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A Manual for House Staff on Pulmonary Service at PCOM

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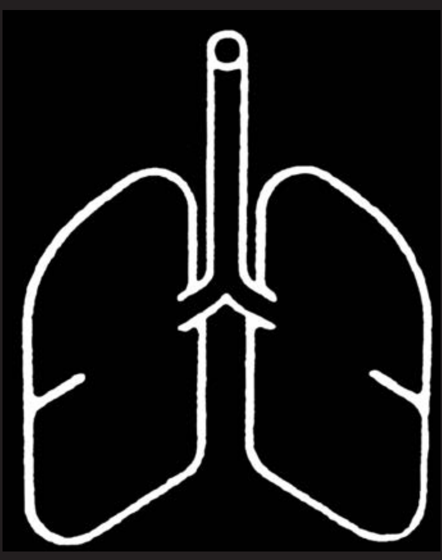

Pulmonary
Division of
Internal Medicine

4th Edition

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ARTERIAL BLOOD GASES

$$\begin{aligned} ph &= 7.38 \text{ to } 7.42 \\ pCO_2 &= 40 \text{ mmHg} \\ pO_2 &= 70 \text{ to } 100 \text{ mmHg} \\ HCO_3 &= 23 \text{ to } 25 \text{ meq./liters} \end{aligned}$$

ph

1. Definition: A measure of acidity in relation to body gases.
2. Determined by the Henderson-Hasslebach relationship.

$$\begin{aligned} ph + HCO_3 &= \text{kidney} \\ pCO_2 &= \text{lung} \end{aligned}$$

pCO_2

1. Definition: Pressure exerted by CO_2
   (not a direct measurement of amount)
2. Determined by and is equal to the Alveolar Ventilation Equation:

$$A = (T.V. - D.S.)\ R$$

Where A = alveolar ventilation or that volume of air reaching the alveoli
T.V. = tidal volume
D.S. = dead space, the volume of air in the tracheobronchial tree which is not available for gas exchange
R. = rate

USEFUL TERMS REGARDING THE pCO_2:

1. Hyperventilation: pCO2 $\downarrow$ 35 mmHg
2. Hypoventilation: pCO2 $\uparrow$ 45 mmHg

These are blood gas diagnoses (lab), do not confuse with “TACHYPNEA” which means an increase in respiratory rate and is a physical diagnosis.

BICARBONATE ION HCO_3

1. Definition: Direct measurement of base solute in a solvent (blood) . . . . a measurement of amount

2. Control of this ion is by the kidney which excretes or retains it

p_aO_2 (determined by Blood Gas Analysis)

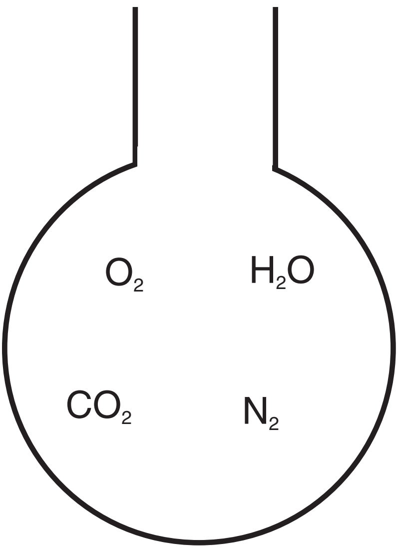
1. Definition: The pressure exerted by O2 in the blood, is not a direct measurement of amount
(Small "a" means arterial)

pAO2 (Calculated by the physician)

1. Definition: The pressure exerted by O_2 in the alveolus, is not a direct measurement of amount

A-a Gradient: The difference between the O2 pressure in the alveolus and the capillary

CALCULATION OF THE A-a GRADIENT



$$pAO_2 = pIO2 - \frac{pCO_2}{.8}$$

$$pIO_2 = (pB - 47)\ FiO_2$$

pIO_2 = pressure of inspired O_2

pB = barometric pressure

47 = pressure of water vapor

fiO_2 = the fraction of inspired O_2 (express as decimal)

CALCULATION OF THE A-a GRADIENT

What is the A-a Gradient
if the fiO_2 = .21 (air) - p_aCO2 = 40 and the P_aO_2 = 60?

$$pAO_2 = pIO_2 - \frac{pCO_2}{.8}$$

$$= (760 - 47)\ .21 - \frac{40}{.8}$$

$$= 150 - 50$$

$$pAO_2 = 100$$

$$A\text{-}a = 100 - 60$$

$$= 40$$

O2 in General

Carried in the blood in two forms:
dissolved and in combination with Hb.

1. Dissolved: Obey Henry's Law – the amount dissolved is proportional to the partial pressure.
   There is .003 ml O_2/100 ml blood for each mmHg p_aO_2 so that arterial blood with a p_aO_2 of 100 mmHg contains .3 ml O_2/100 ml (or .3 vols%).
2. In combination with Hb:
   1 gm Hb can combine with 1.39 ml O_2, so
   15 gm Hb can combine with 20.8 ml O_2/100 ml blood

O_2 Terms:

1. O_2 Capacity: max amount of O_2 that can combine with Hb at full saturation
2. % Saturation: equals $\frac{O_2 \text{ combined with Hb}}{O_2 \text{ Capacity}} \times 100$
3. O_2 Content: O_2 combined with Hb plus O_2 dissolved in the plasma

CLINICAL APPLICATION:

Anemic patient with 7.5 gm Hb but a P_aO_2 of 100 mmHg

O_2 combined	=	7.5 X 1.39	=	10.4
O_2 dissolved	=	100 X .003	=	.3
O_2 content	=			10.7

SHUNT

The amount of blood expressed as a % coming from the right heart through the lungs which is unoxygenated in returning to the left heart.

$$\frac{\dot{O}s}{\dot{Q}t} = \frac{Cc'O_2 - CaO_2}{Cc' - CvO_2}$$

TOO CUMBERSOME?? – Use the chart on the next page.

CLINICAL USE OF THE SHUNT CHART

1. Now able to reduce fiO_2 to a precalculated PaO_2. This helps avoid oxygen toxicity at high fiO_2.

2. Locate fiO_2 (fraction of Inspired Oxygen or Percentage of O_2), then locate PaO_2. Where the two parameters intersect is the percentage shunt.

3. As long as there are no major hemodynamic changes such as cardiopulmonary arrest, hemorrhagic shock, etc., the shunt will hold.
4. Please note, this is a calculated value and not a true value but can be utilized quite well in clinical practice.
5. EXAMPLE:
   Patient is on a ventilator and the fiO_2 is 1.00 (100%). The PaO_2 is 400. the calculated shunt is 17%. Now, suppose we want a PaO_2 of 100. All you do is locate the PaO_2 of 100 and read horizontally until you get the shunt of 17%, then read vertically to fiO_2 of 0.39. So, in effect, you have decreased the fiO_2 from 1.0 to 0.39.

PaO_2	FiO_2 PiO_2 PAO_2	.35 250 200	.39 275 225	.42 300 250	.45 325 275	.49 350 300	.53 375 325	.56 400 350	.60 420 375	.63 450 400	.66 475 425	.70 500 450	.74 525 475	.77 550 500	.81 575 525	84 600 550	.88 625 575	.91 650 600	.95 675 625	.98 700 650	1.00 725 675
30		65	65	65	65	66	66	66	66	66	67	67	67	67	68	68	68	68	68	69	69
40		53	53	54	54	55	55	55	56	56	57	57	57	58	58	58	59	59	59	60	60
50		41	42	43	43	44	45	45	46	46	47	47	48	48	49	49	50	50	51	51	52
60		34	34	35	36	37	38	38	39	40	40	41	42	42	43	44	44	45	45	46	47
70		26	27	28	29	30	31	32	33	34	35	35	36	37	38	39	39	50	41	41	42
80		23	24	26	27	28	29	30	31	32	32	33	34	35	36	37	37	38	39	40	40
90		19	20	21	22	24	25	25	27	28	29	30	31	32	33	33	34	35	36	37	37
100		15	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	35
120		10	11	13	14	15	17	18	19	21	22	23	24	25	26	27	28	29	30	31	32
140		10	11	13	14	15	17	18	19	21	22	23	24	25	26	27	28	29	30	31	32
160		7	9	11	12	14	15	16	18	19	20	21	22	24	25	26	27	28	29	30	31
180		5	7	9	10	12	13	15	16	17	19	20	21	22	23	25	26	27	28	29	30
200		5	7	9	10	12	13	15	16	18	19	20	21	22	23	26	26	27	28	29	30
225				2	4	5	7	9	10	12	13	15	16	18	19	20	21	22	24	25	26
250				0	1	3	5	7	8	10	11	13	14	16	17	18	20	21	22	23	24
275					0	1	3	4	6	8	9	11	13	14	15	17	18	19	21	22	23
300						1	3	4	6	8	9	11	13	14	15	17	18	19	21	22	23
325								2	4	6	7	9	11	12	14	15	16	18	19	20	21
350									2	3	5	7	9	10	12	13	15	16	17	19	20
375										1	3	5	6	8	10	11	13	14	16	17	18
400												2	4	6	8	9	11	12	14	15	17

TABLE OF SHUNTS - Hb. = 15; A.V. O_2 = 4; pH = 7.5

ACID BASE DIAGNOSIS

DEFINITIONS:

	pH	PCO_2	HCO_2
Respiratory Acidemia	↓	↑	
Respiratory Alkalemia	↑	↓	
Metabolic Acidemia	↓		↓
Metabolic Alkalemia	↑		↑

	pH	PCO_2	HCO_2
Respiratory Acidosis		↑	
Respiratory Alkalosis		↓	
Metabolic Acidosis			↓
Metabolic Alkalosis			↑

ACID BASE EFFECT ON ELECTROLYTES

	pH	H^+	Na^+	K^+		$C1^-$	HCO_3^-
Alkalosis	↑	↓	↑	↓		↓	↑
Acidosis	↓	↑	↓	↑		↑	↓

Key A1 K+ loss is

Compensatory mechanisms are opposite so alkalosis corrects by acidosis and vice versa.

Na+ exchanges for H+ or K+ in the kidney

pCO_2 regulated by alveolar ventilation of the lung

COMMON CAUSES OF RESPIRATORY ACIDOSIS

$PCO_2 \uparrow$

1. COPD – asthma, bronchitis, emphysema
2. Depression of the respiratory center – anesthesia, drugs
3. Traumatic – flair chest
4. Polio

COMMON CAUSES OF METABOLIC ALKALOSIS

$HCO_3 \uparrow$

1. Vomiting
2. N G Suction
3. Drugs (diuretics, steroids, antacids)
4. Hypokalemia Al K+ loss

COMMON CAUSES OF RESPIRATORY ALKALOSIS

$PCO_2 \downarrow$

1. Emotion or pain
2. Pneumonia
3. CHF
4. Pulmonary Embolism

COMMON CAUSES OF METABOLIC ACIDOSIS

$HCO_3 \downarrow$

1. Diabetes
2. Renal Failure
3. Lactic Acidosis
4. Diarrhea

CORRECTION OF METABOLIC ACIDEMIA

pH ↓ HCO_3 ↓

Meq. of $NaHCO_3$ = 0.2 X kg (body weight) X Base

EXAMPLE:

pH = 7.02

HCO_3 = 10

Question: Correct the pH to calculated 7.4. Patient weighs 70 kg.

pCO_2 = 40

DETERMINATION OF THE B FROM SIGGARD-ANDERSON ALIGNMENT NOMOGRAM

1. Draw a straight line between the above blood gas parameters.
2. Draw a straight line from the pCO_2 through the pH you want the patient to have – say for example, 7.4. The line will intersect an HCO_3 level of 23.8.
3. You have 10 meq./liters of HCO_3 on board for a pH of 7.02 and you want to increase the level of HCO_3 to 23.8 for planned pH of 7.4.

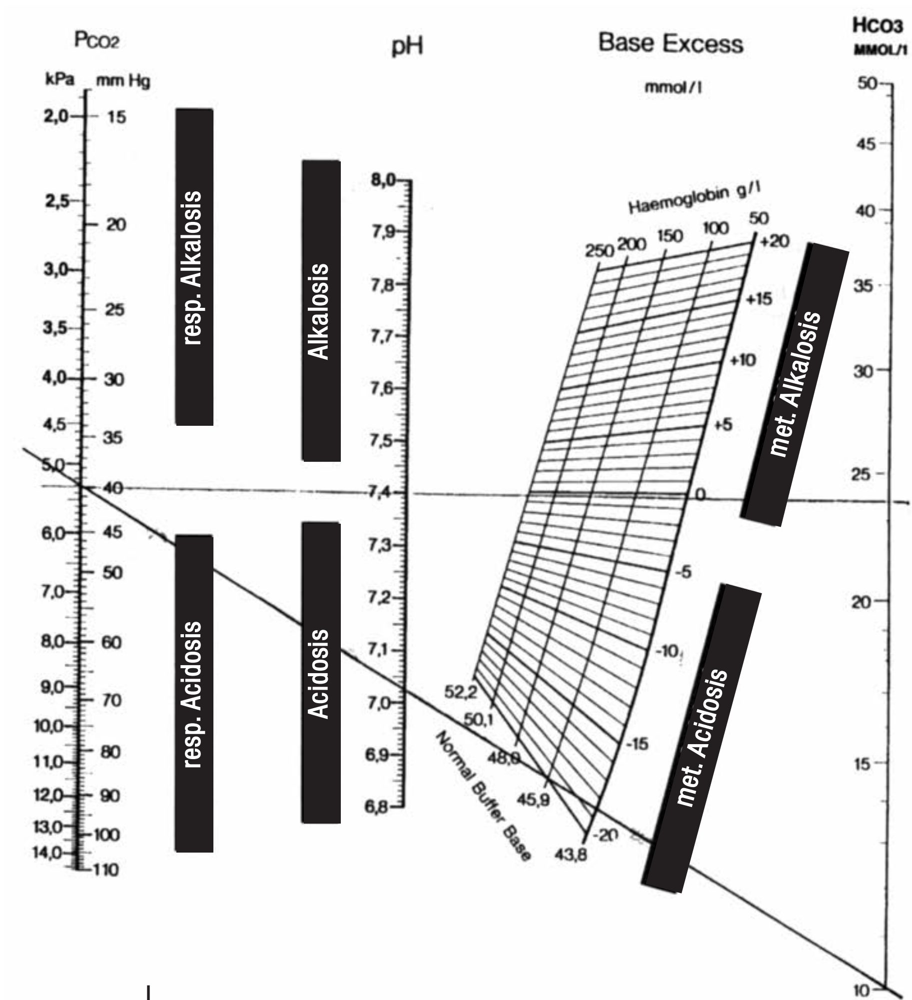
So:

HCO_3 desired	23.8
HCO_3 on board	10
B	13.8

And: Meq. of $NaHCO_3$ = 0.2 X 70 X 13.8

= 193 meq. needed to correct to a ph of 7.4.

CORRECTION OF METABOLIC ACIDEMIA



pH	↓	7.02
HCO_3	↓	10
pCO_2 (N)		40

	$HCO_{3\ desired}$	23.8
(MINUS) —	$HCO_{3\ measured}$	10
(EQUALS)	$\Delta\beta$	13.8

CORRECTION OF METABOLIC ALKALEMIA

pH $\uparrow$ HCO_3 $\uparrow$

Meq. of Arginine X HCl = 0.2 X kg (body weight) X Base

Example:

pH = 7.67

HCO_3 = 45

pCO_2 = 40

Question: Correct the pH to calculated 7.4.
Patient weighs 70 kg.

Determination of the Base from the
Siggard-Anderson Alignment Nomogram:

1. Draw a straight line between the above blood gas parameters.
2. Draw a straight line from the pCO_2 through the pH you want the patient to have – for example, 7.4. The line will intersect an HCO_3 level of 23.8.
3. You have 45 meq./liters on board for a pH of 7.67 and you want to decrease the level of HCO_3 to 23.8 for a planned pH of 7.4.

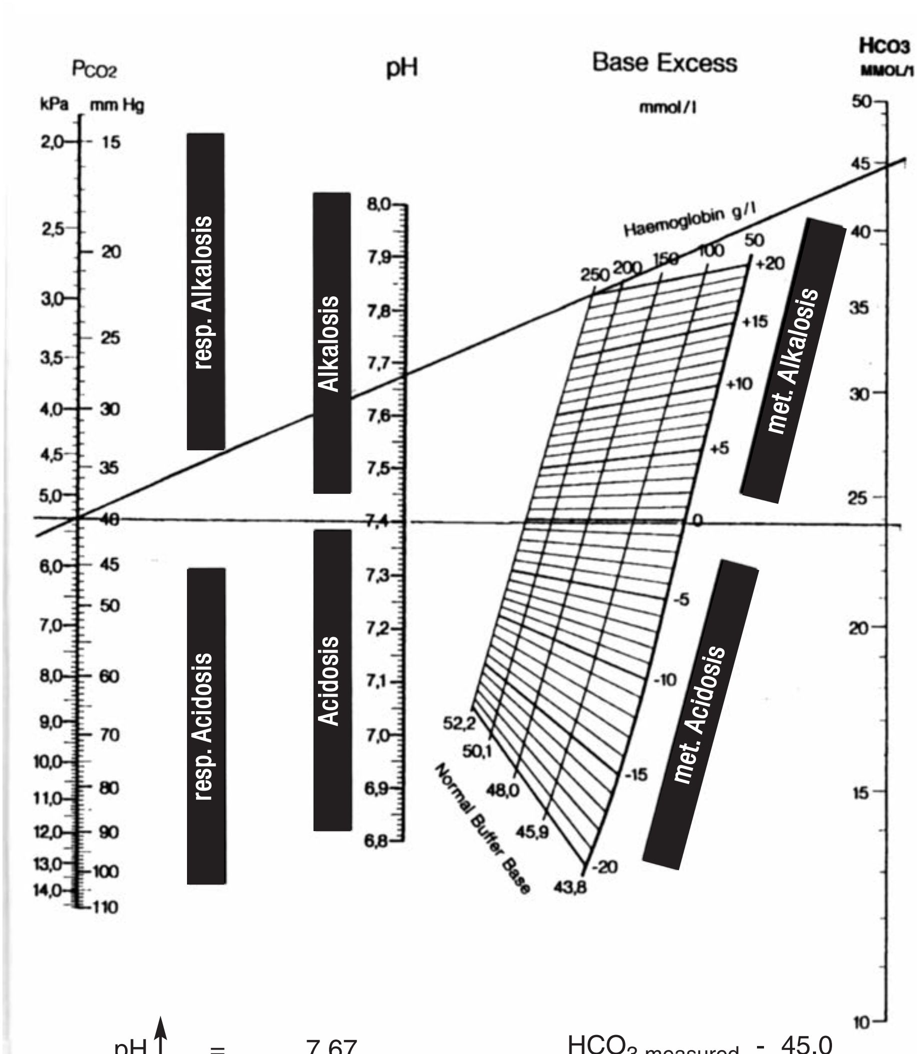
So:

HCO_3 on board	45.0
HCO_3 desired	<u>23.8</u>
Base	21.2

And: Meq. of Arginine x HCl = 0.2 X 70 X 21.2

= 296.8 meq. of Arginine X HCl needed to correct to a ph of 7.4.

METABOLIC ALKALEMIA



pH ↑	=	7.67	HCO_3 measured	- 45.0
pCO_2	=	40	(MINUS) — HCO_3 measured	- 23.8
HCO_3 ↑	=	45	(EQUALS) HCO_3	$\Delta\beta$ 21.2

VENTILATORS

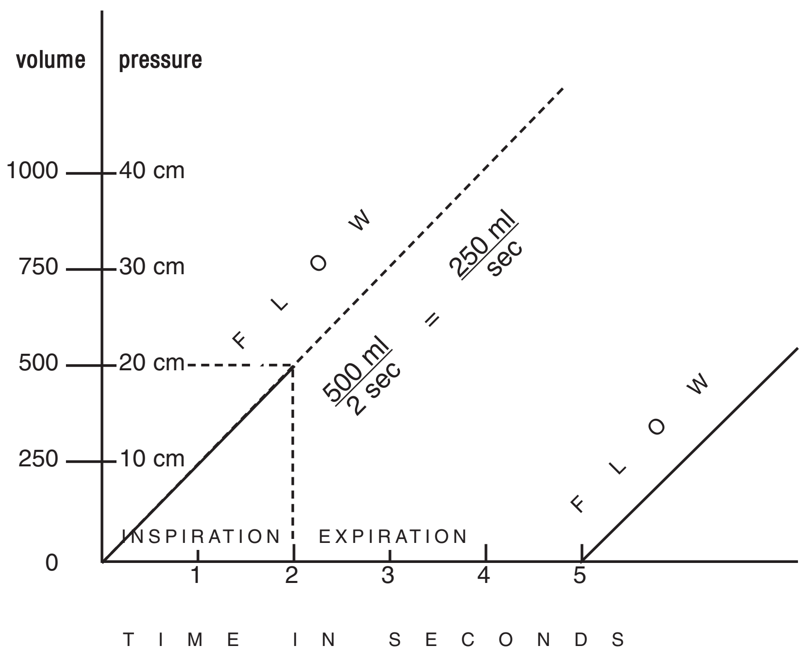
A. CO_2 Control

1. pCO2 is controlled by the alveolar gas equation

$$pCO_2 \approx A = (TV - DS)\ R$$

   a. Four factors which influence A
      1. Volume (TV)
      2. Rate (R)
      3. Pressure
      4. Flow

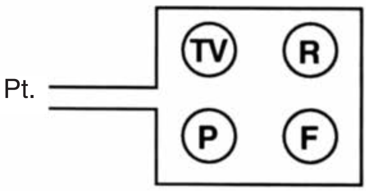
2. Ideal Ventilator



3. Difference between Volume and Pressure Ventilator

	TV	Rate	Pressure	Flow
Pressue Vent.	Varies	Set	Set	Set
Vol. Vent.	Set	Set	Varies	Set

4. Modes of Ventilation on Volume Ventilator
   CMV - patient gets same dialed in volume whether he breathes
   or not



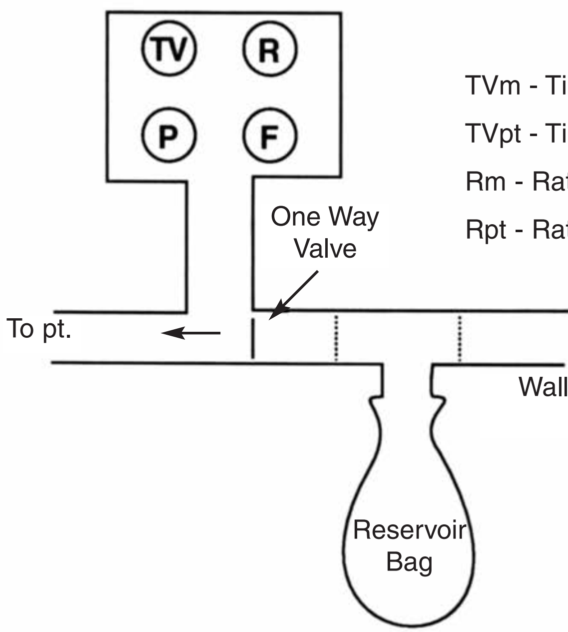
$CMV = (TVm \times RVm) + (TVm \times Rpt)$

$SIMV = (TVm \times Rm) + (TVpt \times Rpt)$

SIMV - Patient breathes on his own and ventilator signs
Patient at frequent intervals
(A Bionic Nurse) S stands for synchronous -
ventilator will not cycle if patient has not exhaled.

USE: Hard Weaning problems
Patient with severe emphysema who needs to be signed so as to lower the pCO_2.

Remember $pCO_2 = (TV - DS) \quad R$



TVm - Tidal Volume Machine

TVpt - Tidal Volume Patient

Rm - Rate on Machine

Rpt - Rate of Patient

5. Correction of Respiratory Acidosis and Alkalosis while on the Ventilator

The CO_2 Adjust Equation

Since A Ventilation produces a certain CO_2 as determined by blood gas analysis then it is possible to calculate what new A is necessary to produce a new CO_2.

$$pCO_2 \times TV_1 \times R_1 = pCO_2 \times TV_2 \times R_2$$

Example: $pCO_{2_1} = 50$ — Need $pCO_{2_2} = 40$

$TV_1 = 500$ — $TV_2 = ?$

$R_1 = 10$ — $R_2 = ?$

$$50 \times 500 \times 10 = 40 \times TV_2 \times R_2$$

$$6250 = TV_2 \times R_2$$

$$625 \times 10 = TV_2 \times R_2$$

$$520 \times 12 = TV_2 \times R_2$$

$$415 \times 15 = TV_2 \times R_2$$

Plug in TV and solve for R or plug in R and solve for TV

NOTE: R_1 is the total rate of machine set plus patient triggering rate or $R_1 = (Rm + Rpt)$

This formula is very accurate in apenic patients.

Setting Up the Volume Ventilator

TV - 10 to 15 ml/kg of body weight

R - normal rate 10 to 20

P - This is an alarm (cannot set pressure on volume ventilator)

A. Turn up pressure alarm to 100 cm

B. Read pressure patient needs for desired volume from gauge or digital display, add 10 and dial down pressure alarm
i.e. meter needs 30 cm - so add 10 cm and set pressure alarm at 40 cm

FLOW - Depends on Ventilator - usually around 40 liters/min

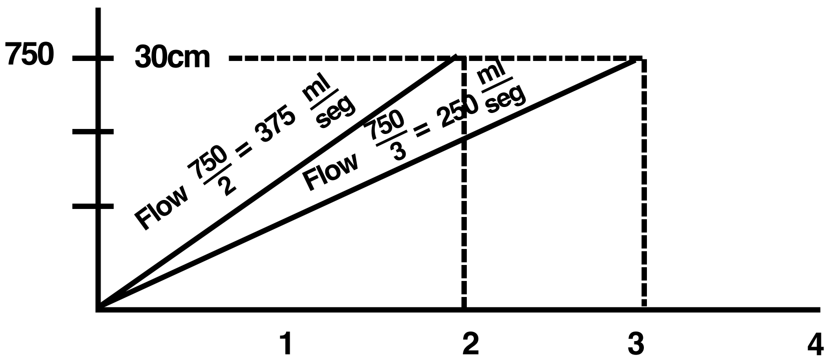
NOTE: In all PCOM books, flow is expressed in ml/sec - less confusing better understood when looking at illustrative Volume, Pressure, Flow, Rate, Graphs

FLOW (continued)

- Check I:E (Inspiratory/Expiratory light) - if on, patient needs more flow

- If you desire a low flow ventilation for better air dispersion, turn down flow until the red light or indicator comes on and then add 10 liters/min

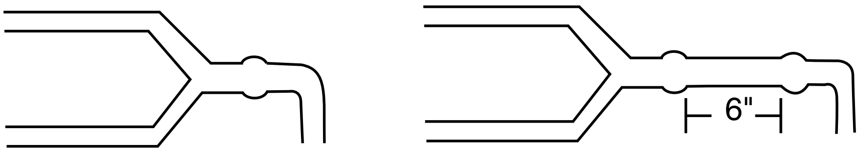
7. Hyperventilation on Ventilator - patient with a low CO_2 and high respiratory rate
   A. Low Flow Trick - you cannot take a deep breath while you are inspiring because you are all ready doing it.



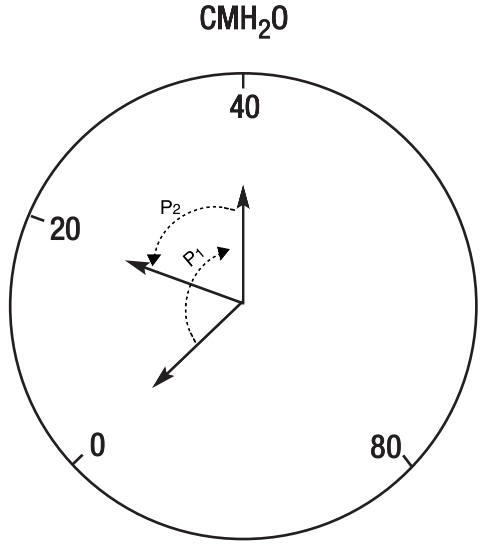
   B. Pavulon - paralyzes respiratory muscles

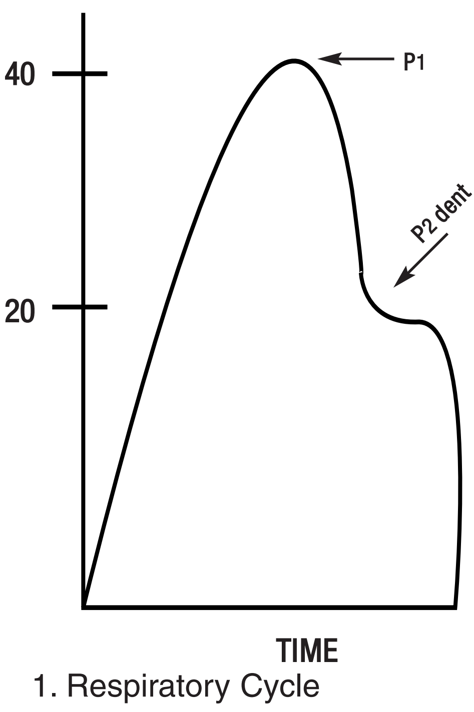
   C. Add Dead Space - patient rebreathes his own expired air

Dead Space Tube
Start at 6”



COMPLIANCE MEASUREMENT ON VENTILATOR





1. Respiratory Cycle

$$C = \frac{\text{Tidal Volume}}{\text{Plateau Pressure - PEEP}}$$

$$C = \frac{V}{P_2 - PEEP}$$

Example:

$$C = \frac{800}{20 - 0}$$

$$C = 40$$

Normal 40 plus or minus 5

NB 1. Turn on expiratory resistance control

or

2. Obstruct the expiratory hose

3. Read the dial gauge or digital display for P_2

B. O_2 Control on Ventilator

1. Shunt Chart - see page 5

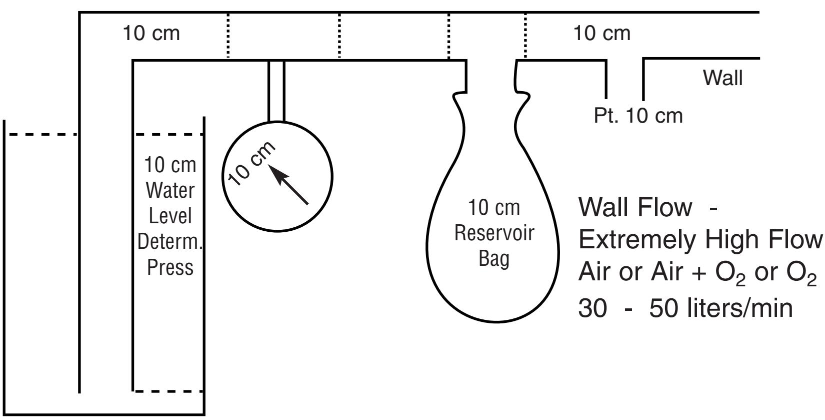
2. CPAP (continuous positive airwave pressure)
   To maintain positive pressure during inspiration and expiration.

   Patient must breathe on his own - he must be able to control his pCO_2

   USE: Oxygenation Problems Only

   EXAMPLE: P.E.

IPEEP Compliance =



3. PEEP (Positive and Expiratory Pressure)

   A. Oximetric Swan Ganz - measure SVO_2 at different levels of PEEP, Highest SVO_2 corresponds to best PEEP

B. Compliance Best PEEP

Best PEEP - PEEP at which compliance is closest to 40

Example:

$$\text{PEEP} \quad \text{Compliance} = \frac{\text{T.V.}}{\text{Plateau Pressure} - \text{PEEP}}$$

PEEP	Compliance			
0	$\frac{500}{20 - 0}$	=	25	
2	$\frac{500}{18 - 2}$	=	31	
4	$\frac{500}{16 - 2}$	=	40	"Best PEEP"
6	$\frac{500}{22 - 6}$	=	30	
8	$\frac{500}{26 - 8}$	=	27	

VD/VT RATIOS: -

During each breath a certain volume of air ventilates the dead space and the remainder the alveolar space where gas exchange occurs. The ratio of dead space ventilation to total ventilation (VD/VT) is a reflection of efficiency of ventilation. Normally, the VD/VT = .35 or less. When the dead space increases so there are abnormally large areas which are being ventilated but which are not exchanging gas, the VD/VT increases. VD/VT is calculated from the following equation:

$$\frac{VD}{VT} = \frac{PaCO_2 - PeCO_2}{PaCO_2}$$

$PaCO_2$ = **arterial carbon dioxide tension**

= **carbon dioxide tension in expired air**

Above VD/VT of .6 patient cannot be weaned off ventilator.

EXAMPLE:

What is the VD in a patient who has a tidal volume of 800, $PaCO_2$ of 50 and $PeCO_2$ of 30?

What is the VD/VT?

$$\frac{VD}{800} = \frac{50 - 30}{50}$$

$$VD = 320$$

$$\frac{VD}{VT} = \frac{320}{800} = .4$$

THE PULMONARY CONSULT

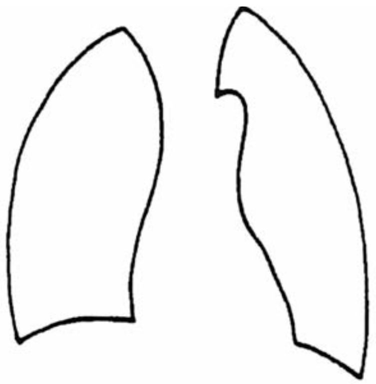


DIAGRAM OF CHEST FILM
Indicate findings

I. HISTORY OF CHIEF COMPLAINT
Includes six major symptoms

1. Cough and time cough occurs
2. Sputum
   a. amount
   b. color
   c. odor
   d. frothiness
3. Hemoptysis
4. Chest Pain
5. Dyspnea
6. Wheezing

II. PAST HISTORY
1. Tuberculosis – active disease, exposure, previous PPD results
2. Smoking – age when began, packs per day
3. Occupations
4. COPD, asthma, past hospitalization

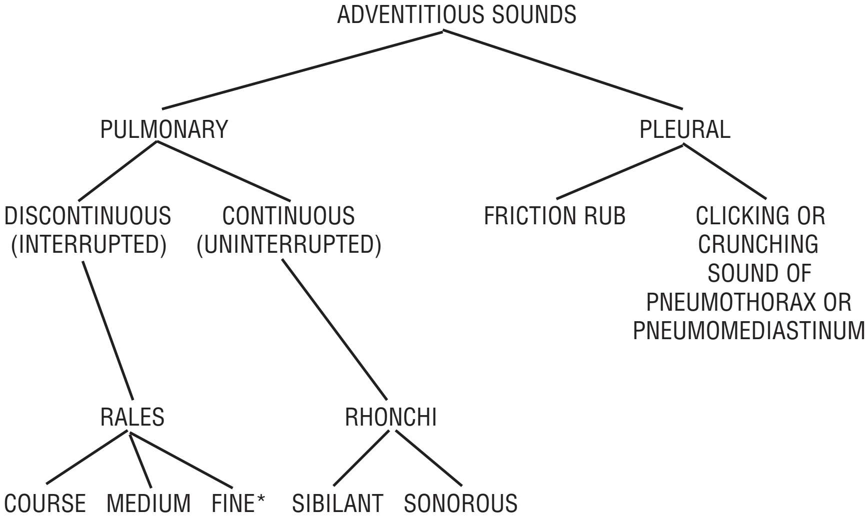
III. PHYSICAL
1. Heart
   a. rhythm
   b. cervical venous distension
2. Lungs
   a. see auscultation flow chart
   b. percussion
   c. tactile fremitus
   d. vocal fremitus
3. Extremities
   a. cyanosis
   b. clubbing
   c. edema
4. Thorax
   a. deformities
   b. spinal and lesion complex
   c. distended veins
   d. adenopathy

IV. LAB
1. Pulmonary function testing, arterial blood gases, other pertinent results

V. IMPRESSION

VI. RECOMMENDATIONS

AUSCULTATION



*Fine rales – crepitations
Sibilant rhonchi – high pitched and musical
Sonorous rhonchi – low pitched

WHO SHOULD RECEIVE INH

1. House contacts and newly developed cases

2. Patients with old tuberculosis but inadequately treated

3. Positive PPD with abnormal chest film

4. Positive PPD adolescents with or without normal chest films

5. PPD reactors who have diabetes, reticuloendothelial disease, silicosis, gastrectomy, or receiving steroids or other immunosuppressive therapy.

ATYPICAL MYCOBACTERIA

Runyan Group	Synonym	Rate of Growth	Pathogens	Disease	Non-pathogens	Antigen	Therapy
I	Photochromogen (Pigment in light)	3-4 weeks	M. kansasii M. marinum (balnei)	Pulmonary, adenitis Swimming pool granuloma		Y (Yellow)	75% INH responsive
II	Scotochromogen (Pigment in dark)	2-3 weeks	M. scrofulaceum	Adenitis	M. aquse M. flavescens	G (Gauss)	Surgery
III	Non-photochromogen	3-4 weeks	M. avium M. intracellulare (Battey) M. xenopei	Pulmonary, adenitis, miliary	M. gastri M. terrae	B (Battey)	Poor response
IV	Rapid growers	3-4 days	M. fortuitum	Skin infection & abscess Pulmonary	M. smegmatis M. phlei M. vaccae	F (Fortuitum)	Poor response

COMMON X-RAY DIAGNOSES

I. DIFFUSE RETICULAR OR NODULAR
   A. Infectious – Tuberculosis, Staphylococcus, Pneumocystis
   B. Neoplastic – Alveolar Carcinoma
   C. Cardiovascular – Interstitial Pulmonary Edema, Fibrosis, Hemosiderosis
   D. Immunologic – Collagen
   E. Inhalation – Organic and Inorganic Dusts
   F. Idiopathic – Sarcoid, Hamman-Rich, DIP

II. DIFFUSE ACINAR
   A. Infectious – Viral
   B. Neoplastic – Alveolar Carcinoma, Metastasis
   C. Cardiovascular – Pulmonary Edema
   D. Immunologic – Necrotizing Alveolitis
   E. Inhalation – Aspiration, Noxious Gases
   F. Idiopathic – Sarcoid, Hyaline Membrane, Shock Lung, Goodpasture's

III. DIFFUSE MIXED ACINAR – RETICULONODULAR
   A. Infectious – Viral, PPLO
   B. Neoplastic – Bronchoalveolar
   C. Inhalation
   D. Idiopathic – Goodpasture's

IV. HILAR AND MEDIASTINAL LYMPH NODE ENLARGEMENT
   A. Infectious – Tuberculosis, PPLO
   B. Neoplastic – Bronchogenic, Hodgkin's, Metastasis
   C. Inhalation – Silicosis
   D. Idiopathic – Sarcoid

V. PLEURAL EFFUSION
   A. Infectious – Klebsiella, Staphylococcus, Tuberculosis, Pseudomonas, E. Coli
   B. Neoplastic – Bronchogenic, Mesothelioma, Meig's Syndrome
   C. Thromboembolis – P.E. with infarction
   D. Cardiovascular – CHF
   E. Immunologic
   F. Traumatic
   G. Incidental – Peritoneal Dialysis

VI. CYST WITH CAVITY
- A. Developmental
- B. Infectious
  1. Bacterial: Staphylococcus, Klebsiells, Tuberculosis, Pseudomonas, E. Coli, Bacteroides, Proteus
  2. Fungal: Aspergillosis, Nocardia, Blastomycetes
- C. Neoplastic – Bronchogenic carcinoma, Metastasis
- D. Thromboembolic – P.E. with infarction
- E. Immunologic
- F. Inhalation
- G. Traumatic

VII. SOLITARY NODULES LESS THAN 6 CM
- A. Developmental – Cyst, sequestration, A-V fistula
- B. Infectious – Tuberculosis
- C. Neoplastic – Adenoma, OMA, Bronchogenic Carcinoma
- D. Immunologic – Rheumatoid Nodule

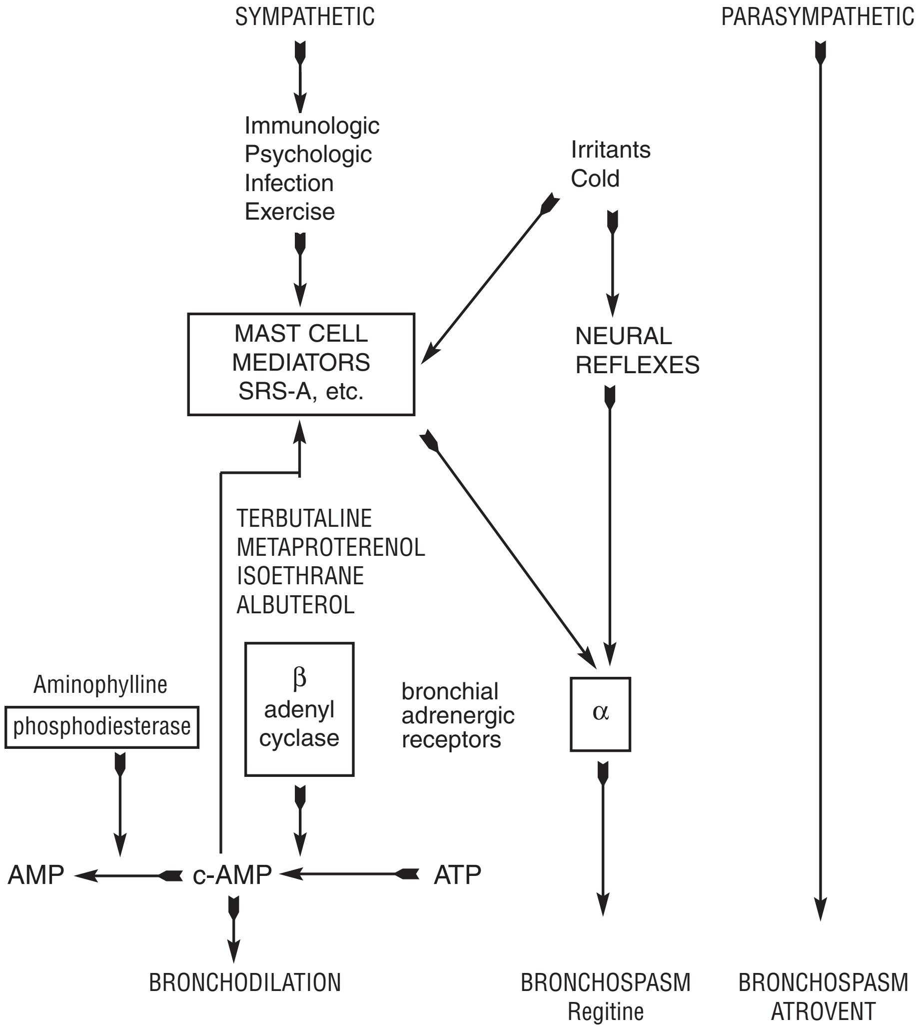
VIII. MULTIPLE PULMONARY NODULES
- A. Developmental – A-V fistula
- B. Infectious
- C. Neoplastic – Metastasis
- D. Immunologic – Wegener's

IX. SOLITARY MASSES GREATER THAN 6 CM
- A. Developmental – Sequstration
- B. Infectious – Abscess
- C. Neoplastic – Bronchogenic carcinoma

X. Mediastinal widening
- A. Developmental – Cyst
- B. Infectious
- C. Neoplastic – Thyroid, thymoma, germinal cell, metastasis
- D. Trauma – Pneumomediastinum
- E. Incidental – Esophageal hiatel hernia, Morgagni hernia (anterior), Bochdalek hernia (posterior)

SIGNS OF INOPERABILITY

1. Metastasis – brain, bone, other organs
2. Lymph Nodes
3. Superior Vena Caval Obstruction
4. Recurrent Laryngeal Nerve Paralysis
5. Phrenic Nerve Paralysis
6. Pancoast Syndrome (Superior Sulcus Tumor Syndrome): Low grade squamous cell carcinoma of the apex of the lung which spreads to the lower cords of the brachial plexus. Gives rise to Horner's syndrome and wasting of the small muscles of the hand.



1. Bronchial Smooth Muscle has both:

   alpha receptors — increase bronchomotor tone (constrict)
   beta receptors — decrease bronchomotor tone (dilate)

2. Beta receptor is probably the enzyme adenyl cyclase (ashmatics may have decreased adenyl cyclase)

Table 1. Physiologic variables, measured and derived: abbreviations, formulas, units, normal values, and “optimal” therapeutic goals.

	Abbreviation	Formulas	Units	Normal Values	Optimal Goals
Volume-Related Variables					
Mean arterial pressure	MAP		mm Hg	90 ± 5‡	90
Central venous pressure	CVP		cm water	5 ± 2	10
Central blood volume	CBV	CBV = CI x MTT x 16.7	$ml \cdot M^{-2}$	830 ± 60	750
Stroke index	SI	SI = CI ÷ HR	$ml \cdot M^{-2}$	46 ± 5	50
Hemoglobin	Hb		$g \cdot 100\ ml^{-1}$	14 ± 1	12
Mean pulmonary arterial pressure	MPAP		mm Hg	13 ± 1	15
Pulmonary wedge pressure	PWP		cm water	6 ± 3	12
Red cell mass	RCM	RCM = BV · Hct •	liter M^{-2}	1.2 ♂ 1.0 ♀	1.2 ♂ 1.0 ♀
Blood volume	BV	BV = PV ÷ (1- Hct)	liter M^{-2}	2.74 ♂ 2.37 ♀	3.0 ♂ 2.7 ♀
Flow-Related Variables					
Cardiac index	CI	CI = CO ÷ SA	$liter \cdot min^{-1} \cdot M^{-2}$	3.2 ± 0.2	4.5
Mean transit time	MTT		sec	15 ± 1.4	16
Left ventricular stroke work	LVSW	LVSW = SI x MAP x .0136	$g \cdot m \cdot M^{-2}$	56 ± 6	60
Left cardiac work	LCW	LCW = CI x MAP x .0136	$kg \cdot m \cdot M^{-2}$	3.8 ± 0.4	4.0
Mean systolic ejection rate	MSER	MSER = SI ÷ time of systole	$ml \cdot sec^{-1} \cdot M^{-2}$	370 ± 50	360
Tension time index	TTI	TTI = MAP x time of systole x HR	$mm\ Hg \cdot sec \cdot cm^{-1}$	780 ± 100	1200
Right Ventricular stroke work	RVSW	RVSW = SI x MPAP x .0136	$g \cdot m \cdot M^{-2}$	8.8 ± 0.9	10.5
Right cardiac work	RCW	RCW = CI x MPAP x .0136	$kg \cdot m \cdot M^{-2}$	0.6 ± 0.06	1.15
Bodily Responses					
Systemic vascular resistance	SVR	SVR = (MAP — CVP) 79.92 ÷ CI∮	$dyne \cdot sec/cm^3/M^2$	2180 ± 210	1400
Pulmonary vascular resistance	PVR	PVR = (MPAP — WP) 79.92 ÷ CI∮	$dyne \cdot sec/cm^3/M^2$	270 ± 45	350
Heart rate	HR		$beats \cdot min^{-1}$	71 ± 4	86
Temperature, rectal	Temp		°F	98 ± 0.2	100
O_2 Related Variables					
Arterial pH	pH_a			7.4 ± 0.02	7.45
Arterial CO_2 tension	$PaCO_2$		torr	40 ± 2	36
Mixed Venous O_2 tension	$P\dot{v}O_2$		torr	38 ± 4	40
Arterial Hb saturation	SaO_2		%	97 ± 1	97
Arterial venous O_2 content difference	a_ADO_2	$a_ADO_2 = CaO_2 - C\dot{v}O_2$	$ml \cdot 100^{-1}$	4.6 ± 0.4	4.5
O_2 availability	O_2 Avail	O_2 Avai = $CaO_2 \cdot CI \cdot 10$	$ml \cdot min^{-1} \cdot M^{-2}$	600 ± 50	600
O_2 consumption	$\dot{V}O_2$	$\dot{V}O_2 = a\dot{v}DO_2 \cdot CI \cdot 10$	$ml \cdot min^{-1} \cdot M^{-2}$	140 ± 25	160
O_2 extraction	O_2 Ext	O_2 Ext = $(CaO_2 - C\dot{v}O_2) \div CaO_2$	%	26 ± 2	24
Perfusion Indices					
Red cell flow rate	RCFR	RCFR = CI x Hct	$liter \cdot min^{-1} \cdot M^{-2}$	1.2 ± 0.3	1.2
Blood flow/ volume ratio	BFVR	BFVR = CI ÷ BV	-----	1.2 ± 0.3	1.6
O_2 transport/red cell mass ratio	OTRM	OTRM = $\dot{v}O_2$ ÷ RCM	-----	0.12 ± 0.03	.25
Tissue O_2 extraction index	TOEI	TOEI = $a\dot{v}DO_2$ ÷ RCFR	-----	4 ± 1.5	4.5
Efficiency of tissue O_2 extraction	ETOE	ETOE = $a\dot{v}DO_2$ ÷ RCM	-----	4.2 ± 1.2	5
O_2 transport/red cell flow ratio	OTRF	OTRF = $\dot{v}O_2$ ÷ RCFR	-----	120 ± 34	130

† — Direct Measurement ‡—Mean = SD ∮—Venous Pressure expressed in m mm Hg • — Hematocrit

PULMONARY SERVICE NOTE

MAIN FORMAT

Type of Oxygenation:

Arterial Blood Gases

Ventilator?
Nasal Prongs?

Blood Gas Diagnosis

Example: A patient with pulmonary edema on MA-1 weighing 70 kg.

pH = 7.14 ↓	MA-1	Severe Respiratory Acidosis Due to Alveolar Hypoventilation
pCO_2 = 80 ↑	TV = 400	
pO_2 = 180	Rate = 12	
HCO_3 = 25	fiO_2 = 1.00	
	P_{c+R} = 40	
	P_c = 20	

(Shunt)

$$\frac{\dot{Q}_s}{\dot{Q}_t} \times 100 = 30\%$$

PAP = 40

Wedge = 25

A-a gradient = 613 – 180 = 433

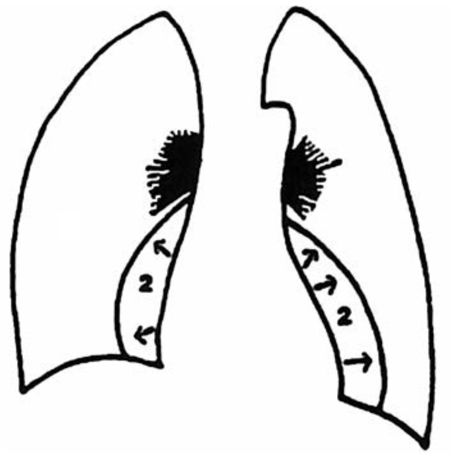
PAO_2 = 613

$$\text{Compliance} = \frac{V}{P_c} = 400/20 = 20$$

PaO_2 = 180

LUNGS – bilateral end-inspiratory crepitant rales

Chest Film



1. Bilateral pulmonary vascular engorgement
2. Cardiomegaly

Plan –

1. Increase RV to 800
2. Rate: 12

Why?

$$pCO_{2_1} \times RV_1 \times R_1 = pCO_{2_2} \times RV_2 \times R_2$$

$$80 \times 400 \times 12 = 40\ (TV_2\ R_2)$$

$$9600 = (TV_2\ R_2)$$

$$800 \times 12 = (TV_2\ R_2)$$

$$960 \times 10 = (TV_2\ R_2)$$

3. Decrease fIO_2 to 0.56 for calculated paO_2 of 80.

PULMONARY FUNCTION TESTS

IN OBSTRUCTIVE DISEASE:

	FEV1%
Mild	70% – 55%
Moderate	54% – 45%
Severe	less than 45%

IN RESTRICTIVE DISEASE:

All lung volumes decreased (FVC, FRC or RV)

	FVC	+	FRC or RV
Mild	79%-65%	+	less than 80%
Moderate	64%-50%	+	less than 80%
Severe	less than 50%	+	less than 80%

RV above 125% – – – – – – – – Hyperinflation

BRONCHODILATORS: Increase of 25% in volumes or flows is a good response.

CLASSIFICATION OF TUBERCULOSIS AND OTHER MYCOBACTERIAL DISEASES

Summarized from Diagnostic Standards and Classification of Tuberculosis and Other Mycobacterial Disease, American Thoracic Society, Medical Section of American Lung Association, 1981.

TUBERCULOSIS

0. No Tuberculosis Exposure. Not Infected.
   (no history of exposure, reaction to tuberculin skin test not significant)
1. Tuberculosis Exposure. No Evidence of Infection (history of exposure, reaction to tuberculin skin test not significant)
2. Tuberculosis Infection. No Disease. (significant reaction to tuberculin skin test, negative bacteriologic studies (if done), no clinical and/or roentgenographic evidence of tuberculosis).
   CHEMOTHERAPY STATUS (preventive)
   - None
   - On chemotherapy since (date)
   - Chemotherapy terminated (date)
     - Complete (prescribed course of therapy)
     - Incomplete
3. Tuberculosis: Current Disease (M. Tuberculosis cultured [if done], otherwise both a significant reaction to tuberculin skin test and clinical and/or roentgenographic evidence of current disease).
   LOCATION OF DISEASE
   - Pulmonary
   - Pleural
   - Lymphatic
   - Bone and/or Joint
   - Genitourinary
   - Disseminated (Miliary)
   - Meningeal
   - Peritoneal
   - Other

   The predominant site shall be listed. Other sites may also be listed. Anatomic sites may be specified more precisely.
   BACTERIOLOGIC STATUS
   - Positive by
     - Microscopy only (date)
     - Culture only (date)
     - Microscopy and Culture (date)
   - Negative (date)
   - Not done

   CHEMOTHERAPY STATUS
   - On chemotherapy since (date)
   - Chemotherapy terminated, incomplete (date)

   The following data are necessary in certain circumstances:
   - ROENTGENOGRAM FINDINGS
     - Normal
     - Abnormal
       - Cavitary or noncavitary
       - Stable or worsening or improving

(continued)

TUBERCULIN SKIN TEST REACTION
- Significant
- Not significant

4. Tuberculosis: No current disease (history of previous episode(s) of tuberculosis, or abnormal stable roentgenographic findings in a person with a significant reaction to tuberculin skin test, negative bacteriologic studies (if done), no clinical or roentgenographic evidence of current disease).
   CHEMOTHERAPY STATUS
   - None
   - On chemotherapy since (date)
   - Chemotherapy terminated (date)
     - Complete
     - Incomplete
5. Tuberculosis Suspect (diagnosis pending)
   CHEMOTHEERAPY STATUS
   - None
   - On chemotherapy since (date)

OTHER MYCOBACTERIAL DISEASES
Mycobacterial disease caused by (organism)
LOCATION OF DISEASE

Pulmonary	Genitourinary	Other
Pleural	Disseminated (Miliary)	
Lymphatic	Meningeal	
Bone and/or Joint	Peritoneal	

BACTERIOLOGIC STATUS
- Positive by
  - Culture only (date)
  - Microscopy and Culture (Date)
- Negative

CHEMOTHERAPY STATUS
- None
- On chemotherapy since (date)
  - Complete
  - Incomplete

ROENTGENOGRAM FINDINGS
- Normal
- Abnormal
  - cavitary or noncavitary
  - Stable or worsening or improving

ETIOLOGIES OF PLEURAL EFFUSION

A. Transudates
   1. Congestive heart failure
   2. Cirrhosis of the liver
   3. Nephrotic syndrome
   4. Atelectasis, early
5. Myxedema
6. Peritoneal dialysis

B. Exudates
   1. Parapneumonic effusion
   2. Pulmonary infarction
   3. Neoplasm
   4. Viral disease
   5. Collagen disease (rheumatoid arthritis, lupus erythematosus)
   6. tuberculosis
   7. Fungal disease
   8. Parasitic disease
   9. Rickettsial disease
   10. Gastrointestinal disease (pancreatitis, subphrenic abscess)
   11. Drug reaction (e.g., nitrofurantoin, methysergide)
   12. Asbestosis
   13. Meigs' syndrome
   14. Postmyocardial infarction syndrome
   15. Trapped lung
   16. Lymphatic abnormality
   17. Uremic pleurisy
   18. Atelectasis, late
   19. Chylothorax

Labs – What to Order

WBC increased 1000 Exudate: pneumonia infarction, pancreatitis, subphrenic abscess

Lymphys increased in tuberculosis, carcinoma, uremic pleurisy

RBC increased 5000 hemorrhagic
increased 100,000 carcinoma, trauma, infarction

Glucose decreased 30 rheumatoid
0-60 empyema, carcinoma tuberculosis, rheumatoid

Amalase – 2 times serum – pancreatitis, pseudocyst esophageal rupture, metastasis or carcinoma

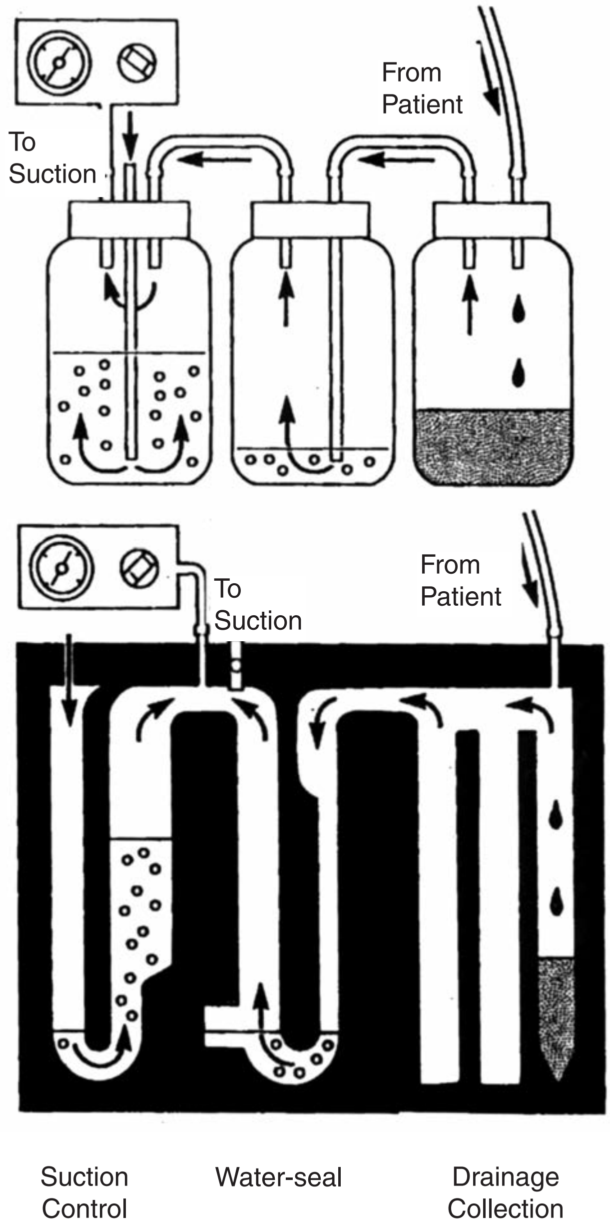
Lipids – tuberculosis, carcinoma, rheumatoid

pH – decreased 7.3 empyema

Cytology

Gram Stain – AFB stain and cultures

Exudate versus Transudate: (Light's criteria)
1. pleural fluid protein divided by serum protein greater than 0.5
2. pleural fluid LDH divided by serum LDH greater than 0.6
3. pleural fluid LDH greater than two-thirds the upper limit of normal for the serum LDH.



Pleur-evac pleural drainage system. Air vent is shown.