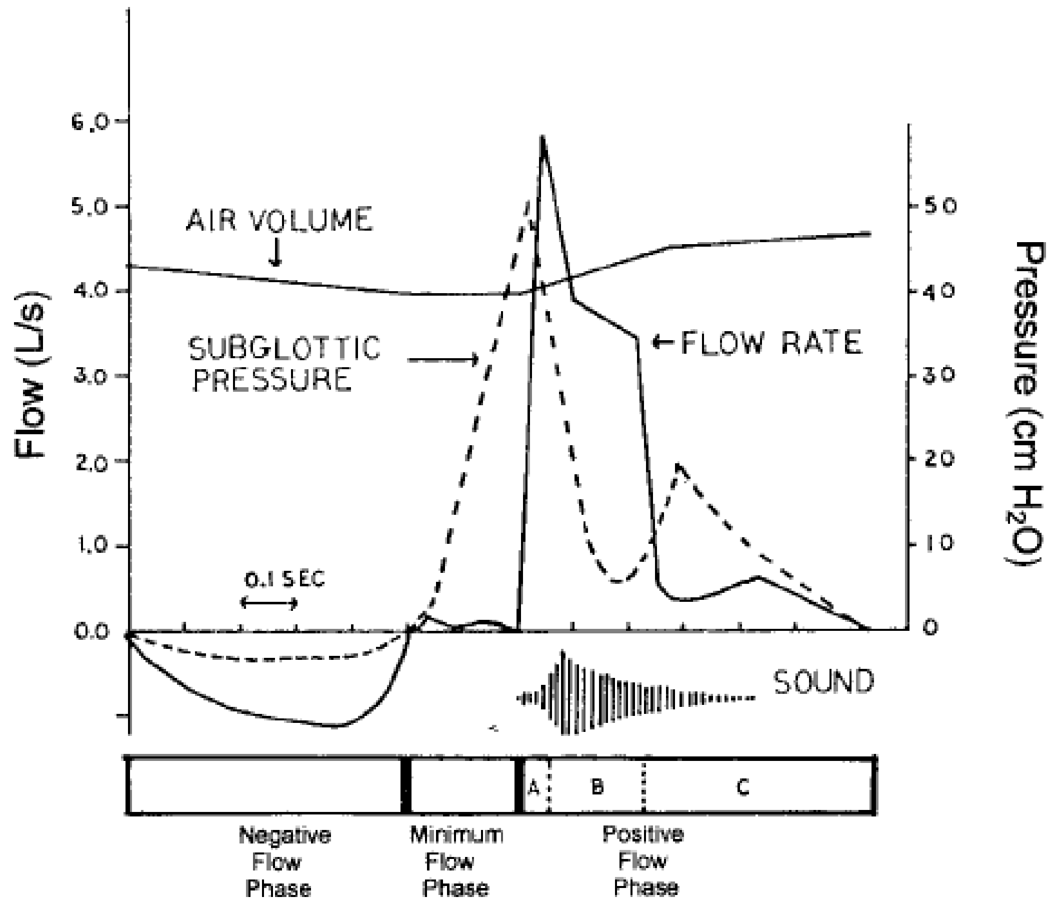
- Purpose: Airway clearance
  - Inhaled/aspirated materials
  - Retained secretions

- Voluntary vs. Involuntary
  - Cough receptors
    - Mechanical, Chemical irritant
    - Afferent – vagus
    - Efferent – phrenic, spinal motor nerves, vagus

Cough - Sequence

Phases of cough:

- Inspiratory
- Compressive
- Expulsive



1) Boitano, et al. Management of airway clearance in neuromuscular disease. Respir Care. 2006 Aug;51(8):913-22; discussion 922-4.

Cough in NMD

- Inspiratory muscle weakness
  - Limits expiratory-muscle length tension relationship, chest wall recoil, decreased alveolar pressures
- Bulbar dysfunction
  - Effects compressive phase
- Expiratory muscle weakness
  - Decreased dynamic airway pressure, velocity

Cough in NMD

- Respiratory illness worsens weakness

MEAN VC, MIP, MEP, S_{O_2} AND END-TIDAL P_{CO_2} AT BASELINE, AT ONSET OF URI AND FOLLOWING RECOVERY

	VC‡ (L)	MIP‡ (*cm H_2O*)	MEP‡ (*cm H_2O*)	P_{CO_2} (*mm Hg*)	S_{O_2} (*mm Hg*)
Baseline	1.16 ± 0.14 (50.1% ± 6.6)	49.2 ± 6.8 (51.5% ± 8.2)	35.5 ± 3.8 (26.8% ± 3.9)	39.1 ± 1.1	95.1 ± 1.0
URI	1.01 ± 0.15* (43.4% ± 6.5)	37.1 ± 6.2* (38.9% ± 7.1)	25.5 ± 3.0* (19.7% ± 2.8)	43.9 ± 2.1†	95.0 ± 1.0
Recovery	1.09 ± 0.14 (48.5% ± 6.5)	46.2 ± 7.0 (47.9% ± 8.4)	34.1 ± 3.2 (25.8% ± 3.3)	38.9 ± 1.2	95.3 ± 1.0

* Significantly less than baseline values ($p < 0.05$).
† Significantly greater than baseline values ($p < 0.05$).
‡ Mean absolute and percent predicted values are provided.

2) Poponick, et al. Effect of upper respiratory tract infection in patients with neuromuscular disease. Am J Respir Crit Care Med. 1997 Aug;156(2 Pt 1):659-64.

What is peak cough flow?

- PCF a measure of cough effectiveness
- Measured via peak flow meter or spirometer
- Following complete inspiration, patient coughs forcibly
- Mouthpiece or face mask
- Normal adult peak cough >600L/min

Fig. 4. Peak-cough-flow meter with an air-cushion face mask.

Is Peak Cough Flow Important?

- Bach & Saporito:
  - Factors predicting successful extubation / decannulation in NM weakness
  - N=63, extubation/decannulation attempts
  - Studied: Age, ventilator use, FVC, PCF
  - PCF only predictor of success
    - All 43 attempts >160L/min – successful
    - All 15 attempts <160L/min – unsuccessful
- Bach et al.:
  - No patients with DMD and assisted peak cough >270L/min developed acute respiratory distress

Bach & Saporito. Criteria for extubation and tracheostomy tuberemoval for patients with ventilatory failure: a different approach to weaning. Chest 1996;110:1566–1571.

9) Bach, et al. Prevention of pulmonary morbidity for patients with Duchenne muscular dystrophy. Chest. 1997 Oct;112(4):1024-8.

Is Peak Cough Flow Important?

- Dohna-Schwake:
  - Retrospective
  - N=46, children with NMD without cough assist
    - Mean age 12.5 ± 3.6 years
  - Comparison
    - With pneumonia admission, N = 22
    - Without pneumonia admission, N = 26

Dohna-Schwake, et al. Predictors of severe chest infections in pediatric neuromuscular disorders. Neuromuscular Disorders 16 (2006) 325–328.

Is Peak Cough Flow Important?

- PCF <160L/min – sensitive, specific predictor of severe chest infections
- PCF, IVC & FEV1 all significantly different between groups

Table 2

Severe chest infections	IVC ≤ 1.1 l (%)	IVC ≤ 30% pred. (%)	PCF ≤ 160 - l/m (%)	PEP ≤ 3 kPa (%)
Sensitivity	90.5	61.9	75.2	85.7
Specifity	70.8	79.2	79.2	47.3
Ppv	73.1	63.2	79.2	62.1
Npv	89.5	65.4	76.2	76.9

IVC, inspiratory vital capacitiy; IVC pred., inspiratory vital capacity of predicted; PCF, peak cough flow; PEP, peak expiratory pressure; Ppv, positive predictive value; Npv, negative predictive value.

	History of severe chest infection ($n=22$)	No history of severe chest infection ($n=24$)	P
IVC (l)	0.65 ± 0.42	1.44 ± 0.65	< 0.00001
IVC % pred.	28 ± 13	47 ± 24	< 0.005
FEV1 (l/s)	0.53 ± 0.36	1.21 ± 0.55	< 0.0001
PCF (l/min)	116 ± 62	211 ± 74	< 0.0005
PIP (kPa)	2.7 ± 1.1	3.6 ± 2.1	n.s.
PEP (kPa)	2.4 ± 1.1	3.0 ± 1.3	n.s.

Comparison of spirometry and respiratory muscle function in patients with a history of chest infections and patients without.

Dohna-Schwake, et al. Predictors of severe chest infections in pediatric neuromuscular disorders. Neuromuscular Disorders 16 (2006) 325–328.

Determinants of Peak Cough Flow

- Trebbia - Peak Cough Determinants in NMD
  - N=155,
  - Age 43 +/- 16 (16-80)
- Chief Determinants
  - Vital capacity
  - Mean inspiratory capacity
- Contribution to PCF Variance
  - MIC > ERV > MEP

Univariate regression analysis between PCF and other non-invasively measured variables

	PCF	
	r^2	p value
VC	0.58	<0.0001
MIC	0.47	<0.0001
MIP*	0.46	<0.0001
TLC	0.34	<0.0001
MEP*	0.31	<0.0001
ERV*	0.23	<0.0001
FRC*	0.07	<0.001

Stepwise regression analysis between PCF and other non-invasively measured variables (excluding VC and TLC)

	PCF	
	r^2	p value
MIC	0.44	0.0001
ERV*	0.13	0.0001
MEP*	0.02	0.0001

3) Trebbia, et al. Cough determinants in patients with neuromuscular disease. Respir Physiol Neurobiol. 2005 Apr 15;146(2-3):291-300.

Airway Clearance Techniques

- Lung Volume Recruitment Manoeuvers
  - Glossopharyngeal breathing
  - Manual breath-stacking (ambubag)
  - Mechanical insufflation (BiPAP, MIE)

- Expiratory flow manoeuvers
  - Manually assisted cough
  - Mechanical exsufflation

- Combination

Mechanical Insufflation-Exsufflation

- First described 1954
- Manual vs. automatic timed
- Pressure-limited insufflation phase
- Rapid reversal to negative pressure
- Exsufflation phase to clear secretions

Mechanical Insufflation-Exsufflation Pro-Side

Mechanical Insufflation-Exsufflation is an important airway clearance technique in patients with neuromuscular disease

Effect on Cough

- Bach: Comparison of PCF with various assisted cough methods (n=21, adults)
  - – N=21, ventilator-dependent adults, VC=490mL

Unassisted PCF =	1.81 ± 1.03 L/s
MIC (breath stacking) =	3.37 ± 1.07 L/s
MIC & manual cough =	4.27 ± 1.29 L/s
Mechanical cough =	7.47 ± 1.02 L/S

- $p<0.001$

4) Bach et al; Mechanical insufflation-exsufflation. Comparison of peak expiratory flows with manually assisted and unassisted coughing techniques. Chest. 1993 Nov;104(5):1553-62

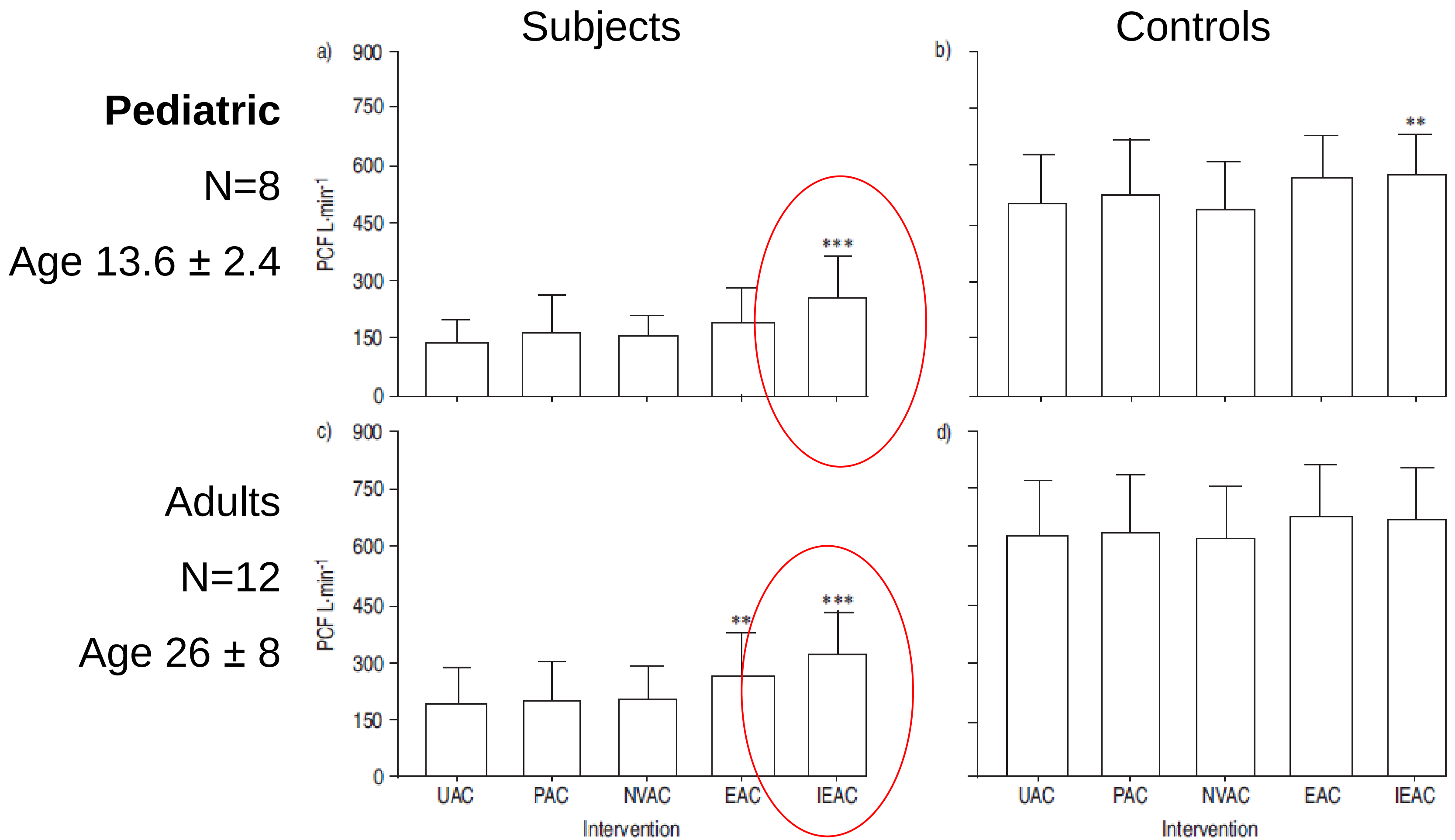
Effect on Cough

- Chatwin
  - Comparison of peak cough flow techniques
    - Physiotherapy, BiPAP, exsufflation, MIE
  - Pediatric N=8, Adult N=14.
  - Age matched controls
  - Ineffective cough or respiratory infections

Patient no.	Age yrs	Diagnosis	SNIP cmH_2O	$P_{mo,W}$ cmH_2O	$P_{I,max}$ cmH_2O	$P_{E,max}$ cmH_2O	FEV_1 L	FVC L	FEV_1/FVC %	S_{p,O_2} %	P_{ET,CO_2} kPa
Paediatric											
1	10	SMA	38.0	40.0	53.2	41.7	1.5	1.7	88.4	98	5.5
2	11	SMA	27.2	25.7	23.7	30.6	0.4	0.4	100.0	95	5.1
3	12	SMA	35.7	15.0			0.2	0.4	50.0	97	5.9
4	14	DMD	21.0	19.0	19.0	16.7	0.4	0.5	73.6	97	5.7
5	17	DMD	10.0	11.2	14.5	9.7	0.4	0.5	72.9	96	4.9
6	15	DMD	18.0	14.6	13.6	15.4	0.4	0.9	44.0	97	6.1
7	14	CMD	29.8	15.1	11.6	7.8	U	U		95	5.3
8	16	CMD	19.0	31.7	23.2	15.9	0.4	0.3	106.1	94	6.0
Mean±SD	14±2		24.8±9.5	21.5±10.0	22.7±14.3	19.7±12.2	0.5±0.4	0.7±0.5	76.41±23.63	96±1	5.6±0.4

5) Chatwin, et al. Cough augmentation with mechanical insufflation/exsufflation in patients with neuromuscular weakness. Eur Respir J. 2003 Mar;21(3):502-8.

Effect on Cough



**, ***: p=0.01, p=0.001 versus UAC.

5) Chatwin, et al. Cough augmentation with mechanical insufflation/exsufflation in patients with neuromuscular weakness. Eur Respir J. 2003 Mar;21(3):502-8.

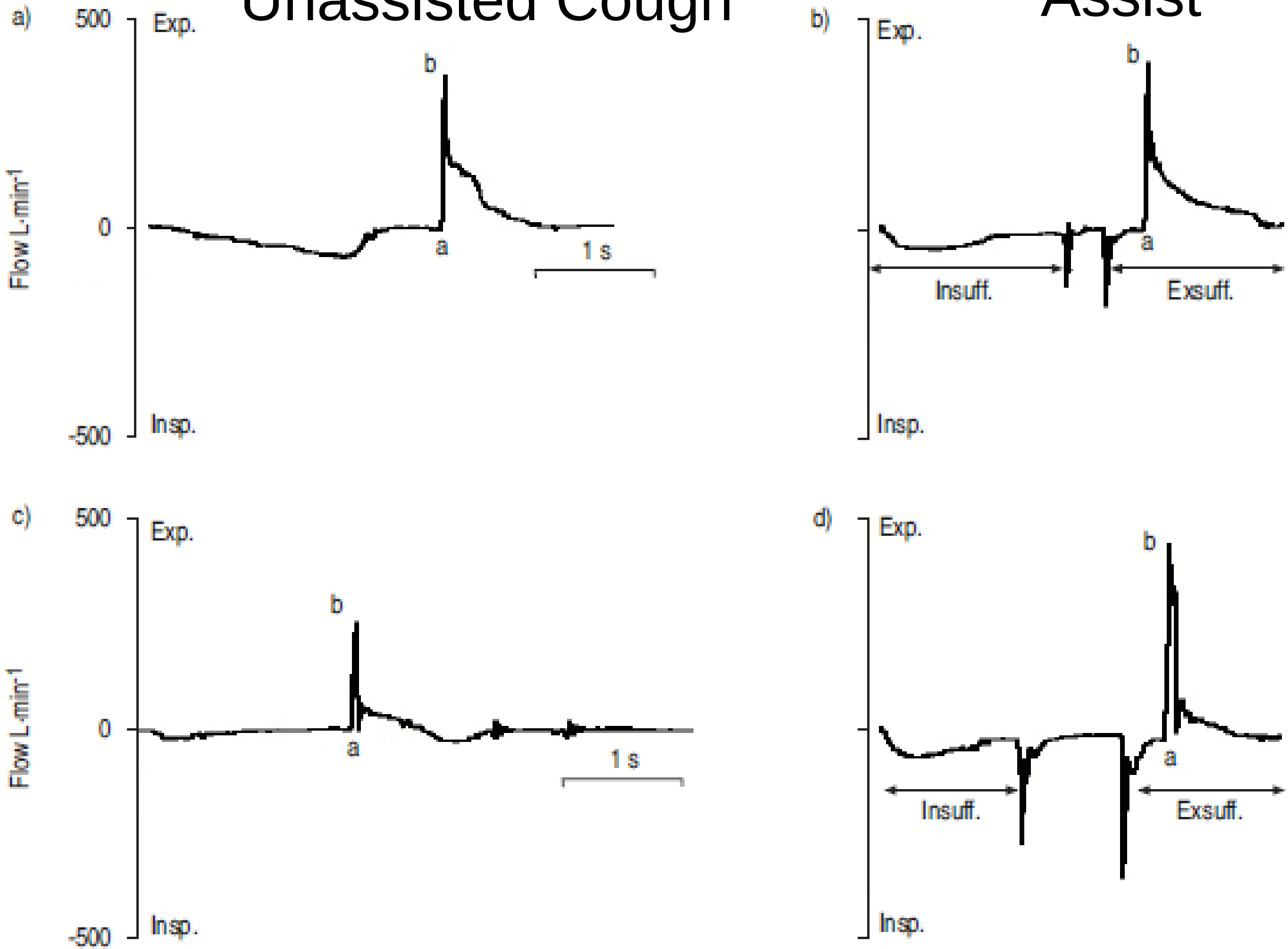
Effect on Cough

Unassisted Cough

Mechanical Cough Assist

Control

Child with NMD



5) Chatwin, et al. Cough augmentation with mechanical insufflation/exsufflation in patients with neuromuscular weakness. Eur Respir J. 2003 Mar;21(3):502-8.

MIE – Effect on Cough

- Faroux:
  - MIE at various pressures
  - 17 consecutive pediatric NMD outpatients
  - Stable at least 1-months

Table 1—*Characteristics of the Patients**

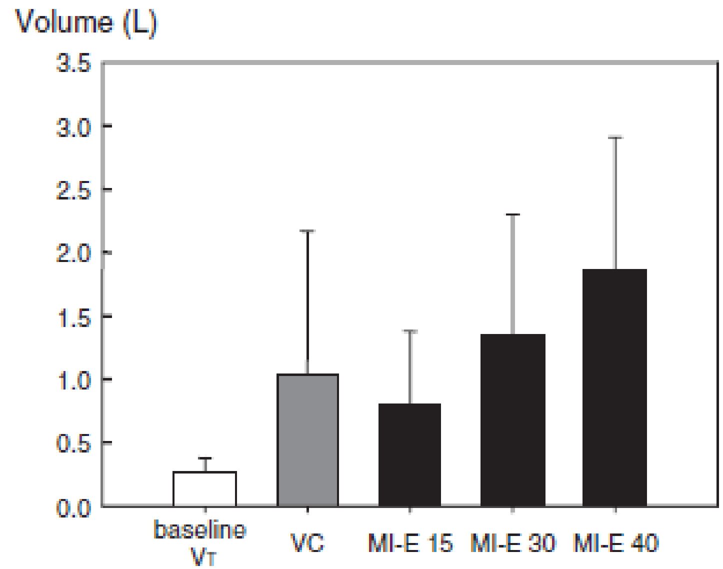
Characteristics	Gender		Age, yr	Weight, kg	Able to Walk, No.	NPPV, No.
	Boy	Girl				
Duchenne muscular dystrophy (n = 4)	4	0	15 ± 3	36 ± 22	1	3
Spinal muscular atrophy (n = 4)	2	2	8 ± 3	16 ± 3	1	2
Other neuromuscular disease (n = 9)	6	3	10 ± 2	38 ± 17	2	5
Total population (n = 17)	12	5	11 ± 4	33 ± 18	4	10

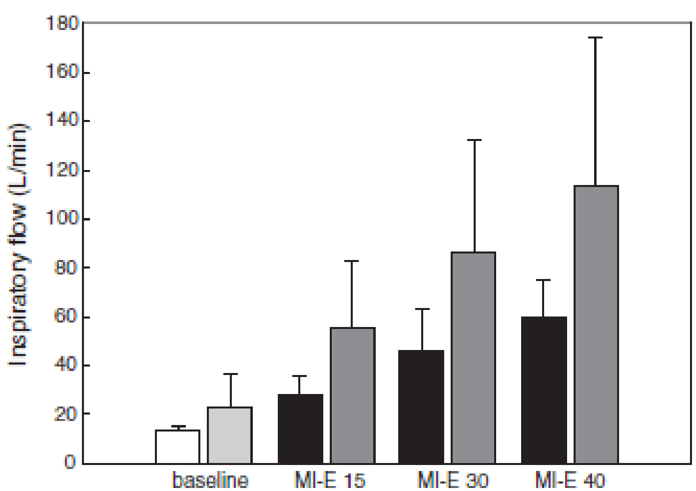
*Values are given as the mean ± SD, unless otherwise indicated. NPPV = noninvasive positive pressure ventilation.

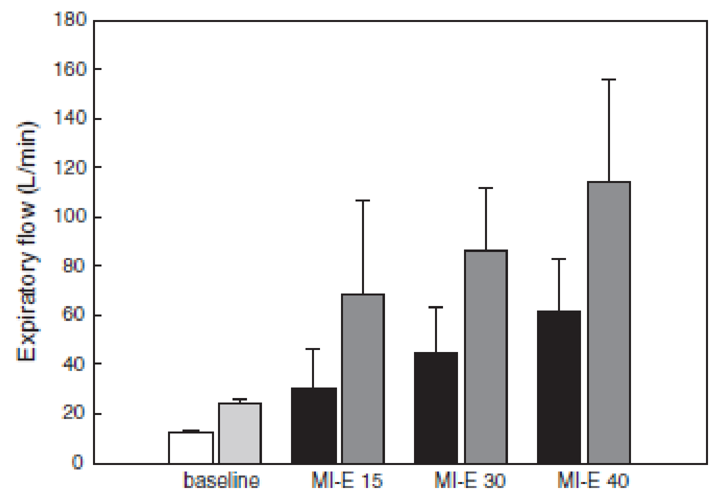
6) Faroux, et al. Physiologic benefits of mechanical insufflation-exsufflation in children with neuromuscular diseases. 1: Chest. 2008 Jan;133(1):161-8. Epub 2007 Dec 10.

Effect on Cough

- Pressures ± 40
  - Greatest effect on VC, Inspiratory/Expiratory flows, and PCF
  - Tolerated







6) Faroux, et al. Physiologic benefits of mechanical insufflation-exsufflation in children with neuromuscular diseases. 1: Chest. 2008 Jan;133(1):161-8.

Effect on Physiologic Measures

Stehling: Retrospective, N=21, placed on MIE

- VC <30% predicted, PCF < 160L/min, nocturnal NIV
- 16 failed intermittent positive pressure breathing for assisted cough
- Home MIE, 10-minutes, twice daily

Table 1. Patient characteristics.[a]

	Duchenne muscular dystrophy (n = 10)	Spinal muscular atrophy (n = 4)	Congenital myopathy without diaphragm weakness (n = 4)	Congenital myopathy with diaphragm weakness (n = 3)
Sex (male/female)	10/0	3/1	2/2	2/1
Age (years)	20.6 ± 3.9 (15–27)	9.3 ± 1.7 (7–11)	14.0 ± 9.6 (5–27)	13.7 ± 0.6 (13–14)
VC (l)	0.48 ± 0.15 (0.25–0.68)	0.34 ± 0.13 (0.25–0.53)	0.54 ± 0.39 (0.33–1.12)	0.62 ± 0.32 (0.52–1.09)
VC (% predicted)	11.0 ± 3.5 (5–15)	15.0 ± 2.6 (12–18)	28.0 ± 20.4 (10–54)	23.3 ± 6.6 (19–31)
Noninvasive ventilation	10/10 (100%)	4/4 (100%)	4/4 (100%)	3/3 (100%)
Hyperinsufflation	7/10 (70%)	3/4 (75%)	3/4 (75%)	3/3 (100%)

11) Stehling, et al. Mechanical insufflation/exsufflation improves vital capacity in neuromuscular disorders. Chronic Respiatory Disease. 2015, Vol. 12(1) 31–35.

Effect on Physiologic Measures

- Significant increase in VC (p=0.002)
- Vital capacity increased in 18/21
  - Average relative increase 28%
- Effect remained stable

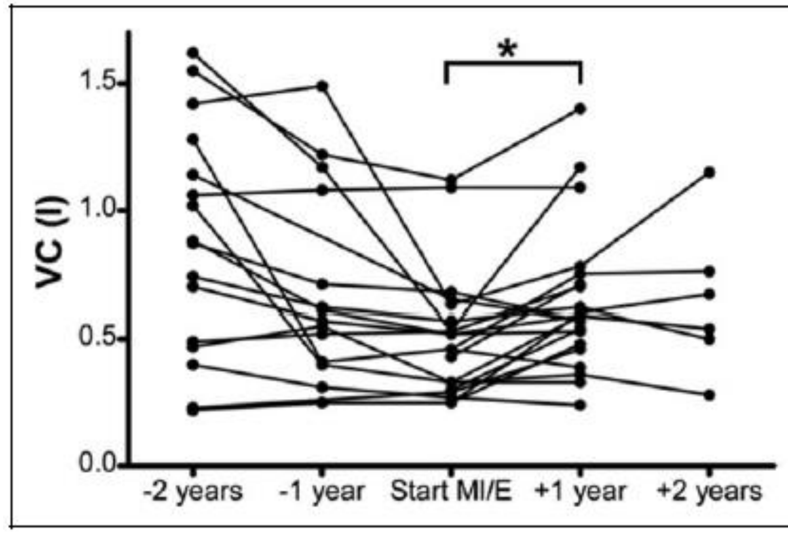


Table 2. Course of VC before and after the initiation of mechanical insufflation/exsufflation.[a]

	−2 years ($n = 16$)	−1 year ($n = 14$)	Start M-I/E ($n = 21$)	+1 year ($n = 21$)	+2 years ($n = 6$)
VC (L)	0.88 ± 0.45 (0.22–1.62)	0.71 ± 0.38 (0.25–1.49)	0.50 ± 0.24 (0.25–1.12)	0.64 ± 0.28 (0.24–1.40)	0.65 ± 0.29 (0.28–1.15)
VC (% predicted)	29.3 ± 18.8 (4–86)	21.3 ± 12.1 (5–45)	16.7 ± 10.9 (5–54)	22.9 ± 16.8 (7–73)	20.0 ± 11.7 (7–39)
Time (months)	28.4 ± 5.5	13.4 ± 3.1	0	9.4 ± 2.8	25.7 ± 7.4

11) Stehling, et al. Mechanical insufflation/exsufflation improves vital capacity in neuromuscular disorders. Chronic Respiatory Disease. 2015, Vol. 12(1) 31–35.

MIE - Effect on Outcomes: Short-Term

- Vianello: MIE in Consecutive patients with NMD in ICU with dyspnea and chest infection
  - N=11, 16 historical controls

TABLE 2 Summary data at study entry

	MIE Group A	Control Group B	*P* Value
Number of subjects	11	16	—
Age, yrs	34.91 ± 17.28	39.75 ± 21.56	0.541
Body mass index	18.76 ± 3.57	20.32 ± 5.08	0.446
Sex (males, females)	7, 4	12, 4	0.541
Patients administered home NPPV, *n*	7	9	0.990
No. of hospitalizations in 1 year	0.64 ± 0.81	0.58 ± 0.67	0.865
FVC, liters	0.38 ± 0.08	0.97 ± 0.88	0.305
PEF, liters/sec	1.54 ± 0.74	2.12 ± 1.14	0.191
Gilardeau score	2.09 ± 1.70	1.38 ± 1.67	0.659
Patients with fever, *n* (temperature > 38°C)	1	3	0.624
Patients with leukocytosis, *n* (WBC > 12,000 × 10^9/liter)	7	5	0.130
Pa_{O_2}, mm Hg	61.5 ± 5.84	66.25 ± 10.48	0.182
Pa_{CO_2}, mm Hg	52.18 ± 12.06	48.25 ± 14.46	0.466
pH	7.36 ± 0.07	7.40 ± 0.07	0.229

NPPV, noninvasive positive-pressure ventilation; FVC, forced vital capacity; PEF, peak expiratory flow; WBC, white blood cell count.

7) Vianello, et al. Mechanical insufflation-exsufflation improves outcomes for neuromuscular disease patients with respiratory tract infections. Am J Phys Med Rehabil. 2005 Feb;84(2):83-8; discussion 89-91

Effect on Outcomes: Short-Term

Reduction in intubation and/or tracheostomy

TABLE 3 Treatment specifics and outcomes

	Group A	Group B	*P* Value
Patients who required NPPV, *n*	8	14	0.370
Intravenous antibiotic treatment, *n*	11	13	0.248
Time spent receiving MV, days	9.4 ± 6.9	13.5 ± 11.9	0.299
Hospital stay, days	20.5 ± 20	19.8 ± 17	0.927
Treatment failure, *n*	2	10	0.047
Pts who required BAA, *n*	5	6	0.710

NPPV, noninvasive positive-pressure ventilation; MV, mechanical ventilation; BAA, bronchoscopy-assisted aspiration.

7) Vianello, et al. Mechanical insufflation-exsufflation improves outcomes for neuromuscular disease patients with respiratory tract infections. Am J Phys Med Rehabil. 2005 Feb;84(2):83-8; discussion 89-91

Effect on Outcomes: Short-Term

- Miske: Retrospective, N=63, MIE users
  - Median use 13.4 mo
  - 4 (6%) – Resolution of chronic atelectasis
  - 5 (8%) – Decreased pneumonia frequency

Table 1—*Patient Characteristics**

Diagnosis	DMD (n = 16)	MYO (n = 12)	NS-NMD (n = 12)	SMA Type I (n = 8)	SMA Type II (n = 14)
Median age at start, yr	21.0 (16.7–27.7)	10.7 (0.2–22.9)	9.7 (0.3–18.5)	2.4 (0.4–15.9)	12.6 (1.5–28.6)
Male patients	16	6	7	0	5
Noninvasive ventilation	5	4	4	3	9
Tracheostomy with ventilation	11	7	5	3	3
No ventilatory support	0	1	3	2	2

*Values in parentheses are ranges.

Table 2—*Pulmonary Function Test Results**

Tests	FVC, % predicted	FEV_1, % predicted	FEF_{25-75}, % predicted	PImax, cm H_2O	PEmax, cm H_2O
DMD	10.6 ± 6.3†	11.6 ± 7.6	26.7 ± 22.2	22.4 ± 12.0	21.1 ± 3.0
MYO	22.1 ± 11.2	21.0 ± 8.5	21.7 ± 10.5	22.7 ± 17.3	17.6 ± 7.4
NS-NMD	36.3 ± 17.8	36.8 ± 19.3	45.2 ± 32.5	23.5 ± 14.4	10.4 ± 2.4
SMA type II	24.7 ± 10.1	25.6 ± 11.4	41.2 ± 18.7	41.1 ± 17.4‡	15.5 ± 5.5

*Values given as mean ± SD. FEF_{25-75} = forced expiratory flow, midexpiratory phase.
†$p < 0.05$, compared with NMD and SMA.
‡$p < 0.05$, compared with all other groups.

8) Miske, et al. Use of the mechanical in-exsufflator in pediatric patients with neuromuscular disease and impaired cough. Chest. 2004 Apr;125(4):1406-12.

Effect on Outcomes: Long-Term

Bach: Retrospective, protocol in DMD adults

"high-risk"

- PCF <270L/min OR respiratory failure
- Protocol: IPPV, manual & mechanical cough during illness, sat monitor and access to the medical team

Table 1—*Hospitalization Rate Comparisons for Nonprotocol Preventilator Use High-Risk Patients vs Protocol Part-time Noninvasive IPPV Users**

Entire Population	Nonprotocol	Protocol	p Value
Patients	17	24	
Hospitalizations/pt	2.41±1.84	0.5±1.0	<0.005
Incidence of hospitalizations/yr/pt	2.25±4.75	0.2±0.5	<0.005
Hospitalizations avoided/pt		1.8±1.7	
Hospitalizations avoided/yr/pt		0.8±1.0	
Hospitalization days/pt	35.4±66.3	3.6±8.7	<0.005
Average hospitalization days/yr/pt	21.4±37.8	1.8±5.2	<0.005
Years	3.6±2.7	3.1±3.2	0.21

*This does not include the hospitalizations for introduction of definitive ventilator use. Pt=patient.

9) Bach, et al. Prevention of pulmonary morbidity for patients with Duchenne muscular dystrophy. Chest. 1997 Oct;112(4):1024-8.

Effect on Outcomes: Long-Term

- Decreased hospitalization rate, days
- Tracheosomtomy vs. full-time non-invasive
  - Most tracheostomy patients "Full-Time"
  - Full-time >16hr/day
  - Difference access to MIE

Table 2—***Hospitalization Rate Comparisons for Tracheostomy IPPV Users and Protocol Noninvasive IPPV Users****

	Nonprotocol Tracheostomy	Part-time Noninvasive	p Value†	Full-time Noninvasive	p Value†
Patients	22	24		14	
Hospitalizations	1.6±2.1	0.5±1.0	0.32	0.4±0.8	0.008
Hospitalizations/yr/pt	0.3±0.4	0.2±0.5	0.34	0.1±0.4	0.04
Hospitalizations avoided/pt		1.8±1.7		1.3±1.4	
Hospitalizations avoided/yr/pt		0.8±1.1		0.5±0.8	
Hospitalization days/pt	17.2±22.1	3.6±8.7	0.01	1.1±5.2	<0.005
Hospitalization days/yr/pt	2.3±2.4	1.8±5.2	0.71	0.3±2.4	0.04
Years	7.6±6.2	3.1±3.2		4.5±3.6	

*This does not include the hospitalizations for introduction of definitive ventilatory support. Pt=patient.
†Comparison with nonprotocol patients.

9) Bach, et al. Prevention of pulmonary morbidity for patients with Duchenne muscular dystrophy. Chest. 1997 Oct;112(4):1024-8.

Effect on Outcomes: Long-Term

Tzeng: Retrospective, protocol in NMD, adults & children

- PCF <270L/min OR respiratory failure
- Protocol: IPPV, manual & mechanical cough during illness, sat monitor and access to the medical team

Table 3—*Hospitalization Rate Comparisons for 47 Group 1 Patients With Preprotocol Periods and Subsequent Episodes of Respiratory Distress*

Category	Preprotocol	Protocol	p Value
Preprotocol vs protocol access patients (n = 10), No.*			
Hospitalizations/yr/patient	1.06 ± 0.84	0.03 ± 0.11	0.003
Hospitalization d/yr/patient	20.76 ± 36.01	0.06 ± 0.20	< 0.001
yr/patient	3.42 ± 3.36	1.94 ± 0.74	0.26
Preprotocol vs protocol access and part-time ventilator-use patients (n = 33), No.†			
Hospitalizations/yr/patient	1.40 ± 1.96	0.08 ± 0.17	< 0.001
Hospitalization d/yr/patient	20.14 ± 41.15	1.43 ± 3.71	< 0.001
Intubations, No.	0.75 ± 1.48	0.09 ± 0.38	0.002
Days intubated	9.21 ± 17.06	2.85 ± 13.37	0.003
yr/patient	5.89 ± 6.89	3.91 ± 3.50	0.50
Preprotocol vs protocol access and full-time ventilator-use patients (n = 12), No.‡			
Hospitalizations/yr/patient	0.97 ± 0.74	0.07 ± 0.14	0.002
Hospitalization d/yr/patient	10.39 ± 8.66	0.39 ± 0.73	0.003
Intubations, No.	0.25 ± 0.45	0	0.25
Days intubated	4.25 ± 9.85	0	0.25
yr/patient	2.18 ± 1.91	5.35 ± 5.10	0.08

10) Tzeng, et al. Prevention of pulmonary morbidity for patients with neuromuscular disease. Chest. 2000 Nov;118(5):1390-6.

MIE - Tolerability & Acceptability

- Miske: Retrospective, pediatric, N=63
  - Median use 13.4 mo
- Well-tolerated (90%)
  - 2 (3%) Chose other devices
    - Contribution to chronic abdominal pain
    - Chest discomfort
  - 3 (5%) Ineffective and/or unpleasant
    - 2 infants – crying, agitation
    - Young adult – no effect on airway clearance

Table 1—*Patient Characteristics**

Diagnosis	DMD (n = 16)	MYO (n = 12)	NS-NMD (n = 12)	SMA Type I (n = 8)	SMA Type II (n = 14)
Median age at start, yr	21.0 (16.7–27.7)	10.7 (0.2–22.9)	9.7 (0.3–18.5)	2.4 (0.4–15.9)	12.6 (1.5–28.6)
Male patients	16	6	7	0	5
Noninvasive ventilation	5	4	4	3	9
Tracheostomy with ventilation	11	7	5	3	3
No ventilatory support	0	1	3	2	2

*Values in parentheses are ranges.

8) Miske, et al. Use of the mechanical in-exsufflator in pediatric patients with neuromuscular disease and impaired cough. Chest. 2004 Apr;125(4):1406-12.

MIE - Adverse Events

- Adverse events = Rare
  - No pneumothorax in pediatric population
  - No pulmonary haemorrhage, barotrauma.
- Miske[8]: N=63, pediatric
  - No symptomatic reflux
  - PVCs in one patient, first-use, acute illness
  - When used only during respiratory illness, caregivers were less comfortable and less effective with the device.
- Faroux[6]: N=17, pediatric
  - No abdominal distension, reflux, chest pain
- Vianello[7]: N=11, adult
  - 1 GER, 1 epistaxis, 1 abdominal distension

Summary

Mechanical insufflation-exsufflation in NMD

- Increased peak cough flow
- Increased VC with regular use
- Decreases need to intubation, tracheostomy
- Improvement in chronic atelectasis, and decrease frequency of pneumonia
- Decreases need to hospitalization
- Safe and well-tolerated

Recommendations

BTS guidelines

NICE accredited
www.nice.org.uk/accreditation

British Thoracic Society guideline for respiratory management of children with neuromuscular weakness

Evidence statements

Use of airway clearance techniques which increase CPF, as part of a homecare treatment package which includes NIV, is associated with decreased hospital admission for respiratory infection and improved survival (evidence level 3).
Several airway clearance techniques are available. The most effective method for a particular child depends on the ability of the child to cooperate with treatment and the severity of the child's weakness (evidence level 3).

Airway clearance and respiratory muscle training

- Children with ineffective cough (including children over 12 years of age with cough peak flow <270 litres/min), particularly if they have had episodes of deterioration with respiratory infection, should be taught augmented cough techniques. [C]
- Manual cough assist and air-stacking methods to achieve maximum insufflation capacity are effective methods of improving cough efficiency and should be used when appropriate. [C]
- Mechanical insufflation/exsufflation (MI-E) should be considered in very weak children, those with loss of bulbar function, and those who cannot cooperate with manual cough assist or air-stacking or in whom these methods are not effective. [C]

Recommendations

- Airway clearance techniques should be used during respiratory infection when oxygen saturation levels fall below 95% while the child is breathing room air. If the techniques being used fail to result in an increase in oxygen saturation to 95% or above, different methods of airway clearance should be used. This may require attendance at hospital for treatment. [D]
- MI-E should be available in the acute setting in all hospitals that treat neuromuscular patients as an alternative method of airway clearance with the purpose of preventing deterioration and the need for intubation and mechanical ventilation. [D]
- Children who use regular night-time or diurnal NIV should use their ventilator to support deep breathing during airway clearance treatments. Use of NIV during airway clearance sessions can help prevent respiratory muscle fatigue. [√]
- Children who use MI-E for airway clearance should be given long enough periods of rest during treatment sessions to prevent respiratory muscle fatigue due to coughing. [√]
- At the end of a treatment session with MI-E it is important to complete the session with an insufflation to leave the child with an appropriate functional residual capacity. [√]

Recommendations

American Thoracic Society Documents

Respiratory Care of the Patient with Duchenne Muscular Dystrophy

ATS Consensus Statement

Recommendations

- Patients with DMD should be taught strategies to improve airway clearance and how to employ those techniques early and aggressively.
- Use assisted cough technologies in patients whose clinical history suggests difficulty in airway clearance, or whose peak cough flow is less than 270 L/minute and/or whose maximal expiratory pressures are less than 60 cm H_2O.
- The committee strongly supports use of mechanical insufflation-exsufflation in patients with DMD and also recommends further studies of this modality.
- Home pulse oximetry is useful to monitor the effectiveness of airway clearance during respiratory illnesses and to identify patients with DMD needing hospitalization (8).

Recommendations

The Respiratory Management of Patients With Duchenne Muscular Dystrophy: A DMD Care Considerations Working Group Specialty Article

David J. Birnkrant, MD,[1]* Katharine M.D. Bushby,[2] Raouf S. Amin, MD,[3] John R. Bach, MD,[4] Joshua O. Benditt, MD,[5] Michelle Eagle, PhD,[2] Jonathan D. Finder, MD,[6] Maninder S. Kalra, MD,[3] John T. Kissel, MD,[7] Anastassios C. Koumbourlis, MD,[8] and Richard M. Kravitz, MD[9]

Step 1: Volume Recruitment / Deep Lung Inflation Technique

- Volume recruitment / deep lung inflation technique (by self-inflating manual ventilation bag or mechanical in-/ex-sufflation) when FVC < 40% predicted

Step 2: Manual and Mechanically Assisted Cough Techniques

Necessary when:
- Respiratory infection present and baseline peak cough flow < 270 lpm*
- Baseline peak cough flow < 160 lpm or max expiratory pressure < 40cm water
- Baseline FVC < 40% predicted OR < 1.25 liters in older teen / adult

* All specified threshold values of peak cough flow and maximum expiratory pressure apply to older teenage and adult patients

Recommendations

Home Mechanical Ventilation

A CANADIAN THORACIC SOCIETY CLINICAL PRACTICE GUIDELINE

For at-risk individuals and patients using NIV:

1. Education and preventive strategies in airway clearance must precede the need for mechanical ventilation whenever possible. (Consensus)
2. In the absence of contraindications, LVR techniques should be introduced with measurement of PCFs and MIC in those with PCFs<270 L/min. (GRADE 1C)
3. MAC is recommended alone or in addition to LVR to increase PCFs to >270 L/min. (GRADE 1C)
4. In the absence of contraindications, MI-E should be recommended for patients unable to achieve PCFs >270 L/min with LVR and/or MAC particularly during respiratory infection. (GRADE 1C)

Recommendations

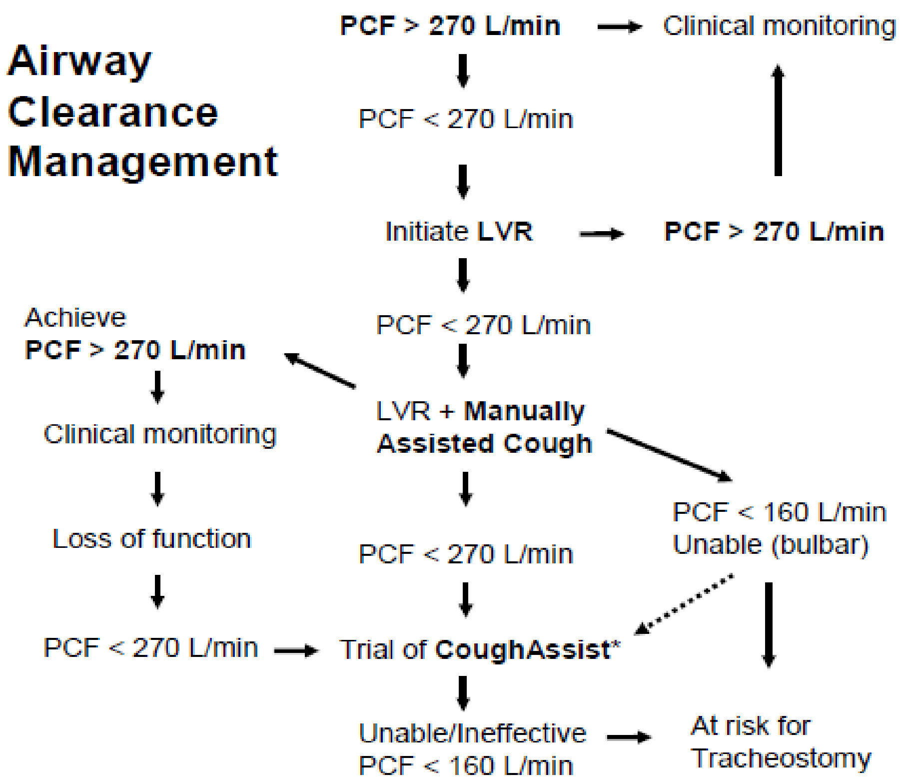


Figure 1-2) *Flow diagram for preventive airway clearance techniques. LVR: Lung volume recruitment; PCF: Peak cough flow.* *Note: Manually Assisted Cough can be added to increase effectiveness of CoughAssist® (Philips Heathcare, USA)

- *Trebbia: Cough determinants in NMD*
- *Boitano: Cough physiology*
- *Chatwin: Comparison of PCF using different methods*
- *Faroux: Tolerance, Physio benefits (CO2, Respiratory comfort)*
- LT: Merino: Incr Survival in DMD with Mech Cough used during URI
- *ST: Miske: Peds, Tolerance, Decreased atelecatasis, and PNA'*
- *Toussaint: Useless*
- *LT: Tzeng: Avoidance of hosp with IPPV and cough-assist*
- *ST: Vianello: MIE avoids Rx failure / ETT in NMD resp illness*
- *LT: Bach – DMD: Protocol of IPPV, Cough assist – avoid hosp in DMD*
- *Bach – Comparison of cough augement techniques*

Effect on Cough

- Significant: PCF, Respiratory Comfort (VAS)

Table 3—*Evolution of Breathing Pattern, Gas Exchange, and Respiratory Muscle Function After the MI-E Sessions With 15, 30, and 40 cm H_2O***

Variables	Baseline	After MI-E 15 cm H_2O	After MI-E 30 cm H_2O	After MI-E 40 cm H_2O	p Value†
Breathing pattern					
V_T, L	0.27 ± 0.11	0.27 ± 0.13	0.27 ± 0.16	0.28 ± 0.15	NS
f_R, breaths/min	26 ± 11	27 ± 12	26 ± 11	26 ± 10	NS
$\dot{V}_E$, L/min	6.3 ± 1.9	5.9 ± 1.5	6.2 ± 2.1	6.3 ± 1.7	NS
Gas exchange					
Sp_{O_2}, %	97.1 ± 2.1	96.6 ± 2.6	96.5 ± 2.2	96.4 ± 2.3	NS
P_{ETCO_2}, mm Hg	39.9 ± 3.8	38.0 ± 4.4	37.7 ± 4.6	37.8 ± 4.7	< 0.0003
Respiratory muscle function					
VC, L	1.04 ± 1.13	1.01 ± 1.05	1.00 ± 0.99	1.04 ± 1.06	NS
SNIP,‡ cm H_2O	29 ± 19	30 ± 19	28 ± 18	31 ± 20	0.046
PEF or PCF, L/min	162 ± 97	173 ± 112	170 ± 102	192 ± 99	0.02
Respiratory comfort, VAS/100	73 ± 21	75 ± 18	76 ± 24	83 ± 15	0.02

*Values are given as the mean ± SD, unless otherwise indicated. NS = not significant.
†Analysis of variance.
‡Analysis of variance was performed in 16 patients.

6) Faroux, et al. Physiologic benefits of mechanical insufflation-exsufflation in children with neuromuscular diseases. 1: Chest. 2008 Jan;133(1):161-8. Epub 2007 Dec 10.