PART SIX

AN OVERVIEW OF VOLUMETRIC DIFFUSIVE RESPIRATION (VDR®)

VOLUMETRIC DIFFUSIVE RESPIRATION (VDR®) was conceived as a clinical rationale by Dr. Forrest M. Bird in the late 1970’s as an effective universal diffusive/convective ventilation for neonates through pediatrics to the largest adults.

THE PERCUSSIONAIRE® VDR®-4

HIGH FREQUENCY PERCUSSIVE VENTILATION (HFPV™) IS THE PROFESSIONAL VENTILATOR FOR “THE PROFESSIONAL CLINICIAN”

HIGH FREQUENCY OSCILLATORY DEMAND CPAP SUPPORTING SPONTANEOUS RESPIRATION

TYPICAL MULTIPLE STAGE VDR® PERCUSSIVE LUNG INFLATION
THE UNIQUE VDR®-4 CRITICAL CARE VENTILATOR
provides
DIFFUSIVE/CONVECTIVE CARDIOPULMONARY SUPPORT
to the most critical Neonates through Pediatrics to the largest Adult

The independent fluidic VDR®-4 critical care ventilator (Percussionator®) is monitored by a high frequency wave form analyzer (Monitron®), which provides, about a three millisecond response presentation of a pictorial wave format and a digital read out of key VDR®-4 ventilatory programming.
Monitron Wave Format with digital readout of both Diffusive and Convective Ventilation

PREFERENTIAL AIRWAY - A PRIMARY FACTOR OF MECHANICAL BAROTRAUMA
During the mechanical ventilation of the lung, the inspiratory proximal to distal intrapulmonary flow gradients will determine alveolar distribution. The greater the sustained pressure differential, the more the potential for alveolar mal-distribution and associated barotrauma.

Therefore, the most patent airways serving the most dependent (functional) alveolar structures will be the first to experience over expansive barotrauma. This mal distribution is created by an elevated sustained proximal/distal "flow gradient" during the intrapulmonary proximal-distal inspiratory lung inflation to the scheduled PIP.

Barotraumatic lung injury must be an ever-present consideration in all patients being managed with a mechanical ventilator. A “lung protective strategy” is only as effective as “the clinical efficacy of the ventilator design”. Various forms of Respiratory Distress Syndromes, regardless of applied description, can be related to mechanical ventilatory protocols with sustained peak physiological airway flow gradients and elevated final oxygen concentrations (FIO2’s).

It follows that the true clinical efficacy of a mechanical ventilator in each patient population is directly related to the clinician’s overall medical knowledge and ability to effectively program the device and accessories. All else being equal, the clinical efficacies of the ventilatory device and the operational knowledge of the attending can determine the patient’s survival and/or the level of residual injury secondary to the mechanical ventilatory protocol.
Dr. Bird always stated, “the mechanical ventilation of the lung is truly cardiopulmonary critical care and should not to be taken lightly”.

Hyperinflational Pendeluft during the mechanical ventilation of the lung has been long advanced in the classical texts describing barotraumatic lung injuries.

The concept of Volumetric Diffusive Respiration (VDR®) is based upon providing, all patient populations with maximized clinical efficacy, while presenting the lowest level of potential barotrauma compared to all other means of effective Trach Positive Ventilatory protocols.

The physical properties and pathophysiology employed in the conception and development of the devices for the administration of VDR® have employed pure Bernoullian and Newtonian physics as well as fluid dynamics as they apply to advanced airflow. Meteorological covenants were employed to define humidification and aerosolization. The operational reliability and wide access to programming has allowed the truly skilled clinician to program the VDR® ventilators for near their maximum level of clinical efficacy using each patient as their own control.

The clinical operational logic of VDR® is well within the understanding of the average Clinician if they have an applicable command of cardiopulmonary pathophysiology in the patient populations they are attending.

The reason the average scientist does not understand the fluidic programming and general logic involved in the scheduling of the VDR® devices is due to the fact that there are thirty-four concomitant events occurring simultaneously and relatively few scientists have a functional physical understanding of fluid dynamics.
This schematic is analogous to thirty four parallel railroad tracks with locomotives departing at different times at different velocities down the tracks, requiring millisecond calculations at any point to determine the location of each locomotive. This logic provides for the interlocks to prevent a VDR® clinical program, from being scheduled contrary to design logic. While the average knowledgeable individual can carry a quadratic equation in their minds, it requires knowledge of advanced mathematics to interpolate a variable thirty-four level of simultaneous events.

There is no reason for the clinician to understand the physical operational logic.

The clinical efficacies of Dr. Bird’s serialized concepts for mechanical cardiopulmonary management, advanced by the near precise control of intrapulmonary airflow, required a dedicated lifetime of study and resolve to conceive and develop. Because of the lack of understanding of his concepts in certain institutions (for one reason or another), only a fraction of the potential clinical efficacy of VDR® may be currently realized.
In one instance Clinicians using VDR® devices stated “that the VDR® concept on burn patients is the same as CMV programming”. This reflects the lack of programming knowledge on behalf of the attending. However, this reflects back upon Percussionaire® for failure to provide adequate educational follow up.

The concept of Volumetric Diffusive Respiration (VDR®) has proven to be effective in all patient populations requiring mechanical cardiopulmonary management, often when all other clinical choices have been unsuccessful.

The VDR®-4 can be programmed to ventilate the most critical low birth weight neonate with cardio-respiratory compromises, often when all other ventilatory means have failed.

Exposure to the thermal elements of fire as well as to the potential chemical releases can create clinical challenges to the attending, including inhalational injuries. Associated inhalation injuries can produce the most challenging consequences to clinicians relative to the maintenance of pulmonary functions.
The burn patient can present with both thermal exterior (surface) injuries as well as a progressive delayed onset of inhalational chemical induced endobronchial mucosal sloughing. Burn patients with both burn and inhalation injuries can present one of the greatest combined cardio-pulmonary challenges to the attending.

A typical patient with acute obstructive lung disease receiving VDR®
The above algorithm was created by clinicians with substantial VDR® experience, for general educational purposes.

The combination of diffusive intrapulmonary gas mixing with a convective intrapulmonary gas exchange can manage the most critical patient with obstructive endobronchial airways resultant from mucosal and sub mucosal edema and retained endobronchial secretions.

Dr. Bird’s four generations of fluidic Aeromedical devices have served to demonstrate the continuing reliability and clinical efficacy of the four progressive generations of ventilators and high frequency Intrapulmonary Percussionators®.

With tens of thousands of hours of continuous service since 1984, the VDR® Percussionators® have essentially reached a point where any technological or physiological barotraumatic potentials have been exposed.

THE FLUIDIC AIRMOTIVE COMPONENTS OF THE MODULAR FLUIDIC VDR®-4 VENTILATOR ARE RELIABLY INTEGRATED TO PROVIDE FOR THIRTY-FOUR SIMULTANEOUS FUNCTIONS WITH AN INTEGRATED MILLISECOND RESPONSE.

The unique VDR® FAILSAFE ALARMING and De-pressurization circuit is controlled by the Red SENSITIVITY control knob. A (counterclockwise) rotation increases Sensitivity (alarming at a lower sustained PIP). Before initial patient set up select the 12:00 SENSITIVITY control knob Arrow position.
The Red SENSITIVITY FAILSAFE ALARMING/DEPRESSURIZATION system is calibrated with the SENSITIVITY control knob Arrow at 12:00 to activate with a sustained PIP of over 100 cm H2O for over two seconds. If the Red RE-SET button is “pushed” to cancel the alarm and the FAULT HAS NOT BEEN RESOLVED, Alarming will again re-occur in about two seconds.

If upon patient airway connection the ALARM is activated; it can be assumed that a programming failure of some type exists, where the PIP’s are sustained above 100 cm H2O for over two seconds. This could be caused by the obstruction of the white Phasitron® tubing. In the rare instance where the patient’s compliance (without an airway obstruction) is sufficiently low to create SENSITIVITY alarming, the rotation of the SENSITIVITY control knob Arrow (clockwise) toward the 03:00 position should prevent alarming.

With the full (counterclockwise) rotation of the SENSITIVITY control knob Arrow alarming is calibrated to occur at much lower peak sustained delivery pressures.

VDR® programming is unique compared to CMV, where the INSPIRATORY PHASE is brief, during percussive oscillation the VDR® INSPIRATORY INTERVAL can be extended for up to 10 seconds by INSPIRATORY TIME selection, to maintain a programmed oscillatory equilibrium.

The VDR®-4 has several dedicated universal breathing circuits, providing for neonatal, pediatric and adult mechanical cardio-respiratory care

The classical VDR breathing circuit has sometimes been altered by others to insert a number of various proprietary heated humidification systems. Certain of these systems can encroach upon the failsafe features of the circuit; OTHER MODIFICATIONS DO NOT PROVIDE FOR ADEQUATE HUMIDIFICATION OR NEBULIZATION, CREATING MUCOSAL DEHYDRATION WITH ASSOCIATED MUCOSAL IRRITATION.

Percussionaire®received a complaint that the VDR programming on critical patients was clinically effective beyond CMV scheduling. However, upon bronchoscopic examination of the upper airway inflammation was noted. This was most likely due to the lack of adequate humidification. In this case the VDR® Breathing was more than likely mis-configured.
Drawing depicts an assembled Hub to enable the use of certain available heated humidification breathing circuits. By the translocation of the Phasitron® from the proximal airway, the resistances within the breathing circuit may be slightly elevated.

THE VDR®-4 BREATHING CIRCUIT HUB PROVIDES FOR THE REMOTING OF THE PHASITRON AND THE INTERFACING OF AVAILABLE HEATED HUMIDIFICATION BREATHING CIRCUITS FOR NEONATAL, PEDIATRIC AND ADULT PATIENTS.
THE VDR® HUB FOR EMPLOYING AVAILABLE HEATED HUMIDIFICATION BREATHING CIRCUITS INTERCONNECTED WITH A STATE OF THE ART HEATED HUMIDIFIER AND BREATHING CIRCUIT TUBINGS. The apparent “clutter” is mandated by the effective heated humidification components.
RATIONAL FOR
THE PERCUSSIONAIRE® VDR®-4 VENTILATOR
SERVOLATOR® PERCUSSIONATOR® FOR (HFPV™)
VOLUMETRIC DIFFUSIVE RESPIRATION

The VDR®-4 has been continually facilitated to comply with clinical learning experiences. Over the years, the VDR®-4 Percussionator® ventilator has not been altered from the initial VDR®-4 design configuration; however, logical updating serves to conform with past and current UNIVERSAL clinical applications.

In 2005 Percussionaire® advanced the VDR-4® operational facilities, to comply with every known constructive criticism. To this end, some fifty VDR-4 Ventilators were entered into the field. These were identified by ALUMINUM FACE PLATES. From over ten-months of clinical “FEED BACK” from experienced clinicians these units have served to perfect the VDR-4® ventilators to the highest possible standards based upon CLINICAL EXPERIENCES.

If you have a VDR®-4 ventilator with an Aluminum face plate (panel) received before April 30th 2006 without a Red SENSITIVITY control knob, Percussionaire® will be exchanging your VDR®-4 operational panel at no cost to you during the months to come. Your Percussionaire® Technical Representative will advise you when the conversion will be done. This will start a new Warranty period. While the changes involve mostly intuitive calibration, they will allow you all the past as well as expanded clinical programming. This will make “ALL VDR®-4 ventilators” almost exactly alike for all patient categories. Percussionaire would like to thank all those Clinicians who have participated in the upgrading program.

The following text serves to explain the general operational covenants of Volumetric Diffuse Respiration (VDR®).

DISCUSSIONS-
Adjustments to the PULSE FREQUENCY and i/e RATIO allow a selection of oscillatory i/e RATIOS and resultant FREQUENCIES to be programmed.
The VDR®-4 Percussionators® are calibrated with a 12:00 INDEX default position.
NOMINALLY:

a.) With a 40 psig OPERATIONAL PRESSURE selected, and the PULSE FREQUENCY as well as the i/e RATIO control knob arrows rotated under their 12:00 indexes-

b.) Then with the PULSATILE FLOWRATE control knob rotated to the full (counterclockwise) position-

c.) An obstructed PHASITRON® OUTLET, will cause a pressure rise to a PIP of about 70 cm H2O on the Manometer.

d.) Simultaneously, cyclic oscillatory frequencies of about 500 cycles per minute should be displayed on the Monitron.

Over the past two decades, the VDR®-4 Percussionators have been responsible for many clinical reversals of patients failing volume oriented low frequency ventilators. During these last twenty years, the management of oscillatory PIP while ventilating critical care patients (failing Convective Volume Oriented Ventilators) has been almost totally controlled by the first stage PULSATILE FLOW control knob, without the programming of the second phase CONVECTIVE PRESSURE RISE.

While this initial first stage programming with a step increase in lung volumes has greatly decreased preferential airway and potential ventilatory associated barotrauma, the total clinical efficacies available with the Volume Diffusive Respiration (VDR®) concept have not necessarily been achieved.

To obtain optimal oscillatory sub tidal lung volume exchange, the "PEAK TO PEAK" percussive oscillatory pressure rise and drop must be maximized. Mechanical endobronchial gas mixing will determine the efficacy of the scheduling, which must be directed toward enhancing diffusion (mechanical gas mixing) within the pulmonary structures. Therefore, the VDR®-4 (high frequency) percussive programming with the greatest "PEAK TO PEAK" pressure differential will create the optimal level of intrapulmonary gas mixing.
The above type of positive oscillatory programming produces ventilation in a high lung compartment creating a form of CPAP, whereby much of any noted improvement could be secondary to an elevated mean alveolar pressure. Any ventilator-caused increase in pulmonary arterial pressure secondary to mechanically increased mean intrathoracic pressure (in a patient with a compromised right heart) can decrease cardiac output.

NOTE: Selected Percussive Frequencies above 600 cycles per minute with a (counterclockwise) rotation of the PULSATILE FLOWRATE control knob sufficient to cause a departure from the selected expiratory BASELINE, will serve to narrow the oscillatory bandwidth, decreasing intrapulmonary percussive gas mixing.

Above with a programmed 15 cm H2O of Oscillatory Demand CPAP the first stage of oscillation does not depart the zero Baseline. A further (counterclockwise) rotation of the PULSATILE FLOWRATE control knob will cause the baseline of the first stage of oscillation to start rising above the programmed Oscillatory Demand CPAP.
Monitron® screen depiction of a VDR®-4 programmed with a cycling frequency of 905 cycles per minute during a first stage proximal airway inflational pressure rise to 80 cm of H2O. This scheduling directed toward recruiting a stiff low compliance lung would result in a very high-sustained mean intrapulmonary pressure with a compromised intrapulmonary mechanical gas mixing.

When the VDR®-4 programmed with a frequency of 905 cycles per minute, above, is compared to the VDR®-4 calibration below with a default cycling rate of about 490 cycles per minute, presented below, it can clearly be seen that the first stage bandwidth is increased without leaving the zero Oscillatory Baseline. This provides for a similar "PEAK TO PEAK" intrapulmonary pressure changes at lower peak pressures, thus enhancing the mechanical mixing of endobronchial gases in a lower lung compartment.

Instead of further increasing the first stage oscillatory inspiratory phase PIP by increasing the PULSATILE FLOWRATE to obtain “pulmonary recruitment”, the mean intrapulmonary pressures can be decreased by initiating the second stage oscillatory pressure rise (PIP). This is accomplished by the gradual (counterclockwise) rotation of the CONVECTIVE PRESSURE RISE control knob.
Monitron® II screen, showing a PULSATILE FLOWRATE pressure rise to about 35 cm H2O seamlessly transitioning into a CONVECTIVE PRESSURE rise to a hypothetical lung recruitment with a CONVECTIVE PRESSURE rise to about 60 cm H2O.

Suggested VDR®-4 programming utilizes a second stage CONVECTIVE PRESSURE RISE programming to effect pulmonary recruitment. Nominally, a first stage inspiratory pressure rise to about 35 cm H2O is programmed by the (counterclockwise) rotation of the PULSATILE FLOWRATE control knob. This programming serves to expand the endobronchial airways with minimal preferential airways, providing an optimal mean airway pressure induced expansion in preparation for a secondary flow acceleration.

After about one second, the second stage flowrate is seamlessly increased by the selected (counterclockwise) rotation of the CONVECTIVE PRESSURE RISE control knob. Pulmonary recruitment into increasingly higher lung compartments can be precisely scheduled. Selection of a convective pressure rise determines the PIP at oscillatory equilibrium. At a 40 psig operational source pressure, convective pressure rises of up to 100 cm H2O are available.

Note: The VDR® is calibrated for a one second first stage interval before the second stage flow acceleration commences. Therefore the duration of the second stage OSCILLATORY EQUILIBRIUM INSPIRATORY INTERVAL is determined by the selection of INSPIRATORY TIME. If the Inspiratory time is not over one second the second stage is locked out.
The above labeled wave format serves to demonstrate the optimal method of VDR® scheduling when ventilating stiff low compliance lungs. By decreasing the potential for preferential airway the two-step inflation of the lung decreases the risk of Barotrauma.

Once we as human beings develop a habit with general acceptable results we don’t like to change, even if it makes the end results a bit better. For the most part, VDR® when compared with volume oriented CMV protocols, will often perform better than CMV on critically ill patients. Obviously, the clinical efficacy of the VDR® programming is determined by the operational scheduling.

IT FOLLOWS:

The lower the MEAN INTRAPULMONARY PRESSURES during the mandated peak recruitment, the more favorable the ventilatory program to CARDIAC OUTPUT.

OF NOTE: INSTITUTIONS, BECAUSE OF HABIT AND PREDICTABILITY OVER TIME, MAY DESIRE TO CONTINUE TO ATTEMPT PULMONARY RECRUITMENT USING THE FIRST STAGE PRESSURE RISE WITHOUT EMPLOYING A SECOND STAGE RECRUITMENT. THIS IS A CLINICIAN CALL.

FREQUENCY SELECTIONS UNDER 600 CYCLES PER MINUTE RESULT IN INCREASED OSCILLATORY BAND WIDTHS WITH A GREATER PERCUSSIONAL BANDWIDTH FOR IMPROVED INTRAPULMONARY MECHANICAL GAS MIXING AT LOWER MEAN INTRAPULMONARY PRESSURES.

The scheduling of OSCILLATORY DEMAND CPAP serves to stabilize the pulmonary structures during the programmed expiratory interval. Additionally, there is a more efficient “wash out” of the mechanical as well as certain of the anatomical dead space in terms of end exhalation CO2. The rotation of OSCILLATORY DEMAND CPAP control knob Arrow to the 09:00 position is a nominal starting point.
During the mechanical ventilation of the lung, the greater the inspiratory flowrate from beginning tidal inflation to end inspiration will determine the preferential airway selection; other factors being equal.

Therefore, during conventional CMV programming the most patent airways serving the most dependent (functional) alveolar structures will be the first to experience over expansive barotrauma. Ventilator induced barotrauma can be aggravated by an excessive sustained proximal/distal "flow gradient" during inspiratory lung inflation to a scheduled PIP followed by a post inspiratory apneustic plateau.
Barotraumatic lung injury must be an ever-present consideration in all patients being managed with a mechanical ventilator. A “lung protective strategy” is only as effective as “the clinical efficacy of the ventilator design”.

Various forms of Respiratory Distress Syndromes, regardless of applied description, can be related to mechanical ventilatory protocols with sustained peak airway pressures (PIP’s) and elevated final oxygen concentrations (FIO2’s).

**OF MAJOR CONSIDERATION**

THE CONCEPT OF VOLUMETRIC DIFFUSIVE RESPIRATION (VDR®) FOR HIGH FREQUENCY PERCUSSIVE VENTILATION (HFPV®) IS NOT FREQUENCY CRITICAL as it is on TIDAL VOLUME CMV VENTILATORS or push-pull OSCILLATORS FOR HFOV. HFPOV™ delivers a selected sub tidal volume at selected higher frequencies.

THE CONCEPT OF NEONATAL HIGH FREQUENCY OSCILLATORY (push-pull) VENTILATION (HFOV) DEPENDS UPON A MAJOR CONTINUOUS POSITIVE AIRWAY PRESSURE TO INCREASE THE FUNCTIONAL RESIDUAL CAPACITY (FRC) IN ORDER TO INCREASE THE STATIC BLOOD GAS INTERFACE. THEREFORE, HIGH FREQUENCY OSCILLATORY VENTILATION (HFOV) PROCEDURES CAN BE JUDGED TO BE CRITICAL TO FREQUENCY SELECTION.