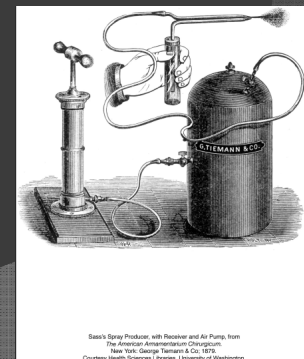


# Inhaled Medication Delivery in Mechanically Ventilated Patients –

**Saving money and Quality can co-exist**  
Return to another time, Back to the Future,  
or a work in Progress?

William R Howard MBA, RRT





# **NCSRC 2012 Symposium Survey**

- **HME vs. active humidification circuit**
- **IBD by MDI**





Consider: AARC promoted aerosol therapy concepts:<sup>1</sup>

- the right dose is technique and delivery system-dependent
- billions of dollars are spent on aerosol medications
- you can have a profound impact to match medications with delivery device to your patients

Ask yourself: in delivery of IBDs to MV patients:

- the most cost-effective and
- the most beneficial delivery method for your patient

1. Ari A, Hess D, Myers, Rau J. with a forward by Giordano S. A Guide to Aerosol Delivery Devices for Respiratory Therapists, 2nd Edition. 2009 American Association for Respiratory Care.



# So – why am I here and what's my story?

- Medical Director - 25 years ago challenge and expectation -
  - Do not follow the standard of care – **ESTABLISH** it!
- Discuss 2 success stories – help pay back your symposium fee
  - Hospital/department costs - daily demands to find savings
  - Engage *YOU* as the instrument of change



# The Objectives

- To identify realistic and *significant savings* in the administration of inhaled medications while increasing efficiency.
- To describe and demonstrate success changing from decades-old MDI to a cost-savings alternative.
- To identify barriers, partners, and change management strategy that will result in your having the same success.



# What we will cover –

Address one of the most common practices in the respiratory therapist's profession:

- **Inhaled bronchodilator administration in the MV patient**
  - **Challenge the current “SOC” -**
    - MDIs with or without spacers
    - Unit dosing
    - Is SOC a contradiction in terms?
  - **Surveys: opinions from our peers at academic medical centers**
  - **Barriers/opposition/partners, the inertia/resistance, reluctance to change: Physicians, nurses, RTs, and pharmacy**
  - **YOU can add benefit to your patient while saving \$\$**
  - **Implementation success story**



# What we will not cover – the science

(at least most of it)

## Recommend reading -

1. Ari A, Areabi H, Fink J. Evaluation of aerosol generator devices at 3 locations in humidified and non-humidified circuits during adult mechanical ventilation. **Respir Care** 2010;55(7):837-844
2. Ari A, Atalay OT, Harwood R, Sheard MM, Aljamaa EA, Fink JB. Influence of nebulizer type, position, and bias flow on aerosol drug **Respir Care** 2010;55(7):845-851.
3. Duarte A. Inhaled bronchodilator administration during mechanical ventilation. *Respir Care*;2004 ;49 (6).
4. Dolovich M. Changing delivery methods for obstructive lung diseases. *Curr Opin Pulm Med* 1997;3(3):177–189.
5. Fink JB, Dhand R. Laboratory evaluation of metered-dose inhalers with models that simulate interaction with the patient. *Respir Care Clin North Am* 2001;7(2):303–317.
6. Fink JB, Dhand R, Grychowski J, Fahey PJ, Tobin MJ. Reconciling in-vitro and in-vivo measurements of aerosol delivery from a metered-dose inhaler during mechanical ventilation, and defining efficiency enhancing factors. *Am J Respir Crit Care Med* 1999;159(1):63–68.
7. Everard ML, Devadason SG, Le Souef PN. In vitro assessment of drug delivery through an endotracheal tube using a dry powder inhaler delivery system. *Thorax* 1996;51(1):75–77.
8. Duarte AG, Dhand R, Reid R, Fink JB, Fahey PJ, Tobin MJ, Jenne JW. Serum albuterol levels after metered-dose inhaler administration to ventilated patients and healthy controls. *Am J Respir Crit Care Med* 1996;154(6 Pt 1):1658–1663.
9. Dhand R. Inhalation therapy with **metered-dose inhalers** and dry powder inhalers in **mechanically ventilated patients**. **Respir Care** 2005;50(10):1331–1344.



**Why suggest change from MDIs – used for decades – to unit dose (UD) IBDs?**

**Is this crazy?**

**Or said another way: “why have we been using MDIs?”**

**Motivation began with completion of AARC  
Asthma educator certification course.**

**EDUCATION!**





## Why the focus is on MDI – and the ventilator circuit?

### Consider:

- Drug deposition after actuation: variety of locations for deposits-
  - the actuator
  - the ventilator circuit
  - the endotracheal tube } = Less drug available to reach target
- The amount of drug reaching the distal end of the ETT is available for deposition in the lung...but 1<sup>st</sup>...
  - a small proportion of this drug is exhaled and
  - a variable amount is systemically absorbed.
  - The **remainder of the drug** deposits in the lung (the lung dose) - **responsible for the pharmacologic effects**
- Patient response to inhaled drug directly related to amount of deposition in the lower respiratory tract.

Less  
and  
less  
drug

**Our job is not done...**



# Why we are not done –

- **Delivery device: less than adequate; so little of “nominal dose” is delivered.**
- **Variability – no consensus**

## Surveys:

- **Several national (informal peer surveys)**
    - **US academic medical centers – during past 3 years**
    - **common theme re: delivery methods for inhaled bronchodilators...**
- 1) **MDI proponents: “We have a protocol that dictates the use of MDIs instead of SVNs in mechanically ventilated patients. An option for SVNs is not given in those patients.”**
  - 2) **Unhappy “unit-dosers” who want the MDI option:**
    - **“Has anyone been able to move away from unit dose to MDI?”**
      - **Tufts, Southcoast and many others:**
        - **MDIs – ICU and floors for 30 years - until very recently**

**There is no agreement on a single SOC**



# My response to each survey:

1. **Why reluctance for unit dose (UD)?**
2. **MDIs –**
  - **Evidence of superiority?**
  - **HHN at least equivalent!**
3. **HFA propellants, less drug delivery than CFC**
4. **Ventilator settings – adjust for breath hold prior; & DC after each Rx**
5. **We switched to unit dose A&A and Combivent for all MV patients (2009)**
6. **Practice fully endorsed by pulmonary group; we have not turned back.**
7. **Net savings ~ \$100/patient (2009 \$\$).**
8. **Savings even more with UD budesonide substituted for MDI Fluticasone.**

**END OF EMAIL THREAD.....**



#1 reason for *not* switching over to unit dose?  
(e-mail/phone call follow-up)

The savings will not come out of “**My budget**”  
..... **My** Department will have added costs and  
it’ll affect **My** bottom line” - All reasonable but...

**The silo mentality**



# The # 2, 3, 4, etc. reasons for *not* switching over to unit dose – until now?

- ✓ ? denial that there is a more effective method  
How can I be wrong with my current method?
- ✓ ? Ego
- ✓ *Financial attractiveness not apparent*
- ✓ “We’ve always used MDI”
- ✓ Mis-perceptions, or reservation due to educational challenges?



## The “Boston – attitude; cross-town rivalry”

October 2010 from RT Director at a major Boston Teaching Hospital –  
**Speculation from ‘cynics’ -**

“Bill – I am curious as to how you can save \$ using the Aerogen. Aren’t you using this at \$40 each?”



# The “Boston-attitude”

**August 11, 2011 e-mail/follow-up phone call from RT Director at even BIGGER Boston Teaching Hospital -**

- **Aerogen neb is being considered as an alternative delivery system for “.....” but we never considered it for IBDs.”**
- **I am amazed that Tufts saved ~ \$100.00/patient as an MDI replacement.**



# Consideration.....

August, 2011 e-mail from clinical manager at a Children's Hospital in Boston:

“We are looking for alternatives to deliver **continuous** albuterol delivery”

“I was wondering if you could tell me a little about how you use the Aerogen device in this capacity.”

Slowly making headway.....



## **Hartford Hospital Connecticut query –**

**February, 2012 e-mail from clinical manager:**

**“We spoke a few months back about your use of UD for IBD at Tufts.”**

- **“We are still looking to initiate the use of this nebulizer at our institution and I've been asked to give evidence of cost savings and its increase in efficacy of care to our VP of Patient Care Services.”**

**H.H. cost for Combivent: \$196.00 each!**

Slowly making headway.....



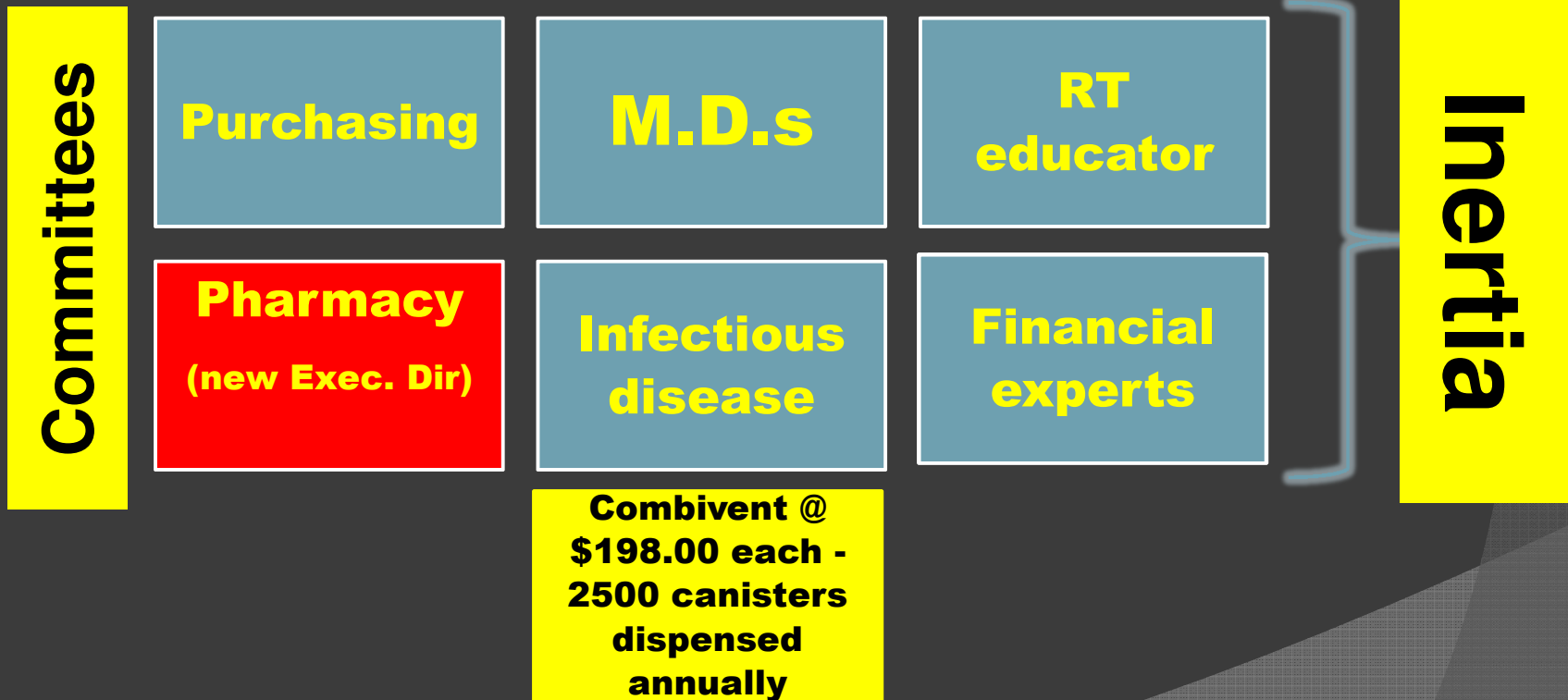


# Most recent – 3 hospital system

January, 2012

On radar screen since 2010; never went forward.

Remained - “Interested”



# From Background to “the Original Plan”: Convert MDI delivery IBD to UD aerosol administration with MV patients.

***Initial plan (2009) was a discussion of:  
potential alternatives to i-NO .***



**Bigger picture – convert decades old practice of MDI use to unit dosing.....**



# The Original Plan: Convert MDI delivery of inhaled bronchodilators to unit dose aerosol administration.

## Phase -1

### The story that brought the opportunity into Tufts

- Initial target audience to address –
- Change 30 years of IBD MDIs to UD  
1 person

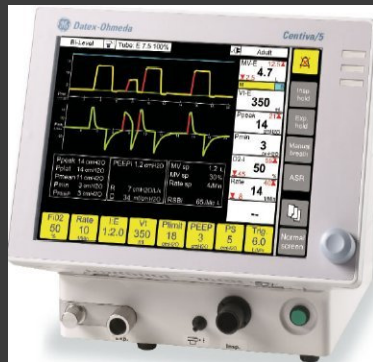
**Chairman of adult pulmonary division  
Respiratory Care Medical Director  
(immediate past President of  
American Thoracic Society)**

**Began with description of vibrating mesh  
nebulizer:**

**Technology - deliver aerosolized medications  
approved for general purpose nebulizers - through  
mechanical ventilators.**

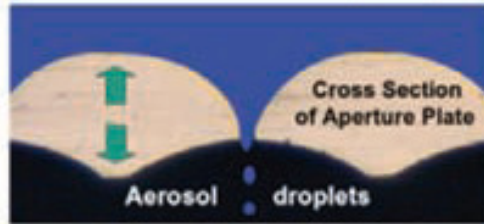
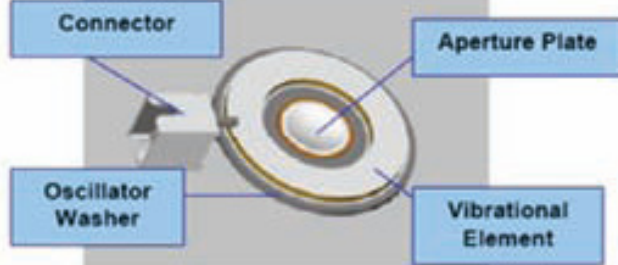


# Explained the barriers: Popular current generation ventilators – powering the neb?



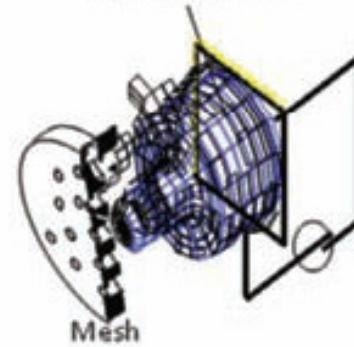
# “Available” nebulizers – separate gas source required





Active Vibrating Mesh

Ultrasonic Horn



Passive Mesh



E-Flow (PARI)



Akita II



Omron  
Healthcare)



Aeroneb® Go and Solo



# Features of the Vibrating Mesh technology

- No added flow or volume from neb
- No pressure/volume loss when adding UD
- No VAP protocol violation (circuit remains closed)
- Convenient for the staff; time saver over MDI
- For routine intermittent or continuous Rxs
- Numerous inhaled medications
- **Remains with patient** throughout hospital stay
- Evidence - deposits up to **4 X more medication** through an endotracheal tube (*in vitro*) during mechanical ventilation than small volume nebulizers (SVNs).
  - Remember the evidence: MDI and SVN = comparable delivery





# 2009 original Plan: Convert MDI delivery of inhaled bronchodilators to unit dose aerosol administration.

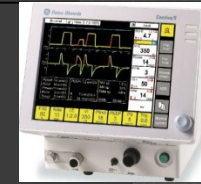
## The RIGHT FIT.....

Unlike pre “current generation” ventilators:

- No flow to nebulize inhaled medications.

Prior to newer nebulizers:

- To nebulize inhaled meds with standard SVN
  - **Change mode AC/SIMV to PCV/Bi-Level**
    - AC with SVN - higher airway pressure generation.
  - PCV/Bi-Level protects against added VT/Pawp from SVN
  - Often – not always requires more sedation
  - **Risk of ventilator failure, (SVM) monitoring and alarm violation if flow too high<sup>1</sup>**



1. Lichtenfels E, Boas G, Oberly D. EVALUATION OF THE WESTMED VIXONE NEBULIZER WITH THE MALLINCKRODT NELLCOR PURITAN BENNETT 840 VENTILATOR. AARC 2006 OF-01-001



# Aerosol delivery

(selling points to medical director)

- The evidence vs. the Perceptions - references
  - 30+ years ago when MDIs introduced: MDI superior?
  - MDI delivery comparable to SVNs – *if* ‘ideal’ techniques used
  - .... but not necessarily superior to SVN

THE picture/ that spoke 1,000 words –  
and sold my medical director –

Rx with Aerogen nebulizer  
during  
bronchoscopy



# Aerosol delivery

**Goal : sell to the M.D. champion(s)**

Target: IBD alternatives to MDIs –

- Unit dose (available in formulary – the low hanging fruit – the easy sell)
  - **Initially** - short acting bronchodilators and anticholinergics
    - Albuterol, Atrovent (Combivent)
  - **Secondary** - Inhaled corticosteroids
    - Pulmicort/Fluticasone (budesonide)
    - Abs
- Continuous
  - Bronchodilators



# Comparison of MDI to unit dose

Goal : more points attempting to sell/influence M.D. champion(s)

## MDI:

### ***Perceived benefits or advantages***

- **Convenient and less labor**
- **Delivery superior to liquid nebulized medication administration**
- **MDIs cost effective alternative to unit-dose solution.**

## MDI Disadvantages:

- **More labor/TIME** involved in delivery of treatment if performed correctly.
- **Needs “to be performed correctly”** to be effective.
  - Spacer, proper coordination, timing of *each* actuation, 60 second pause between actuations.
- Multiple ventilator **circuit breeches** with each treatment.
  - MDI removed from ventilator circuit and re-inserted for each subsequent treatment
- Requires **breath hold** especially with the new HFA propellant.
- **“Tailing off”** – as MDI is depleted, dose declines;
- **When is MDI empty?**
  - H<sub>2</sub>O bath content determination useless with HFAs
  - Counters do not work with Mech. Vent circuit spacers.
- More priming needed – (**wasted doses**) with HFA MDI
- HFA MDIs cost more than CFC MDIs or UD
  - Wasteful if canister is not used completely.  
(Many of our ventilated patients use partial canisters)
- Bedside storage/**security** concerns
  - Can not/should not be returned to Pyxis – **ID**/contamination issues.



# Comparison of MDI to unit dose

Goal : sell to the M.D. champion(s)

## Unit Dose Advantages

- **Timing and coordination of actuation a non-issue.**
- **No lost therapist time/pausing of treatment delivery**
- **Each dose is the same; no “tailing off” with subsequent Rx.**
- **Evidence Aerogen nebulizer - drug delivery to the patient:**
  - **min of 83% of aerosol in the perfect respirable range**
  - **drug delivery 4 X more than MDI or SVN “equivalent” ordered dose.**
- **Unit dose; there is no unused medication – no waste!**
- **Single patient use - no security or ID factors**

## Unit Dose Disadvantages

### PERCEPTIONS:

- **“We’ve always used MDIs they must be better”**
- **“We have been there – we are going backwards by nebulizing”**



# Metered-dose to unit dose – dose equivalency

Goal : sell to the M.D. champion(s)

Initial concern – comparable dose delivery

Identified historical average dose to be 6 -8 puffs/Rx (CFC)

## Short-acting $\beta_2$ agonist

- Albuterol 2.5 mg/2.5 ml
  - (3 puff MDI equivalent) \*\*

## Anticholinergics

- Atrovent 0.5 mg/2.5 ml
  - (3 puff MDI equivalent) \*\*

**\*\* To deliver an equivalent 6-8 puff MDI dose, 2 ampoules of unit-dose will be required for each Rx**

**Neb cup capacity – 6 mL**



# MDI : Single dose – dosage comparisons

## Combivent :

- **Albuterol 2.5 mg/2.5 ml**
  - (3-4 puff MDI equivalent) \*\*
- **Atrovent 0.5 mg/2.5 ml**
  - (3-4 puff MDI equivalent) \*\*



1- ampule of Duoneb

**To deliver an equivalent 6-8 puff MDI dose, 2 ampoules of UD = 6 mL.**



## Unit Dose - Gaining Acceptance

### **Phase 2 - ~ 2 years after initial ICU implementation:**

- **The target – M&S/non-ICU patient floors**
- **The mission – IBD MDI discontinuance**
- **The belief – no downside treating patients with IBD (and i-steroid) with unit dose rather than MDI.**
- **Line in the sand –**

*..... why should we pay for the most expensive delivery method (MDI) while in the hospital?*

**The “challenges” –**





Unit Dose - Gaining Acceptance

## **Phase 2 - ~ 2 years later (cont'd)**

- **Challenge #1 – physician education**
  - **Both unit dose (PRN) and MDI of same medication often ordered for same patients.**
  - **M.D. #1 concern**
    - **“I want to transition my patient to home with MDI”**
- Response:**
- **Most patients on Rx are not new starts**
  - **Should not equate to MDI delivery for total hospital stay.**
    - **No cost or effectiveness justification for MDI.**
  - **Placebo teach pre-discharge**



Unit Dose - Gaining Acceptance

## **Phase 2 - ~ 2 years later (cont'd)**

### **Challenge #2 – nursing education**

- **Perception that most 'scheduled' Rxs would take more time**
  - **Education: issues with MDI delivery discussed earlier**
- **Placebo MDI for 'new start' pre-DC education**
  - **..... reminder that MOST patients going home with IBDs (COPD) already had MDI education; these are not new starts.**
- **Addressed ID and JCAHO issues with return of MDIs to Pyxis vs unit dose**



## Tufts Medical Center partners/opportunities:

### **Pharmacy – proposal and endorsement from P&T:**

- **MDIs** when properly used are at least as effective as nebulized solutions.
- The economics have changed. New environmentally friendly' MDIs significantly more expensive.
- In the past 6 months we have spent more on respiratory medications than on antibiotics or chemotherapy!
  - **Proposed policy: automatic substitution of MDIs to unit dose - albuterol, Atrovent, Combivent, and Fluticasone.” (APPROVED)**



# The next chapter:

## New opportunity - Southcoast Hospitals Group

- **Approached initially - 2010 – \$\$ identified**
- **Acknowledged benefits for the patient**
- **No forward progress - until Jan-2012**
- **The same target: MV patients**
- **The practice:**
  - **MV patients - MDI - Combivent**
    - **Cost (identified Opportunity-1)**
    - **Dosing efficiency (Opportunity-2)**
  - **Barriers – HME circuits = (Opportunity – 3)**
    - - **not considered by in-house ‘sponsor’ as a barrier**
      - **“we’ve always done it this way” (HME circuit)**
    - - **absence of HME practice monitoring: patient assessments**
      - **Actual vs. perceived HME cost**



# The next chapter:

## New opportunity - 3 Hospital Group

- **Barriers – HME circuit - not considered a barrier**
  - “we’ve always done it this way”
  - - absence of HME practice monitoring:
  - Patient assessments
    - Every exclusion criteria routinely met
    - 2 acute airway obstructions with HMEs
- **HME with optional flow path**
  - Is it possible HME directed flow path will not be reset or re-adjusted after Rx?
    - If it can happen it will (not)



Project – change from passive to active humidification

**Humidification of artificial airways**  
**Passive or active?**

Project – change from passive to active humidification



# Debate - read the science -

## **Drug delivery from the vibrating mesh nebulizer was 2–4-fold greater than that from the jet nebulizer under all test conditions**

1. Ari A, Areabi H, Fink J. Evaluation of aerosol generator devices at 3 locations in humidified and non-humidified circuits during adult mechanical ventilation. *Respir Care* 2010;55(7):837-844
2. Ari A, Atalay OT, Harwood R, Sheard MM, Aljamaa EA, Fink JB. Influence of nebulizer type, position, and bias flow on aerosol drug *Respir Care* 2010;55(7):845-851.
3. DiBlasi R. Clearing the mist from our eyes: bronchodilators, mechanical ventilation, new devices, locations, and what you should know about bias flow. *Respiratory Care*. • July 2010;55(7).
4. Ari A, Hess D, Myers, Rau J. with a forward by Giordano S. *A Guide to Aerosol Delivery Devices for Respiratory Therapists*, 2nd Edition. 2009 American Association for Respiratory Care.



## **New target – 3 hospital group**

### **The Plan:**

**Replaced HME circuit with active humidification in conjunction to Aerogen implementation**

- **Selling points to leadership:**
  - **Investment in active humidification**
  - **Overall savings with improvements in clinical practice**
- **Barriers – selling to admin.**
- **Pushback from MDs who prefer MDIs**
  - **1<sup>st</sup> round – group meeting with Pulmonologists**
  - **2<sup>nd</sup> round – staff acceptance**
  - **3<sup>rd</sup> round – P&T Committee**



# The next chapter:

New organization – non-academic medical center but.....

(Opportunity – 4): sell to M.D.s (Pulmonologists) at their quarterly meeting (4 attendees)

- **Defiant M.D** - pulmonologist
  - Wanted comparison of MDI to VM delivery/efficiency
- Not buying ATS President story
- Suggested - paid by Aerogen
- The gauntlet thrown- \$100.00 wager
- ...my last slide – (coming soon) \$\$ saved



# The next chapter:

New organization – non-academic medical center but.....

Goal #2: all Pulmonologists

- To all pulmonary M.D.s across the 3-hospital system
- EDUCATE –
  - Letter
  - Slide set
  - Evidence; References
- Target: Same as at Tufts
  - MDIs – UD alternatives



# The next chapter:

**Goal: convert all 3 hospital sites**

Letter(s) and meetings :

- Team Leaders and staff
- Educator
- Purchasing
- Divisional VP - Finance
- Pharmacy
  - Pharmacy Finance Manager
  - Expense and savings details
    - Aerogen consumables
    - **Ventilator circuit**
    - **Medication SAVINGS**



The next chapter:

Goal : influence all stakeholders

**THE UNIVERSAL MESSAGE – MY MESSAGE - STATED AT EACH MEETING TO ALL AUDIENCES:**

**“There is absolutely no logical or scientific reason that we should be administering IBD medications using the most expensive method that we have – MDI where there is a UD alternative!”**



# “Why single dose - why now?”

Anticipated net savings to -

- **\$198.00/canister** (equivalent to 5 days of Q4H or 25 treatments)
- **Compare: UD equiv: \$7.25 plus \$40.00 neb cup = \$47.25**
- **SAVINGS: \$198.00 – 47.25 + 7.00 Incr cir cost ~= \$143.00/patient or ~ \$190,000 annually.....**

**Savings will be significantly more - many MV patients receive > 1 MDI canister (average = 1.5/patient)**

**Additional savings - unit dose budesonide vs. MDI Fluticasone.**



	UNIT/ DEVICE COST	UNITS/ DEVICES DISPENSED FY2011**	ANNUAL Patient VOLUME	ANNUAL SPEND	SUBSTITUTION (THERAPEUTIC INTERCHANGE - AEROGEN nebulizer)	UNIT COST	PROJ ANNUAL VOLUME	PROJ ANNUAL COST	Incrmtal Cost incr	POTENTIAL ANNUAL SAVINGS
<b>MDI BRONCHODILATORS</b>										
COMBIVENT (200)	198.00	1,800	1,200	356,400	DuoNeb	0.29	23,040	6,682		\$349,718
					Aerogen Neb	40.00	1,200	48,000	48,000	
SUB-TOTAL				356,400						
<b>PROJECT: HME vs Active Humid POTENTIAL COST SAVINGS 3/1/12 SHG</b>										
	UNIT/ DEVICE COST		ANNUAL Patient VOLUME		(Active humidification circuit)					
HME circuit	13.50		1,200	16,200	F&P Dual Heated Wire circuit w/chamber	27.00	1,200	32,400	16,200	
TOTAL SPEND				372,600				84,682	64,200	285,518
Annual Net SAVINGS										\$285,518



What if.....

100,000 MV patients hospitalized/year

***What if...***

50%  
receive  
IBDs by  
MDI

X \$240\*\*  
savings ea

= 50K x \$240 or  
**\$12,000,000**

\*\* Assumes average of 2 MDI canisters/ patient on MV





## Unit Dose - Gaining Acceptance

### Who made the conversion work?

#### My staff were the pleasant surprise

- Very accommodating of another change
- Unsolicited compliments
  - The system easy to use
  - Less time/labor
  - Very pleased with the switch from MDIs
- The staff made the switch from decades old MDI method of delivery painless.



# So is the message being heard?



Management Section



## Contents

Management Section

About the Chair

Best Practices Depot

Bulletins

Education



**Where Savvy Managers  
Go for Support!!**

**Best Practice Depot**



So is the message being heard?

## Best Practice Depot: Initiatives By Category

Category = Change in delivery/administration processes



# Tufts Medical Center

Submitted by:

*Bill Howard*

Director, Respiratory Care

[whoward@tufts-nemc.org](mailto:whoward@tufts-nemc.org)

6176365393

Initiative Title:

Cost Savings

Implementation Date:

7/1/2009

Objective:

Improve the method of bronchodilator delivery for mechanically ventilated patients while decreasing the expense.

Description:

We have used MDIs as the method of administering bronchodilators in mechanically ventilated patients for more than 20 years. Recognizing the limitations of HFA propelled MDIs, their expense, coupled with new nebulizer technology, we explored the use of the Aerogen Solo nebulizer system as a replacement.

Costs:

\$10500

Savings:

\$45000

Challenges:

Most of our mechanically ventilated patients prescribed for bronchodilators are administered both Albuterol and Atrovent. Our cost for these MDIs is approximately \$130.00 For each patient that we do not start MDIs but choose the Aerogen system, we save the institution approximately \$90.00. Each Aerogen controller is paid for with the initiation of this plan with approximately every 8 patients started.

# Inhaled Bronchodilators.... Old Habits die hard

- MDI practice – MV - is now ~ 30 years old
- The science is solid
- Barriers are real – change is difficult
- Initial sticker shock - mis-perceptions
- Financial opportunities –
  - YOU are the CHAMPION of CHANGE!

...follow the money and provide a better Rx @ the same time

Good luck--



**My time is done - thank you for yours.....**

Follow-up questions and  
communication:

[BillHoward@CuffSentry.com](mailto:BillHoward@CuffSentry.com)



## Additional References:

1. Hess D. Aerosol delivery devices in the treatment of asthma. *Respir Care* 2008;53(6):699 – 723.
2. Dhand R. The role of aerosolized antimicrobials in the treatment of ventilator-associated pneumonia. *Respir Care* 2007;52(7):866–884.
3. Dolovich M, Ahrens R, Hess D, Dhand R, Rau, J. Device Selection and Outcomes of Aerosol Therapy. *CHEST* 2005; ;127(1):335-371
4. Duarte A. Inhaled bronchodilator administration during mechanical ventilation. *Respir Care* 2004;49(6):623–634.
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