Evolution of Mechanical Ventilation

(according to Downs)

Evolution of Mechanical Ventilation

As much as anything else, timing has been a critical determination of the acceptance, or rejection of a ventilatory technique.

POSITIVE PRESSURE RESPIRATION AND ITS APPLICATION TO THE TREATMENT OF ACUTE PULMONARY EDEMA

Alvan L. Barach, M.D., John Martin, M.D.,
Morris Eckman, B.S.

Ann Int Med 12:754-795, 1938

The Journal of Thoracic Surgery

Traumatic Wet Lung

Observations on Certain Physiologic

Fundamentals of Thoracic Trauma

Major TH Burford and Major B Burbank

Medical Corp, Army of The United States

December, 1945

SYNONYMS FOR ACUTE RESPIRATORY FAILURE

- Adult Hyaline Membrane Disease
- Adult Respiratory Distress Syndrome
- Bronchopulmonary Dysplasia
- Congestive Atelectasis
- Danang Lung
- Diffuse Alveolar Capilary Damage
- Fat Embolism
- Hemorrhagic Atelectasis
- Hemorrhagic Lung Syndrome
- Hypoxic Hyperventilation
- Oxygen Toxicity
- Postperfusion Lung
- Posttransfusion Lung
- Posttraumatic Atelectasis
- Posttraumatic Pulmonary Insufficiency
- Progressive Pulmonary Consolidation
- Progressive Respiratory Distress
- Pulmonary Edema
- Pulmonary Hyaline Membrane Disease
- Pulmonary Microembolism
- Pump Lung
- Respirator Lung
- Shock Lung
- Low Flow Lung
- Stiff Lung Syndrome
- **TRAUMATIC WET LUNG**
- Transplant Lung
- Wet Lung
- White Lung Syndrome

“Regardless of the cause, the entire mechanism by which the lung might be able to cope with the primary lesion is deranged. That mechanism must be restored, if the lung is to react favorably to therapy and if the patient is to survive.”

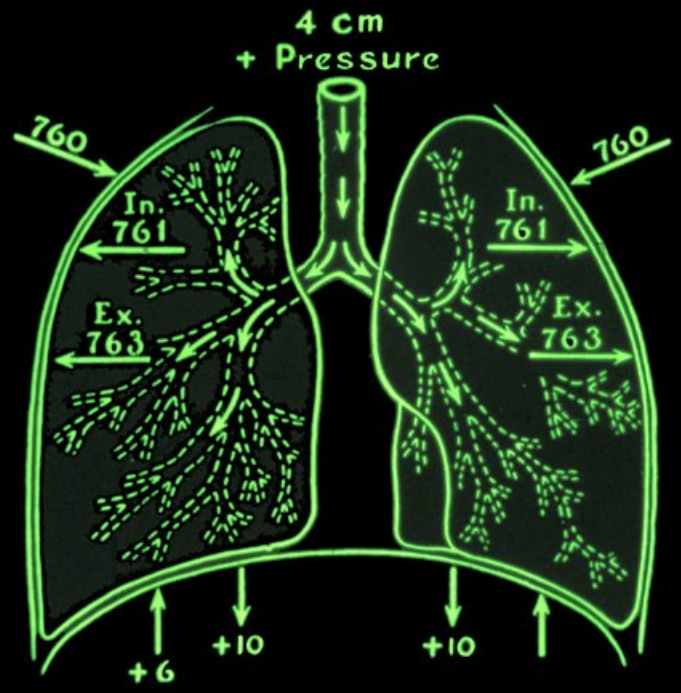
T.H. Burford

Recovery of Pulmonary Function After Crushing Injuries of the Chest

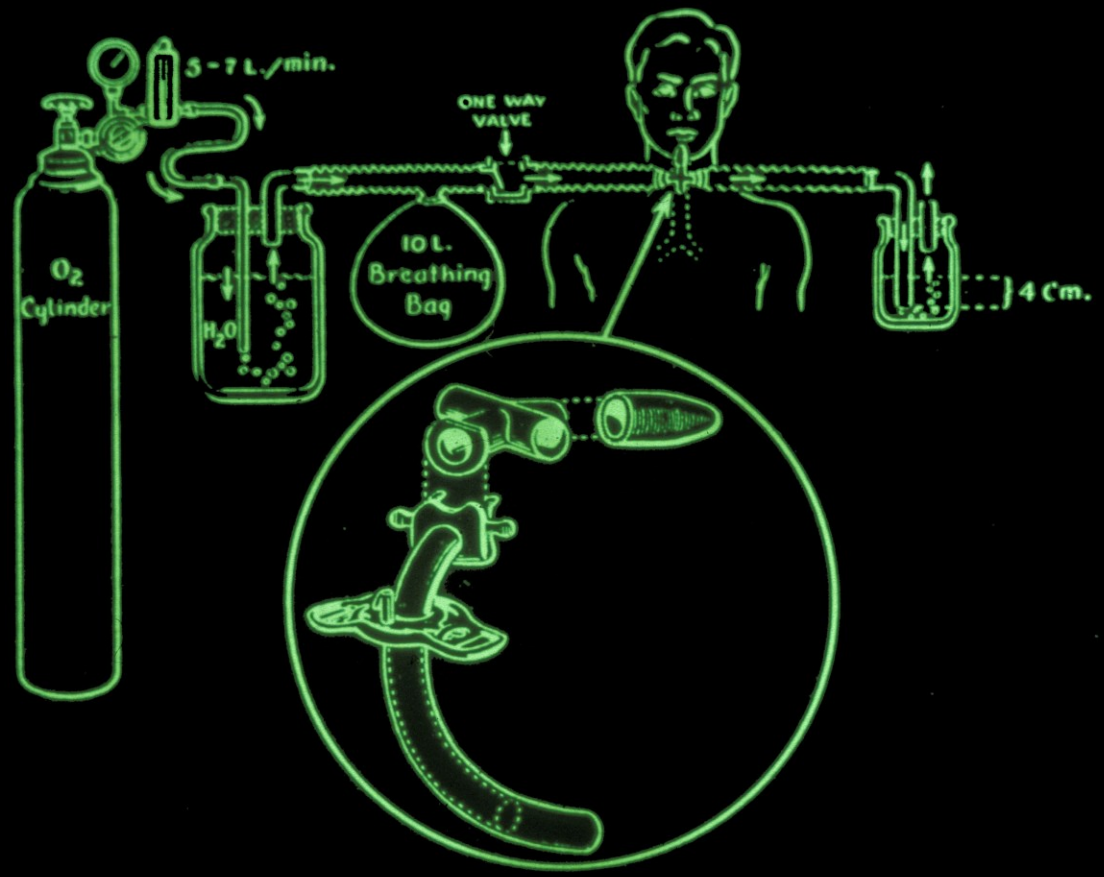
-Nathan K. Jensen, M.D.

Diseases of the Chest 22, 319 - 346

The recovery of pulmonary function following crushing injury of the chest occurs in two phases. The early period after injury, during which time the battle for survival must be won, is one of seriously disturbed ventilation and vascularization of alveolar spaces. The second phase is characterized by residual disturbances in the thoracic musculoskeletal system and the pleural spaces. These must be corrected if efficient respiration is to be regained.



NATHAN KENNETH JENSEN
Dis Chest 22:332, 1952
Figure 9



Nathan K. Jensen
Dis Chest 22:334, 1952
Fig 11

Nathan K. Jensen
Dis Chest 22:334, 1952

WHAT HAPPENED?????

-POLIOMYELITIS

It is difficult to identify the "who, when and where" of advances in medicine and surgery, because it is a rare advance indeed (such as the use of digitalis by William Withering) that can be clearly related to the astuteness of one person at one time and place. It's a bit easier to identify the "who, when and where" of some delays in progress along a frontier in medical science.

To become a "who" who held up the advance in science, one must meet certain criteria. These include: (1) the scientist or clinician must be a highly respected "eminent authority", or "geheimrat" in some field; (2) he must have strong convictions; (3) he must not hesitate to utter these forcibly in his writing, lecturing, or both; (4) he must, in <u>this</u> instance, be <u>wrong</u>, although he surely doesn't recognize his error; and (5) no one dares to challenge him.

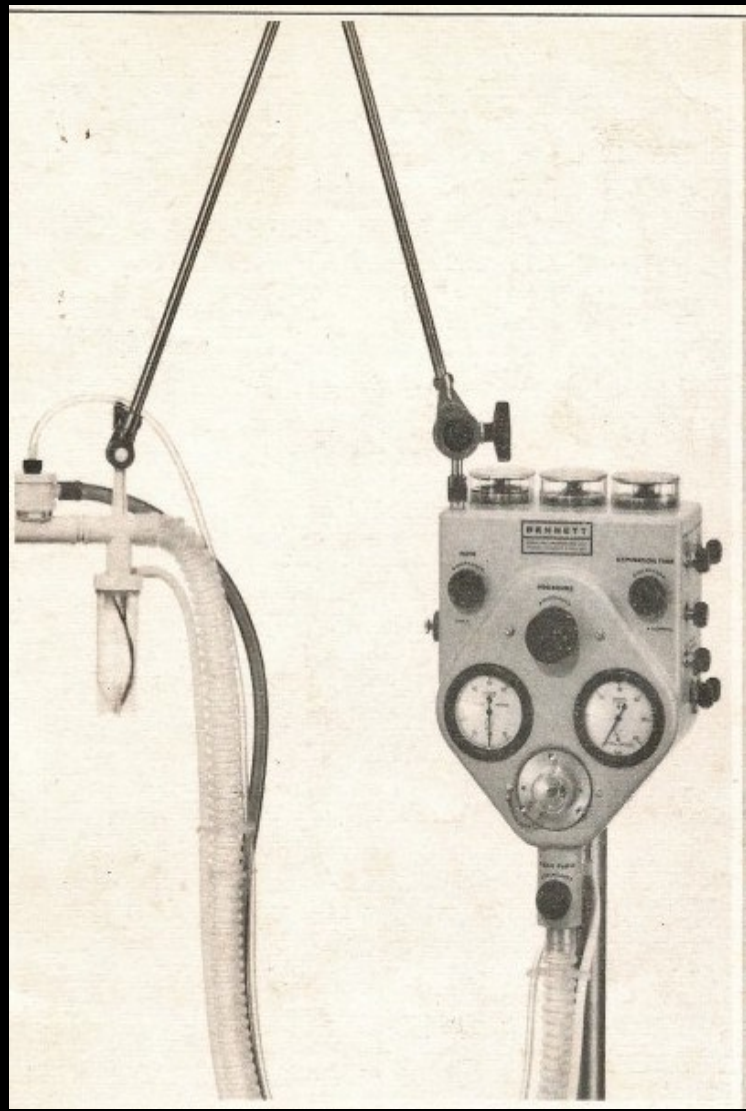
“Fortunately, all five components must be in the recipe, or it won’t work. It’s going to be very hard to eliminate the first four components from our biomedical research family. The hope for the future lies in eliminating the last of the five.”

Julius H. Comroe, Jr.

In regard to the actual supply of oxygen to the tissues, it is quite important to know what amount of blood is actually transported to those tissues. Therefore, it would seem to me that the crucial thing is to use equipment that will give the least reduction of cardiac output. In my opinion, from that point of view, respirators, such as the Bennett X-2, are probably preferable to continuous pressure breathing, because there would be less reduction of cardiac output with them than with continuous pressure breathing.

Andre F. Cournand, M.D.

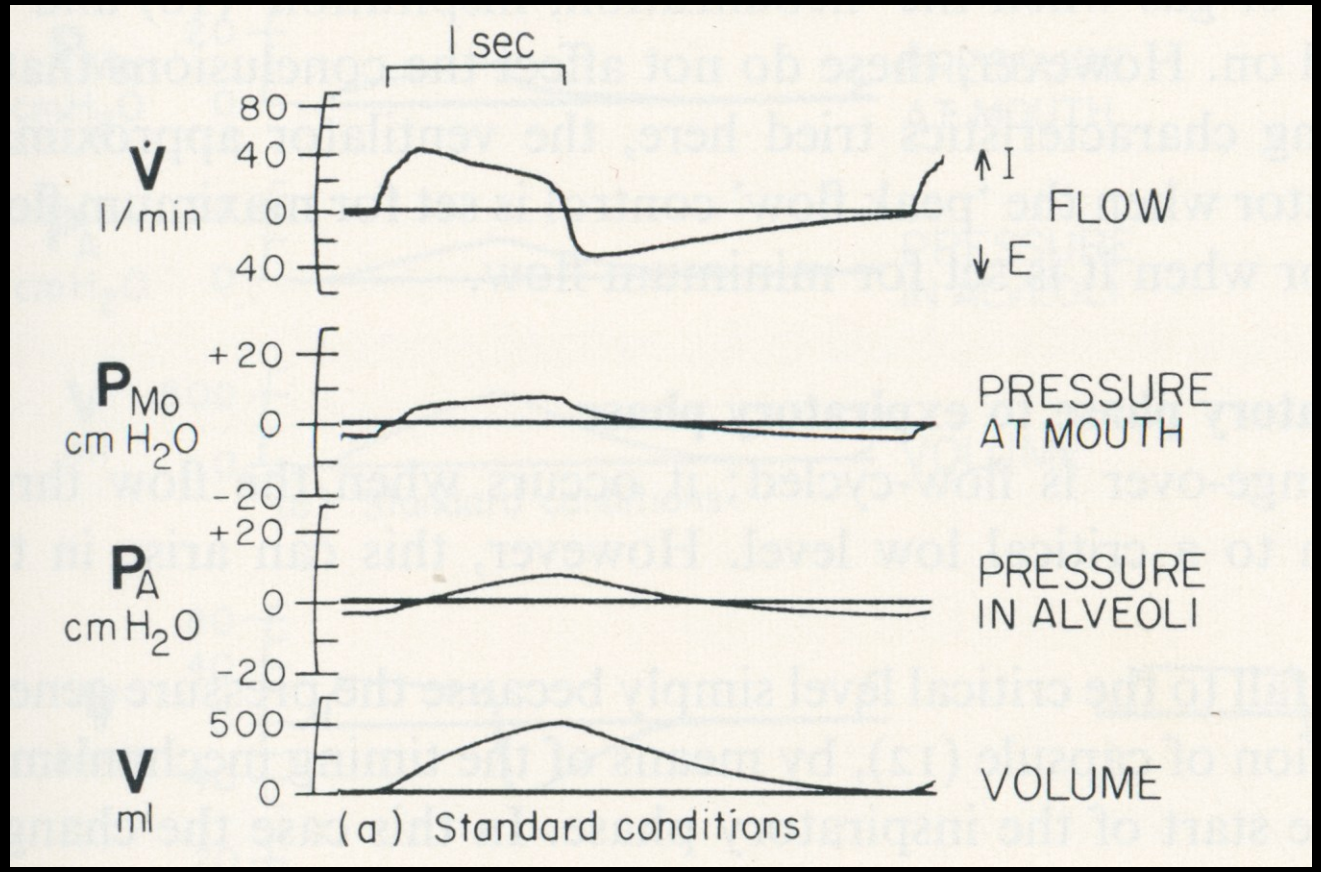
Nobel Prize for Physiology, or Medicine, 1956



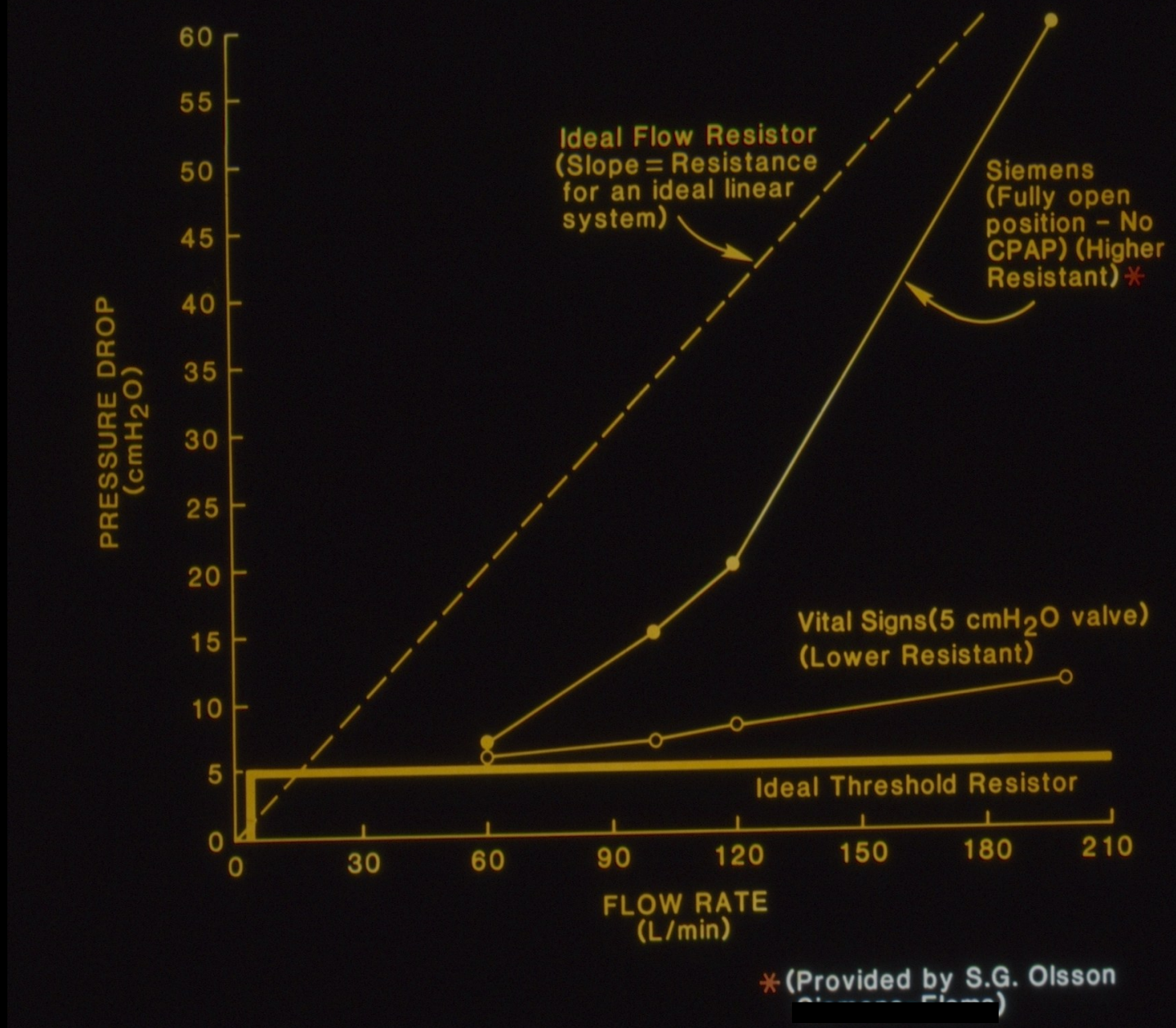
OPERATING INSTRUCTIONS

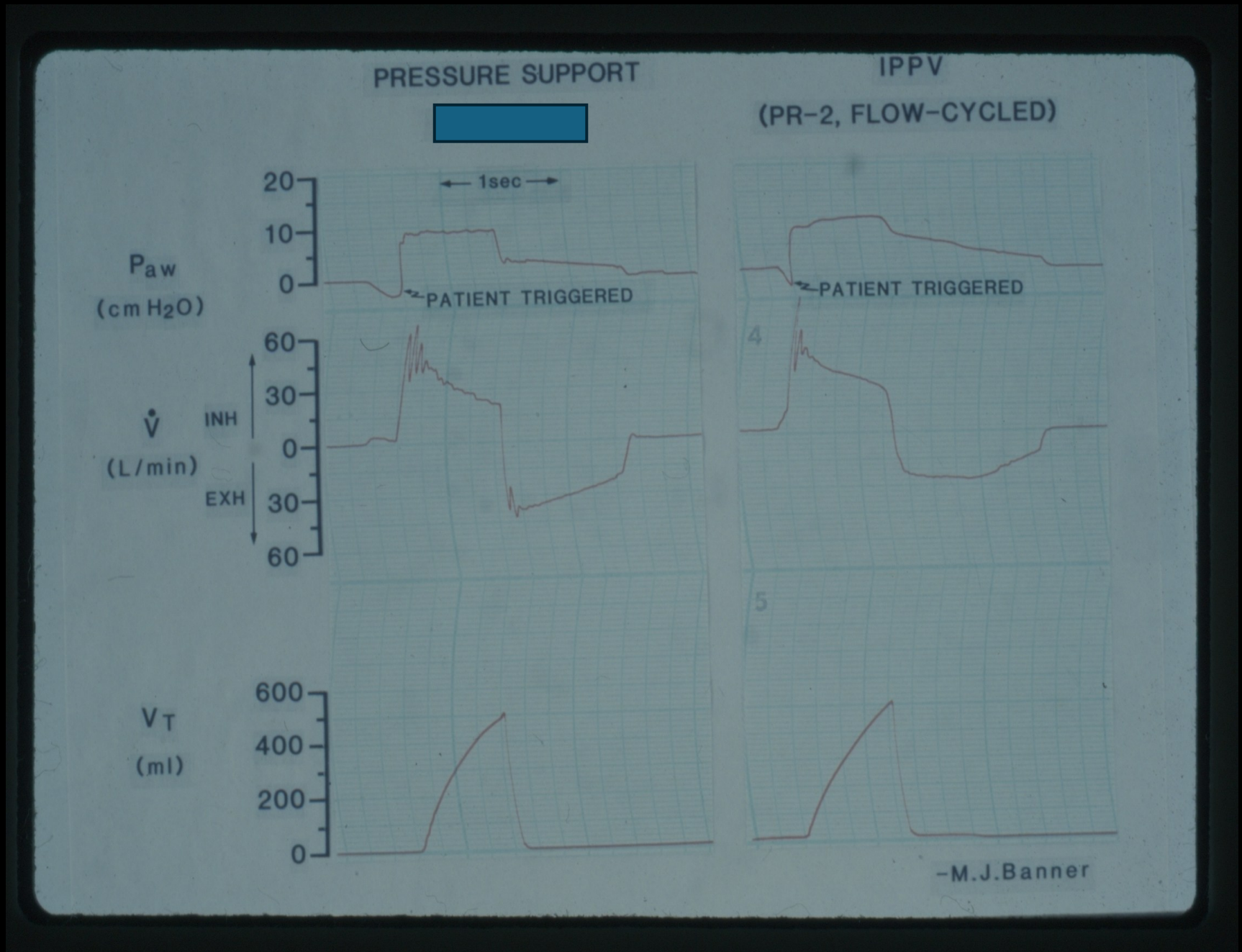
[redacted] MODEL PR-2

RESPIRATION UNIT



(a) Standard conditions


PRESSURE DROP
(cmH2O)
60
55
50
45
40
35
30
25
20
15
10
5
0
0
30
60
90
120
150
180
210
FLOW RATE
(L/min)
Ideal Flow Resistor
(Slope = Resistance
for an ideal linear
system)
Siemens
(Fully open
position – No
CPAP) (Higher
Resistant)*
Vital Signs(5 cmH2O valve)
(Lower Resistant)
Ideal Threshold Resistor
*(Provided by S.G. Olsson


PRESSURE SUPPORT
IPPV
(PR-2, FLOW-CYCLED)
1sec
20
10
0
Paw
(cm H2O)
PATIENT TRIGGERED
PATIENT TRIGGERED
60
30
0
30
60
V̇
INH
EXH
(L/min)
4
5
600
400
200
0
VT
(ml)
-M.J.Banner

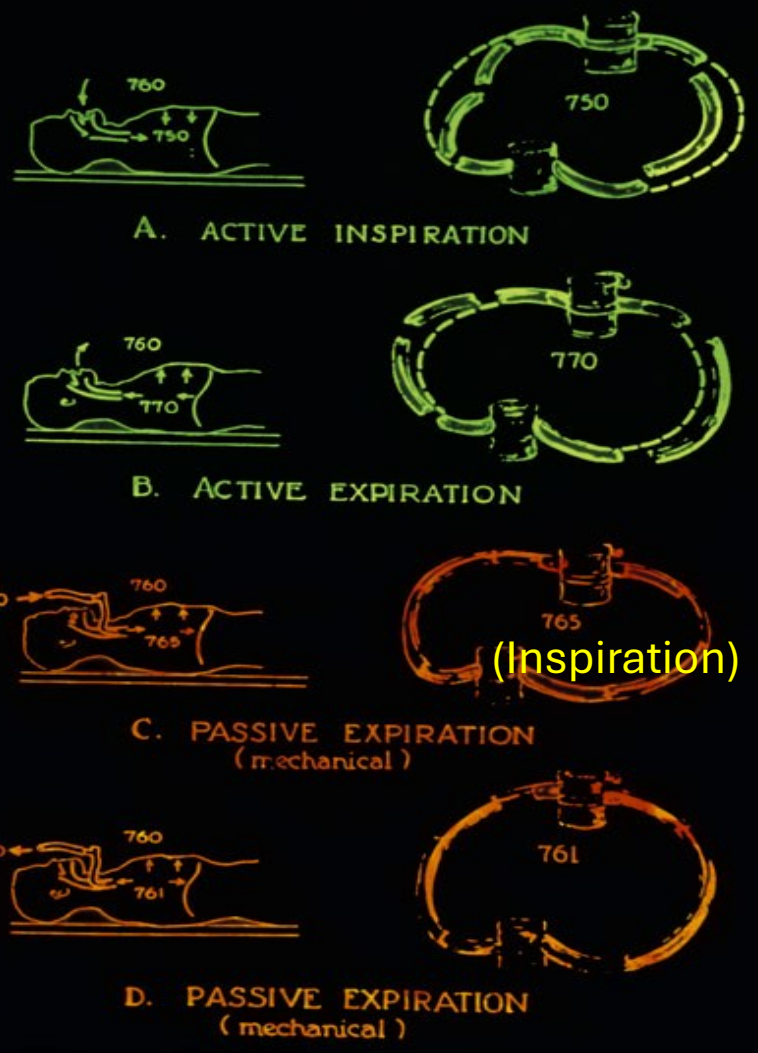
Phase I
(before 1956)

Mechanical ventilation was reserved for patients with neuromuscular inability to maintain spontaneous respiration.

Phase II

(1956 - 1958)

Controlled ventilation for postoperative and traumatized patients.



Avery, Morch and Benson
J Thoracic Surg 32:304,1956
Fig 12

Phase III
(after 1968)

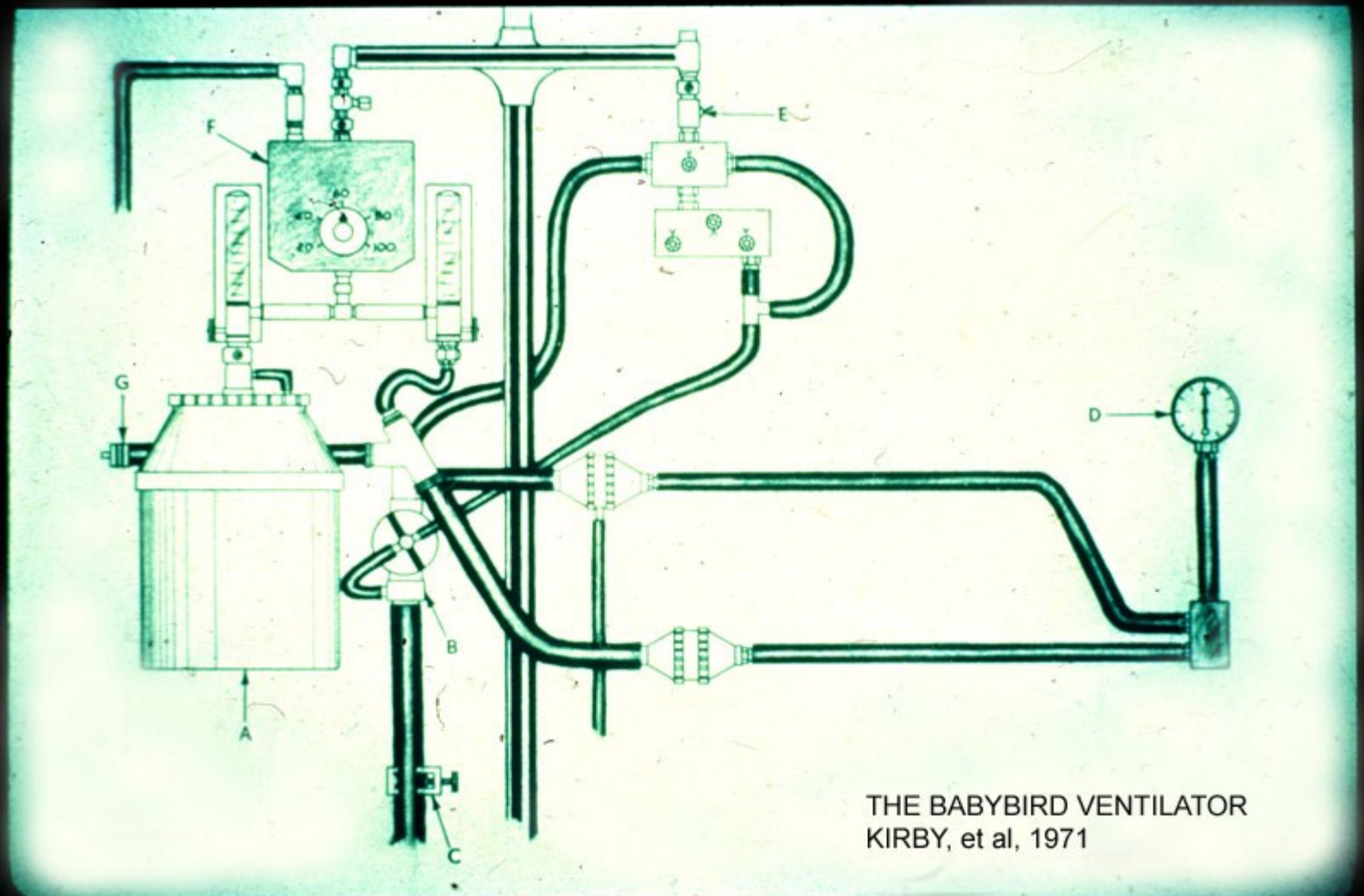
Controlled ventilation with PEEP (CPPV) for treatment of patients with hypoxemia.

CPAP

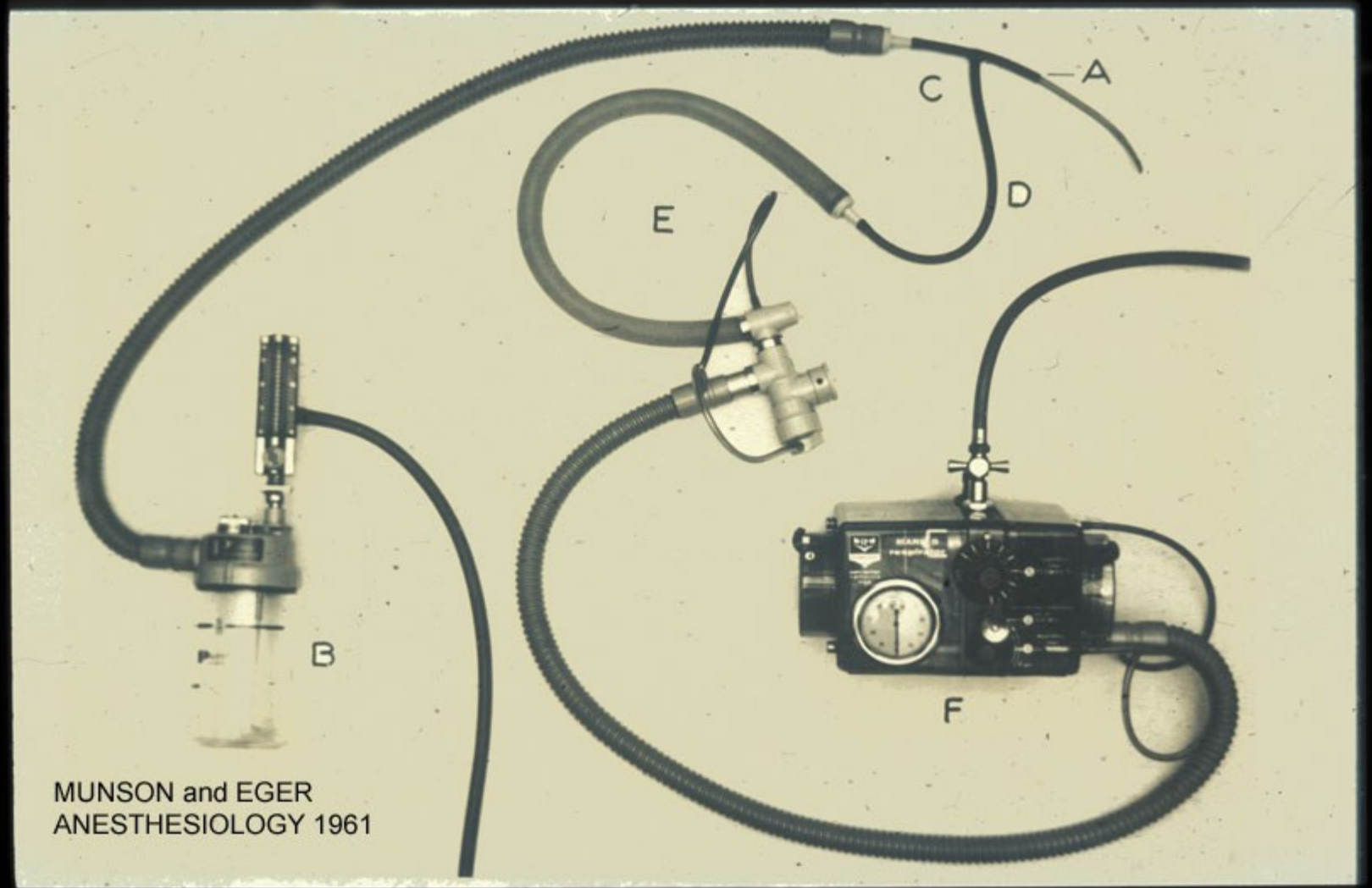
(Google)

continuous positive airway pressure (CPAP) is a gentle ventilation system that revolutionized the treatment of premature infants with respiratory failure developed by Dr. George Gregory at the University of California, San Francisco. Before CPAP, the mortality rate for neonates with respiratory distress syndrome was over 50%.

1971



THE BABYBIRD VENTILATOR
KIRBY, et al, 1971



MUNSON and EGER
ANESTHESIOLOGY 1961

CMV + Optimal PEEP

Q_S/Q_T	50% to 32%
Optimal PEEP	13.2 cmH_2O
Survival	25%

n=12

Downs, et al. Anesth Analg 52:210-214, 1973.

Phase IV
(1973)

Partial ventilatory support (not PSV) with CPAP for patients with respiratory failure.

Intermittent Mandatory Ventilation (IMV)

IMV vs IMC

Thomas L. Petty, M.D., FCCP Denver

Chest 67:6, 830-31, 1975

”Intermittent Mandatory Cerebration ***(IMC)*** is therefore, the preferred method of discontinuing mechanical ventilation. Even better, continuous mandatory contemplation ***(CMC)*** must emerge as the preferred method of weaning used in all forms of respiratory care.”,

Thomas L. Petty, M.D., FCCP

Chest 67:6, 830-31, 1975

COGNITIVE DISSONANCE

A phenomenon whereby we have a natural drive for consistency. Our belief system must be consistent with itself, and it must be consistent with our actions. That consistency doesn't always happen, and distress can arise as a result.

-LEO FESTINGER

NEOPHOBIA

A maladaptive coping mechanism.

When confronted with new experiences, the fear response exceeds the scope of any realistic threat.

CENOPHOBIA

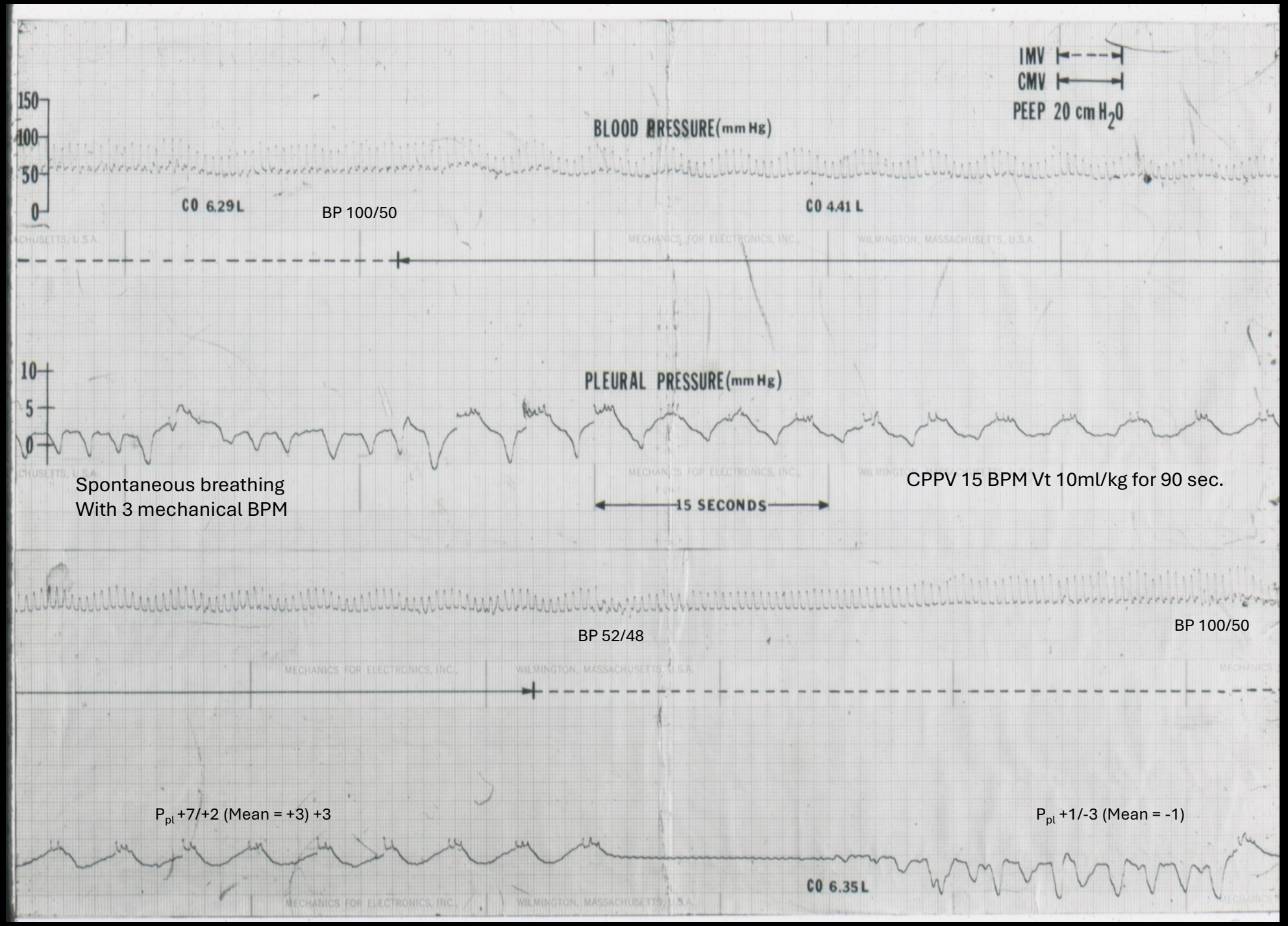
A subset of neophobia, it halts progress and can make it difficult for people to accept new ideas and change. While it is smart not to accept every idea at face value, new ways of thinking about a situation are critical to success, innovation, and effective problem-solving.

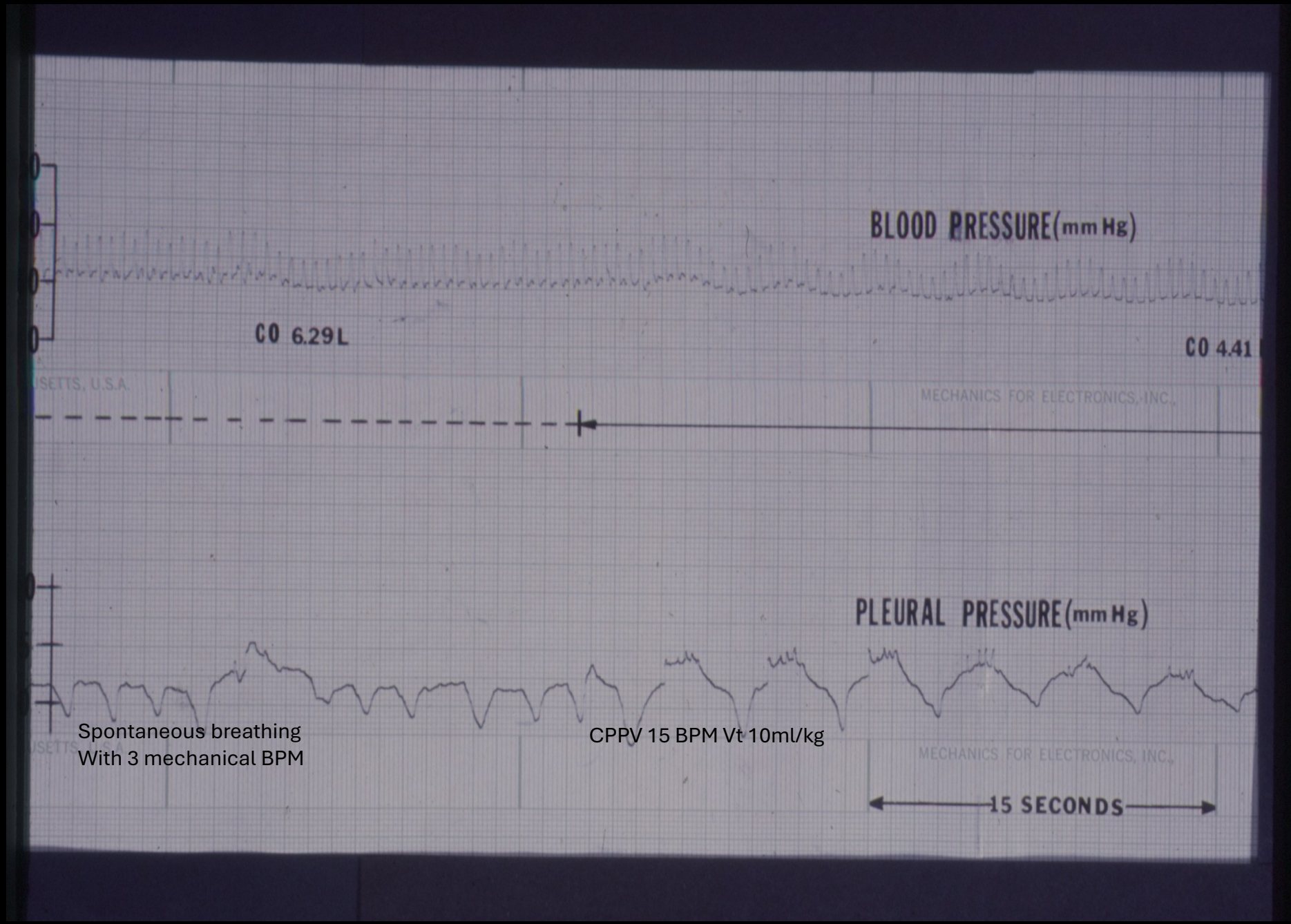
Spontaneous vs Controlled Ventilation

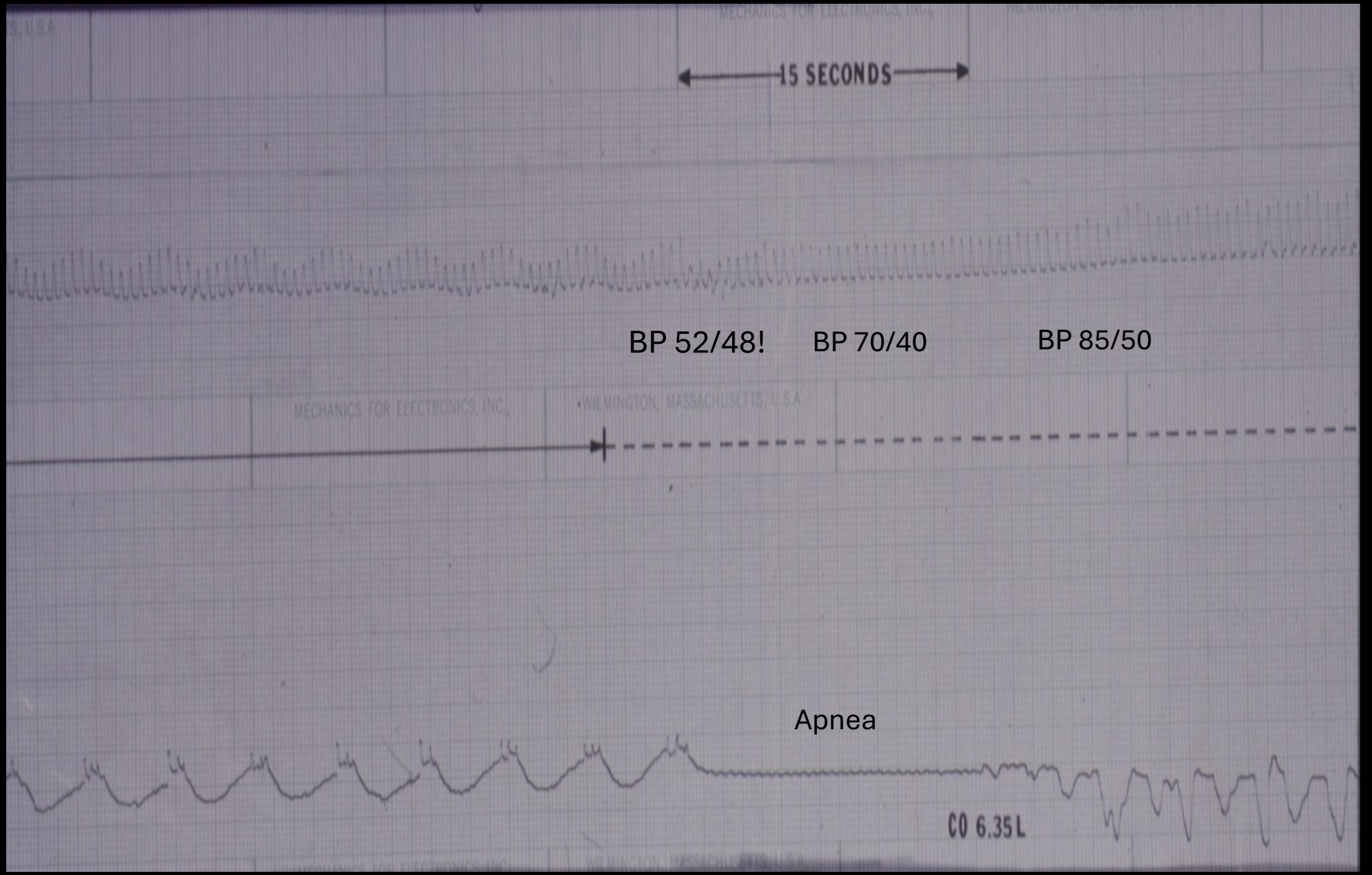
- *V_A/Q*
- *Cardiac Output*
- *Work of Breathing*
- *Outcome*

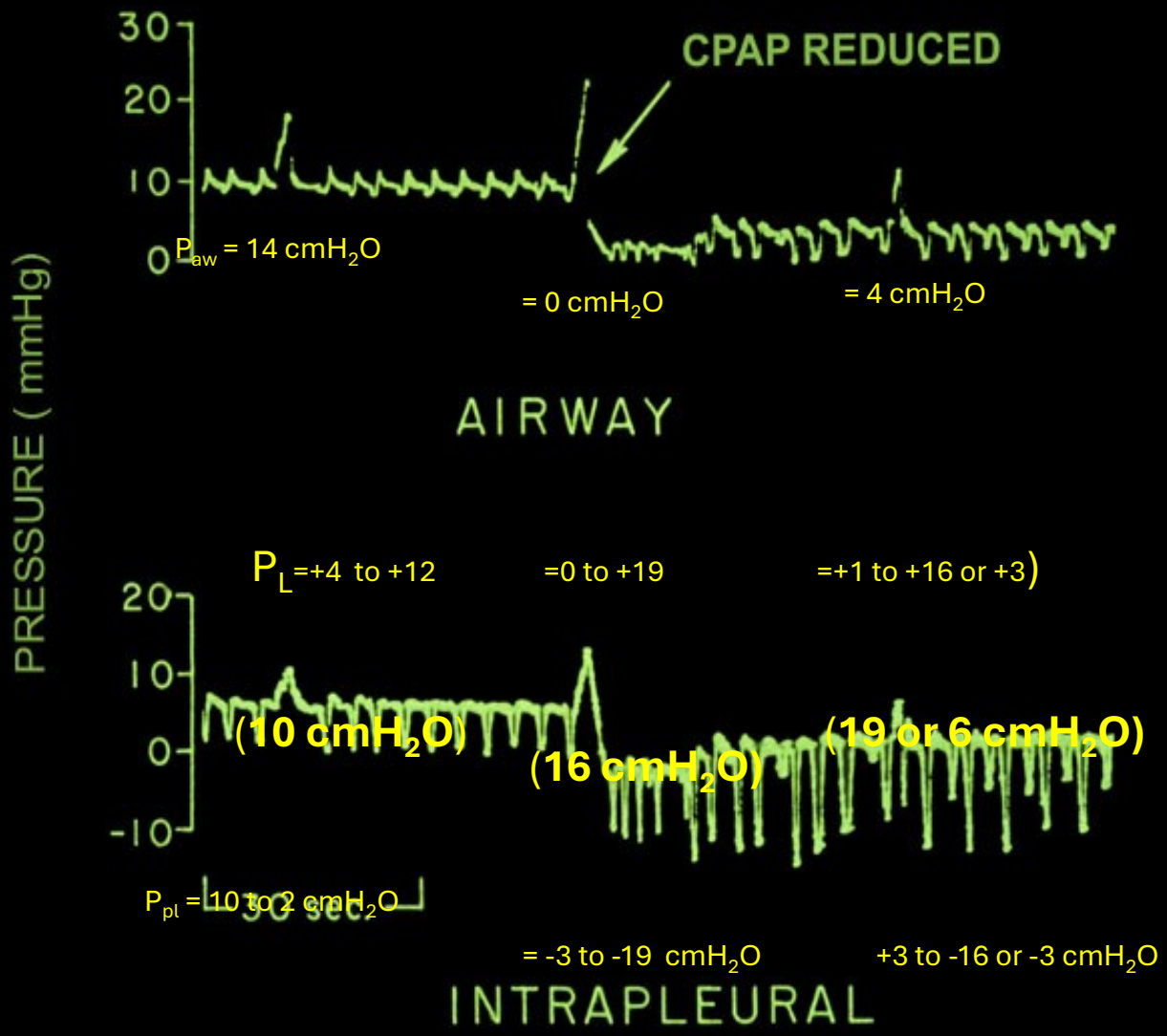
In the patient with respiratory failure, spontaneous respiration permits:

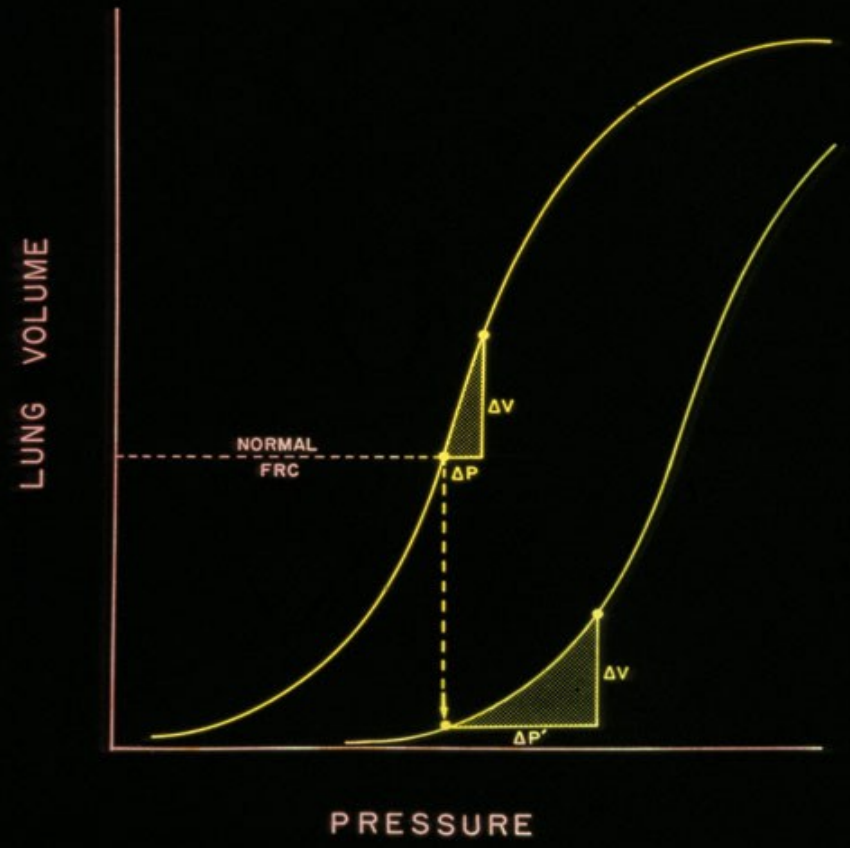
- *A higher level of CPAP*
- *Less positive pressure ventilation*
- *Lower inspired oxygen*
- *Less fluid resuscitation*
- *Greater cardiac output and oxygen delivery*
- *Easier, more rapid weaning*

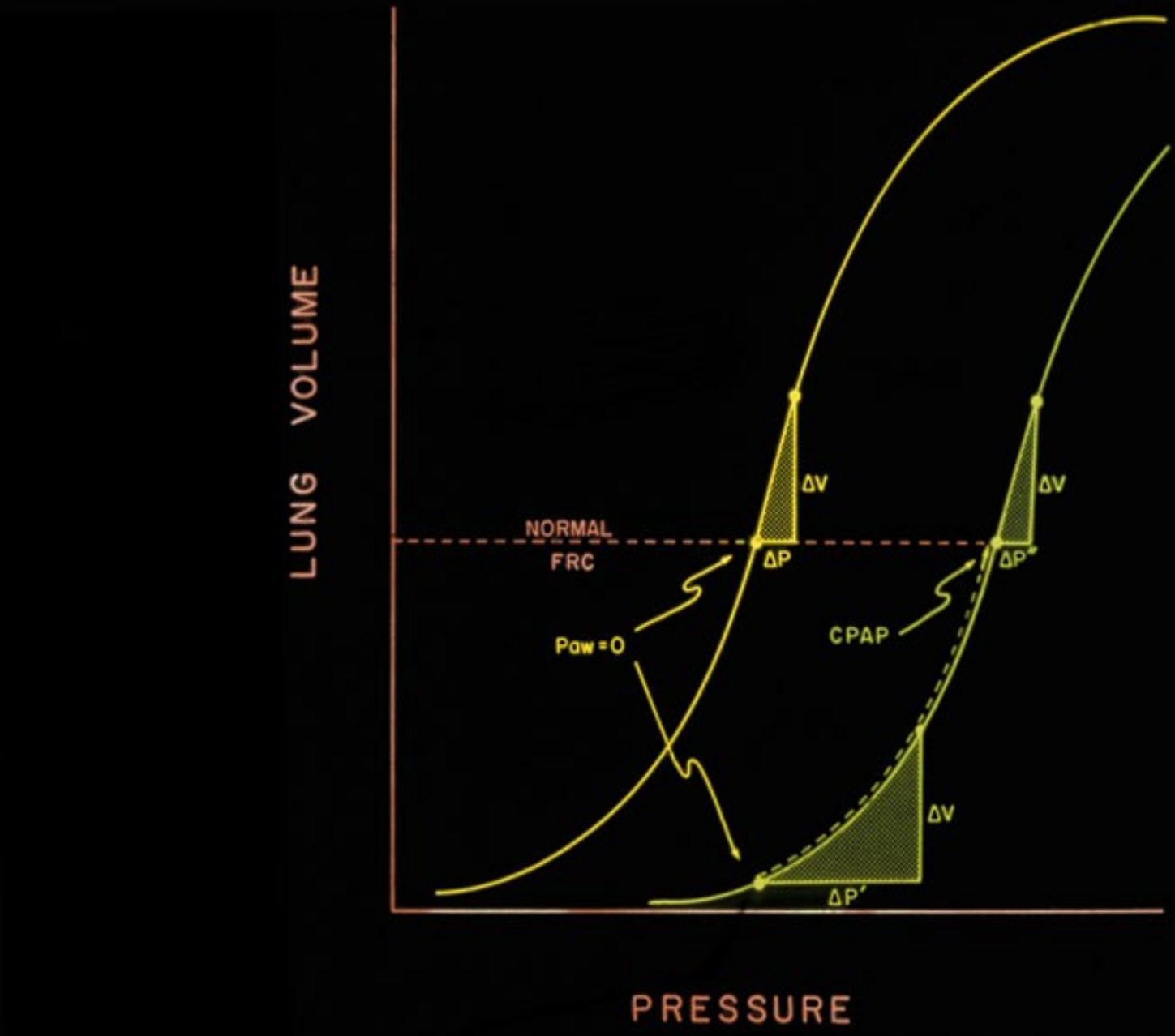

IMV
CMV
PEEP 20 cm H_2O
150
100
50
0
BLOOD PRESSURE(mm Hg)
CO 6.29L
BP 100/50
CO 4.41 L
10
5
0
PLEURAL PRESSURE(mm Hg)
Spontaneous breathing
With 3 mechanical BPM
15 SECONDS
CPPV 15 BPM Vt 10ml/kg for 90 sec.
BP 52/48
BP 100/50
P_{pl} +7/+2 (Mean = +3) +3
P_{pl} +1/-3 (Mean = -1)
CO 6.35L


BLOOD PRESSURE(mm Hg)
CO 6.29L
CO 4.41
MECHANICS FOR ELECTRONICS, INC.
PLEURAL PRESSURE(mm Hg)
Spontaneous breathing
With 3 mechanical BPM
CPPV 15 BPM Vt 10ml/kg
MECHANICS FOR ELECTRONICS, INC.
15 SECONDS


15 SECONDS
BP 52/48!
BP 70/40
BP 85/50
Apnea
CO 6.35L


30
20
10
0
CPAP REDUCED
P_{aw} = 14 cmH_2O
= 0 cmH_2O
= 4 cmH_2O
AIRWAY
PRESSURE (mmHg)
P_L=+4 to +12
=0 to +19
=+1 to +16 or +3)
20
10
0
-10
(10 cmH_2O)
(16 cmH_2O)
(19 or 6 cmH_2O)
P_{pl} = 10 to 2 cmH_2O
30 sec
= -3 to -19 cmH_2O
+3 to -16 or -3 cmH_2O
INTRAPLEURAL


LUNG VOLUME
NORMAL
FRC
ΔV
ΔP
ΔV
ΔP'
PRESSURE


LUNG VOLUME
NORMAL
FRC
ΔV
ΔP
ΔV
ΔP'
Paw=O
CPAP
ΔV
ΔP'
PRESSURE

IMV with CPAP

- *Cardiac Output*
- *$\dot{V}_A/\dot{Q}$*
  - *Shunt*
  - *Dead Space*
- *Ventilator Time*
- *Survival*

Total Patients	*54*
Age (years)	*38±8*
Initial Q_S/Q_T (%)	*35±6*
Initial $PaO_2^{1.0}$ (torr)	*85±8*

Douglas, Downs, et al. Chest 71:18-23, 1977

Total Patients	*54*
Age (years)	*38±8*
Initial Q_s/Q_t (%)	*35±6*
Initial $PaO_2^{1.0}$(mmHg)	*85±8*

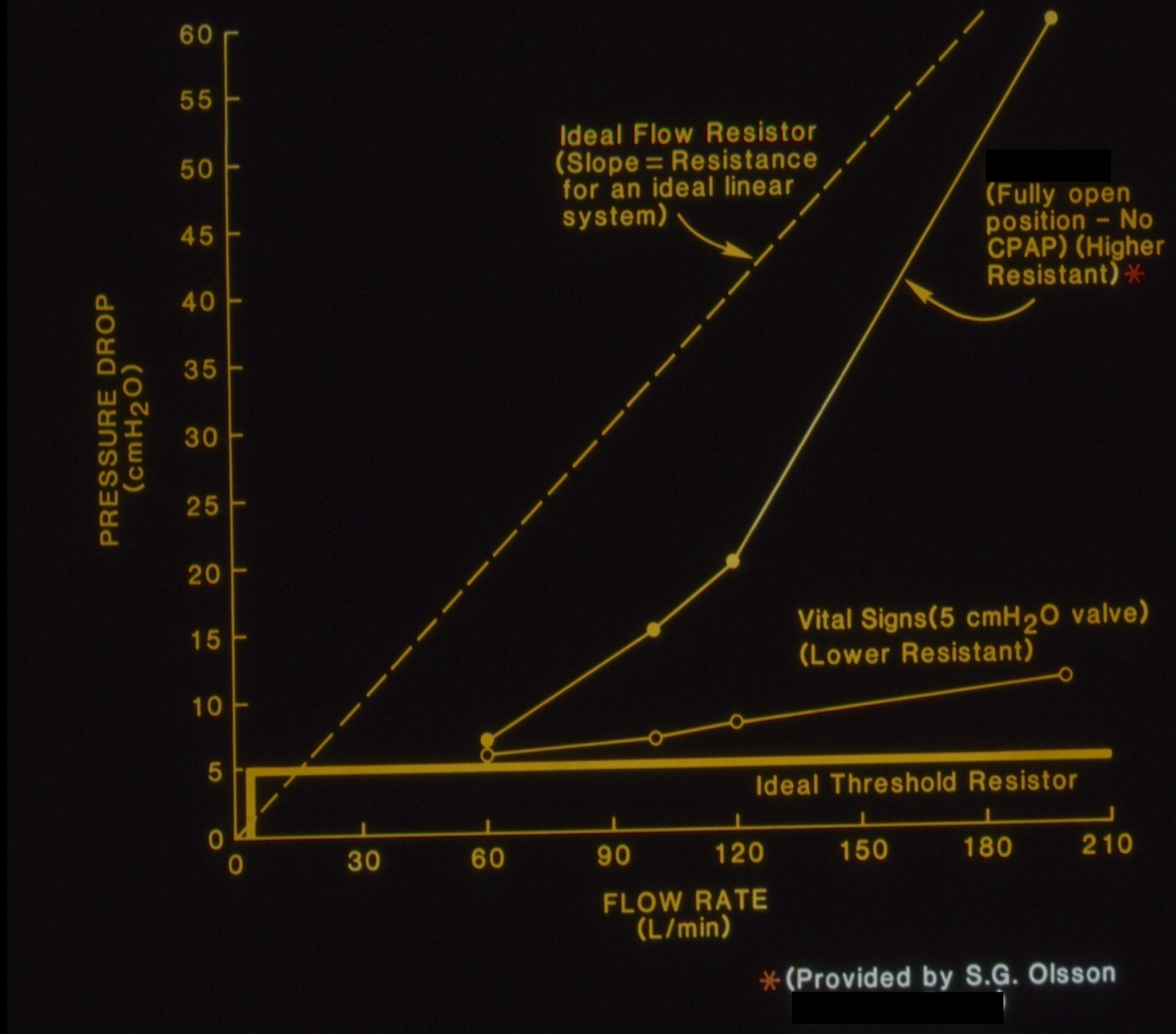
Douglas, Downs, et al. Chest 71:18-23, 1977

Spontaneous vs Controlled Ventilation

- *V_A/Q*
- *Cardiac Output*
- *Work of Breathing*
- *Outcome*

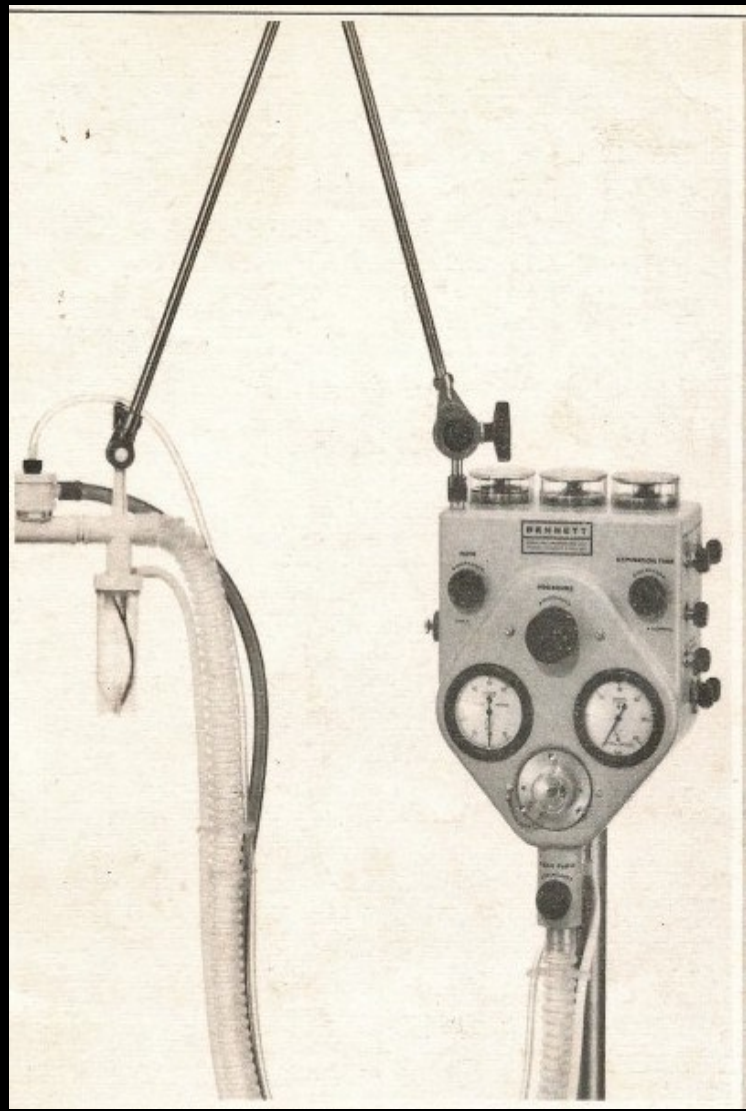
“The only thing new is history we don’t remember.”

Harry S. Truman



*(Provided by S.G. Olsson

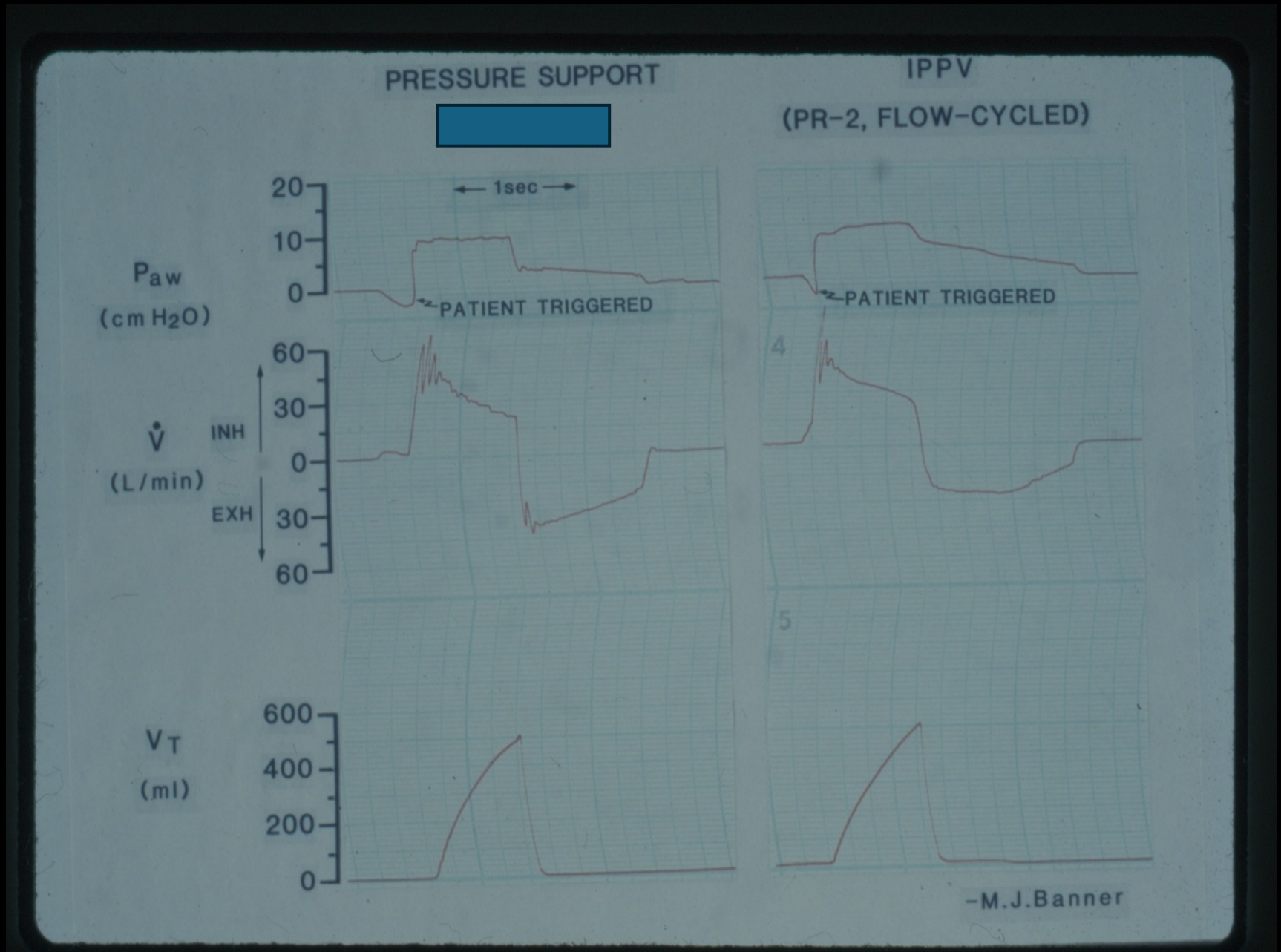
[redacted]



OPERATING INSTRUCTIONS

[redacted] MODEL PR-2

RESPIRATION UNIT


PRESSURE SUPPORT
IPPV
(PR-2, FLOW-CYCLED)
1sec
20
10
0
Paw
(cm H2O)
PATIENT TRIGGERED
PATIENT TRIGGERED
60
30
0
30
60
V̇
INH
EXH
(L/min)
4
5
600
400
200
0
VT
(ml)
-M.J.Banner

All truth passes through three stages
First, it is ridiculed
Second, it is violently opposed
Third, it is accepted as being self-evident

Arthur Schopenhauer (1788 - 1860)

Phase V
(1990's)

Protective ventilatory strategy for patients with lung injury.