DUKE UNIVERSITY HEALTH SYSTEM
CLINICAL LABORATORIES
BLOOD GAS LABORATORY

IL GEM 3000 AND 682 CO-OXIMETER

Principles of Operation

The central component of the GEM Premier 3000 is the reagent cartridge which contains the analytical sensors, flow system, calibrators, process control modules, wash solution, and waste receptacle. The pH, PCO2, PO2, Na+, K+, Ca++, glucose, lactate, and hematocrit sensors, together with the reference electrode, are integral parts of the chamber, with chemically sensitive membranes permanently bonded to the chamber body. When the cartridge is installed in the instrument, the chamber resides in a thermal block which maintains the sample temperature at 37 +/- 0.3°C and provides the electrical interface to the sensors.

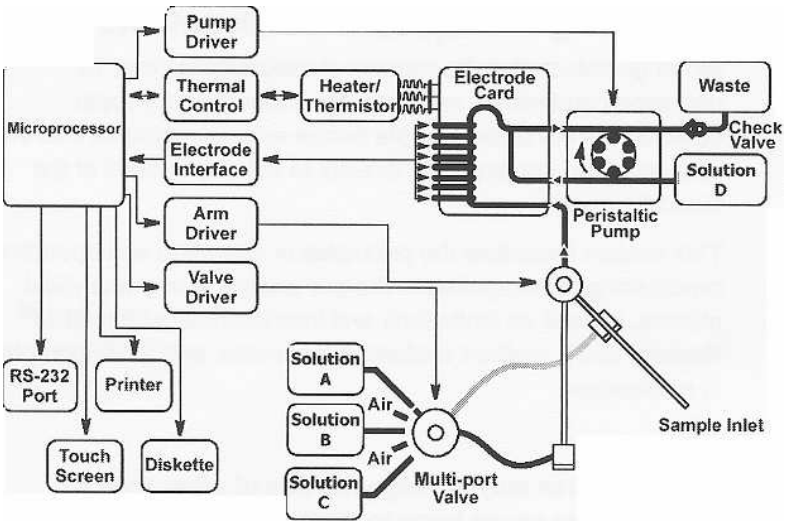


Figure 10.1: GEM Premier 3000 Block Diagram

Included in the cartridge are two solutions called "A" and "B." These solutions allow for calibrations and/or internal process control checks. The "A" and "B" solutions provide high and low concentrations for all parameters except hematocrit, which calibrates at one level using the "B" solution. Prior to calibration, the "A" and "B" solutions are read as unknown solutions, and these values are recorded in the instrument's database. During calibration, these values are adjusted for any slope or drift that may occur over time.

There is a third solution called "C" that is used to calibrate the PO_2 electrode at a low oxygen level. The "C" solution is also used for conditioning the glucose and lactate sensors, removing micro clots, and cleaning the sample path.

Each solution is contained in a gas-impermeable bag. The solutions are tonometered to the appropriate gas levels at the time of manufacture, then the bags are filled in such a manner as to eliminate any head space. The lack of head space, or gas bubbles, in the solution allows it to be maintained and used over a range of temperatures and barometric pressures with no change in dissolved gas concentration.

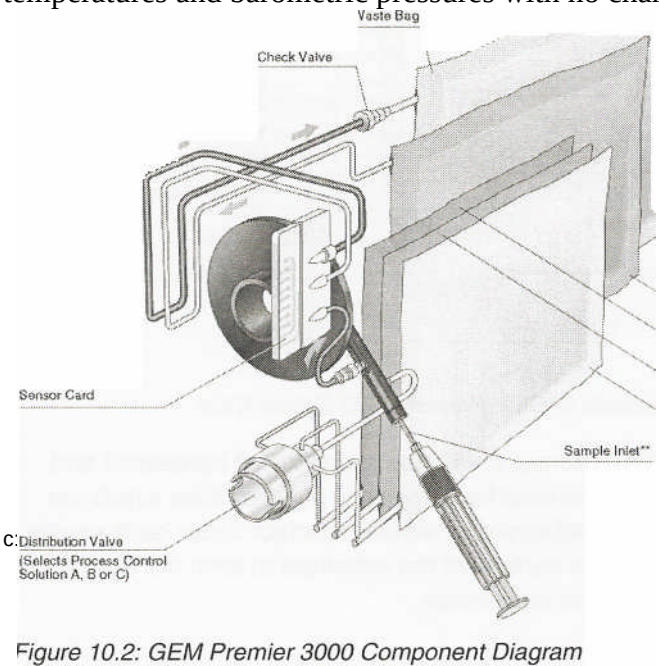


Figure 10.2: GEM Premier 3000 Component Diagram

The cartridge also includes a reference solution, distribution valve, pump tubing, sampler, and waste bag. Blood samples that have been analyzed are prevented from flowing back out of the waste bag due to the presence of a one-way check valve in the waste line.

Electrochemical Sensors

The electrochemical sensors used in the GEM Premier 3000 PAK disposable cartridge are all formed on a common plastic substrate. The reference electrode on the sensor card provides a highly stable reference potential for the system.

The individual sensors, with the exception of hematocrit and reference, are formed from layers of polymer films which are bonded to the substrate. A metallic contact under each sensor is brought to the surface of the substrate to form the electrical interface with the instrument.

pH and Electrolytes (Na+, K+, **and** Ca++)

The pH and electrolyte sensors are all based on the principle of ion-selective electrodes; that is, an electrical potential can be established across a membrane which is selectively binds to a specific ion. The potential can be described by this simplified form of the Nernst equation:

$$E = E' + (S \times \text{Log } C)$$

where E is the measured electrode potential, E' is the standard potential for that membrane, S is the sensitivity (slope), and C is the ion activity or concentration of the desired analyte. E' and S can be determined by the sensor response to the calibration solutions, and the concentration of the analyte (C) can be calculated for the measured electrode potential (E). For pH, "log C" is replaced by "pH" and the equation solved accordingly.

The pH and electrolyte sensors are polyvinyl chloride (PVC) based ion selective electrodes, consisting of an internal Ag/AgCL reference electrode and an internal salt layer. Their potentials are measured against the card reference electrode. The cutaway view in *figure 10.4* shows the flow of the solution past an ion-selective sensor.

If pH reports with an exception, then pCO_2, HCO_3, TCO_2, BE, and SO_2c will not be reported. If Na+ reports with an exception, then Hct will not be reported.

Ca++ correction to pH=7.4

The following equation is used to calculate the ionized calcium value using a constant pH of 7.4 for each patient sample analysis.

$$\text{Ca++ (corrected)} = (\text{Ca++ (meas)} \times 10^{(-0.178 \times (7.4-\text{pH}))})$$

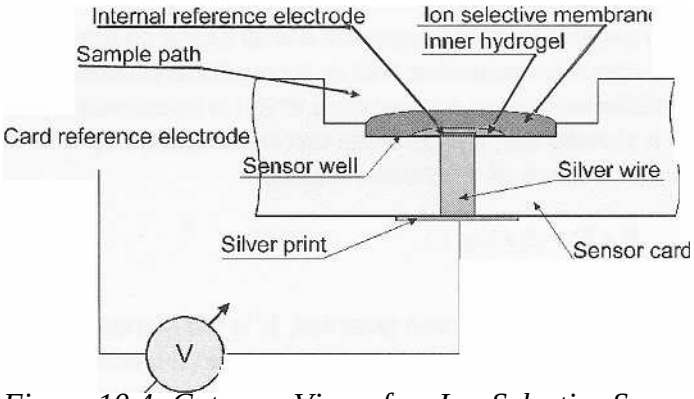


Figure 10.4: Cutaway View of an Ion-Selective Sensor

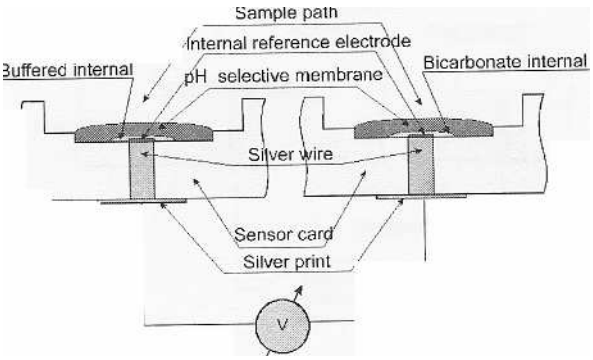
Carbon Dioxide *(pCO2* mmHg)

The *pCO2* sensor is a pH sensor electrode covered by a CO_2 gas permeable outer membrane. The sensor has an internal *Ag/AgCl* reference electrode and an internal bicarbonate buffer. The *pCO2* in the internal solution will come to equilibrium with the *pCO2* of a liquid (e.g. blood) in contact with the outer surface of the membrane. The pH of the internal solution varies with the *pCO2* in accordance with the Henderson-Hasselbalch equation:

$$\text{pH} = p\text{Ka} + \log\left(\frac{\text{HCO}_3^-}{p\text{CO}_2 \times a}\right)$$

where pKa is an equilibrium constant, HCO_3^- is the bicarbonate ion concentration, and "a" is the solubility coefficient of CO2 in water. The generated potential versus the pH sensor is related to the logarithm of *pCO2* content in the sample. Cutaway views of the *pCO2* and pH sensors are shown in *figure 10.5.*

If PCO_2 reports with an exception, then HCO_3^- and TCO_2 will not be reported.

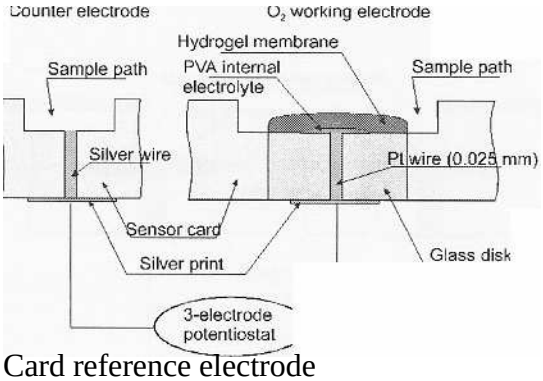


The generated potential versus the pH sensor is related to the logarithm of *pCO2* content in the sample.

Figure 10.5: Cutaway View of *pCO2 and* ***pH*** *Sensors*

Oxygen *(pO2* **mmHg)**

The oxygen sensor is an amperometric electrode consisting of a small platinum electrode poised at a negative potential with respect to the card reference electrode. An O2 gas permeable polypropylene membrane protects the platinum from protein contamination which improves specificity and prolongs sensor life. A cutaway view of the oxygen sensor is shown in *figure 10.6.*



Card reference electrode

Figure 10.6: Cutaway View of Oxygen Sensor

The current flow between the platinum and the counter electrode is proportional to the oxygen partial pressure.

The current flow between the platinum surface and the ground electrode is proportional to the rate at which oxygen molecules diffuse to the platinum and are reduced, which in turn is directly proportional to the *pO2*- This relationship is described by the equation:

$$I = (S \times pO2) + IZ$$

where I is the electrode current, S is the sensitivity, and IZ is the zero current. The values of S and IZ can be calculated from the calibration data for the sensor. The equation can then be solved for PCO2 where I becomes the electrode current produced by the blood sample.

If *pO2* reports with an exception, then BE and SO2c will not be reported.

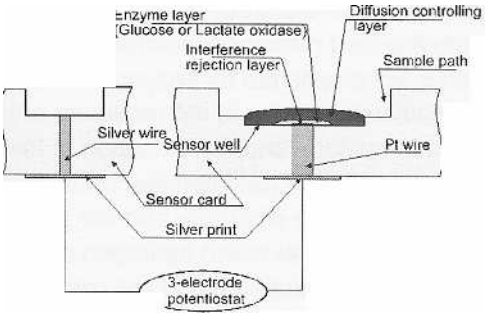
Glucose and Lactate

The glucose and lactate sensors are platinum amperometric electrodes poised at a positive potential with respect to the card reference electrode. Glucose or lactate are determined by enzymatic reaction with oxygen in the presence of glucose oxidase or lactate oxidase to produce hydrogen peroxide, which reacts at the platinum electrode. The current flow between the platinum electrode and the ground electrode is proportional to the rate at which hydrogen peroxide molecules diffuse to the platinum and are oxidized, which in turn is directly proportional to the metabolite (glucose or lactate) concentration:

$$I = (S \times \text{metabolite}) + IZ$$

where I is the electrode current, S is the sensitivity, and IZ is the zero current. The value of S and IZ can be calculated from the calibration data for the sensor. The equation can then be solved for the metabolite concentration, where I becomes the electrode current produced by the blood sample.

A diagram showing the configuration of the sensor is shown in *figure 10.7.* The sensor is constructed of a three-layer composite membrane consisting of an inner layer for screening out the interferences, the enzyme for oxidation reaction, and the outer layer for controlling the metabolite diffusion in the enzyme layer.



I
Card reference electrode

Figure 10.7: Cutaway View of an Analyte Sensor (Glucose or *Lactate)*

The current flow between the platinum and the counter electrode is proportional to the analyte concentration.

Hematocrit

Hematocrit is calculated from the Total Hemoglobin value.

Hematocrit = Total Hemoglobin x 3.

Card Reference

The card reference consists of a Ag/ AgNO3 electrode with an open liquid junction between the silver electrode and the sensor chamber. Every time a sample is pumped into the sensor chamber, fresh reference solution containing silver nitrate flows into the reference chamber and comes in contact with the sample. This process provides a stable and reliable potential independent of the sample composition.

P50

The partial pressure of 02 in a hemoglobin solution having an oxygen saturation of 50%, P50, is calculated only for venous samples. The following equation will be used:

$$P50 = 10^{-(Q/2.7)}$$

$$Q = \log (R / (100 - R)) - 2.7 * \log (pv02(T))$$

R = O2Hb or S02, as selected in configuration

Where:

pvO2(T) *pO2* (mmHg) for the current venous sample, corrected for patient temperature.

Use non- temperature corrected value if *pO2(T)* is not available.

O2Hb — Received from external CO-Ox for current venous sample, %. If 02Hb is not in the range 30 - 75%, P50 becomes incalculable.

S02 — O2 saturation as received from the external IL CO-Oximeter for current venous sample, %. If S02 is not in the range 30 - 75%, P50 becomes incalculable.

Intelligent Quality Management(IQM)

IQM is an active quality process control system designed to help ensure that the GEM Premier 3000 provides reliable results. IQM continuously monitors operation of the testing process, including calibrators, sensors, fluidics, and electronics, and automatically performs and documents corrective actions upon detecting an error.

IQM is designed to provide immediate error detection and correction, replacing the use of conventional external quality controls. IQM is a combination of software, Process Control Solutions, and Calibration Validation Product. During the 3-week use-life of the GEM PAK iQM cartridge, iQM:

- validates the integrity of the cartridge,
- continuously monitors the performance of the system,
- monitors the electrode responses of each sample to detect miroclots, etc that may effect analytical results.
- identifies the source of the change, and
- initiates remedial action, and documents it.

IL 682 CO-OX

Whole blood samples are chemically hemolyzed by with a non-ionic surfactant. The hemolyzed blood is then analyzed spectrophotometrically in a flow-through, thermostatted cuvette.

An anticoagulated whole blood sample is aspirated into the instrument, mixed with diluent, hemolyzed, and brought to a constant temperature in the cuvette. Monochromatic light at six specific wavelengths passes through the cuvette to a photo-detector, whose output is used to generate absorbances. These absorbance measurements are used to calculate Total Hemoglobin (tHb), percent Oxyhemoglobin (%O2Hb), percent Carboxyhemoglobin (%COHb), percent Methemoglobin (%MetHb), and percent Deoxyhemoglobin Hemoglobin (%HHb). Percent measured Oxygen Saturation (%SO2M), Oxygen Content (O2Ct), and Oxygen Capacity (O2Cap) are also calculated.

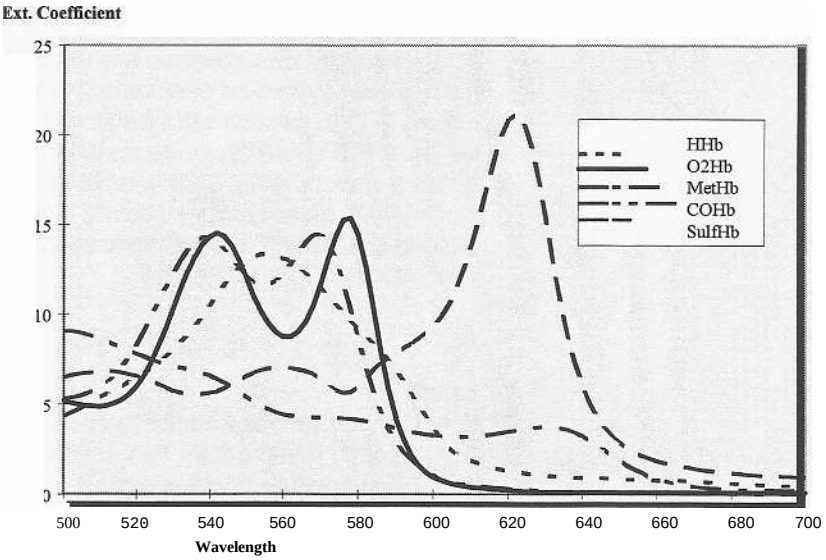


Figure A5-1 Hemoglobin Spectra

A thallium/neon hollow cathode lamp (HCL) emits light at several exact wavelengths. Six specific wavelengths (in the 530 through 670 nm range) are isolated using interference filters mounted on a motor-driven filter wheel. The light beam emerging from the reflective isolator is beam split; one beam is imaged onto the reference detector and the other beam is imaged onto the sample detector.

Computation of Absorbances

1. The Blank Measurement.

   At the end of each sample cycle, or on demand, six blank absorbances (one for each wavelength) are obtained with zeroing solution in the cuvette.

2. Sample Measurement.

   When diluted and hemolyzed sample (blood, Control, or Calibrator) is present in the cuvette, six sample absorbances (one for each wavelength) are obtained.

3. Calculation of Absorbances.

   The six Blank absorbances are subtracted from the six sample absorbances to obtain six net absorbances.

   A(Net) = A(Sample) - A (Blank)

   where A equals the absorbance at each wavelength.

Calculation of concentrations

The measured absorbances are used with a matrix of hemoglobin extinction coeffiecients (molar absorptivities, see Figure 5-1) to calculate the fractional concentrations of the various hemoglobin species present in the sample. At defined wavelengths, each species of hemoglobin in the sample has an absorbance which is the product of the cuvette pathlength, the concentration, and the extinction coefficient for that substance.

$A_x = K[E_1C_1 + E_2C_2 + E_3C_3 \ldots\ldots\ldots E_nC_n]$

where:
C = Concentration of each Hb species.
K = a scalar constant set by the tHb calibration process.
E = Each Extinction coefficient in the matrix.
A = The absorbance value of the blood at each wavelength.

Concentrations are used to determine tHb and relative percent Hb species.

The ctHb value (g/dL) is the sum of the four concentrations:

ctHb = C(O2Hb)+ C(HHb) + C(COHb) + C(MetHb)

Derivation of Measured and Calculated Parameters

This section details the derivations of the five parameters measured by the IL 682 CO-Oximeter system, as well as those parameters that are calculated. Consult related texts listed in the bibliography for further information.

Measured Parameters

Total Hemoglobin Concentration (tHb)

Total hemoglobin concentration is the sum of the concentrations of the hemoglobin species 02Hb, COHb, HHb, and MetHb. This measured parameter is important to the diagnosis and treatment of oxygen transport disorders, anemias, and other clinical problems. Reference range for normal adults is from 12.0 to 18.0 g/dL. Total hemoglobin may be displayed on the IL 682 in mmol/L, g/dL or *g/L*. The choice is operator selectable.

Total hemoglobin on the IL 682 is determined as follows:

tHb =(O2Hb + COHb + MetHb +HHb)xK(a scaling factor)

Oxyhemoglobin Percentage (%O2Hb)

Hemoglobin, with oxygen reversibly bound, to it provides the major source of oxygen for cells. Oxygen is taken up in the lungs and released to the tissues. Each functional hemoglobin molecule binds one oxygen molecule at each iron atom for a total of four molecules of oxygen per hemoglobin molecule. For arterial blood, the normal range is 94.0 to 97.0%.

Oxyhemoglobin on the IL 682 is determined as follows:

$$\%O_2Hb = \frac{[O_2Hb]}{[HHb]+[O_2Hb]+[COHb]+[MetHb]} \times 100$$

Carboxyhemoglobin Percentage (%COHb)

Hemoglobin, with carbon monoxide reversibly bound, represents one of the dysfunctional forms which are unavailable to carry oxygen to the tissues. Hemoglobin affinity for carbon monoxide is 210 times that of oxygen, so COHb is effectively unavailable for oxygen transport. Small amounts of carbon monoxide are present as a metabolic end product in all human blood. Environmental exposure, however, can raise this level appreciably (see Bibliography).

%COHb is represented by the equation:

$$\%COHb = \frac{[COHb]}{[HHb]+[O_2Hb]+[COHb]+[MetHb]} \times 100$$

Methemoglobin Percentage (%MetHb)

Methemoglobin (ferri-hemoglobin) is a derivative of hemoglobin in which the ferrous iron is oxidized to the ferric state. Methemoglobin is a dysfunctional hemoglobin, in that it is unable to combine reversibly with oxygen or carbon monoxide. In addition, it causes a shift of the oxygen dissociation curve (P50) and hinders the transfer of oxygen from the blood to the tissues (see Bibliography).

The ability to measure methemoglobin levels in the blood is an important feature of the IL 682 CO-Oximeter system. At 1evels greater than 10%, however, the level of accuracy for measurement of other hemoglobin species may be affected.

%MetHb is represented by the equation:

$$\%\ \text{MetHb} = \frac{[\text{MetHb}]}{[\text{HBb}]+[\text{OzBb}]+[\text{COBb}]+[\text{MetBb}]} \times 100$$

Deoxyhemoglobin Percentage (%HHb)

Deoxyhemoglobin (formerly referred to as reduced hemoglobin) is a form of hemoglobin which is capable of reversibly binding oxygen, but is not presently combined with oxygen or other substances.

%HHb is represented by the equation:

$$\%\text{HHb} = \frac{[\text{HHb}]}{(\text{HHb})+[\text{O2Hb}]+[\text{COBb}]+[\text{MetHb}]} \times 100$$

Calculated Parameters

Oxygen Content (O2ct)

The oxygen content of a blood sample is directly displayed by the IL 682 system. It is a calculated value, based on the tHb and %OzHb. It has been determined that one gram of hemoglobin can be combined with 1.39 mL of oxygen, at STP (the IL682 allows input of value between 1.00 and 1.99 for oxygen multiplier). The calculation may be represented by the following equation:

$$02\ Content = 1.39 \times tHb \times \frac{\%O2Hb}{100}$$

This expression of oxygen content does not include physically dissolved oxygen and does not, therefore, express total oxygen content, but more correctly the oxygen content of hemoglobin. Data is expressed in terms of milliliters of oxygen at STP per one hundred milliliters of blood, or simply as Vol%O2. It may also be expressed as mmol/L.

Oxygen Capacity (O2Cap)

Oxygen capacity of a blood sample is related to oxygen content. Multiplying the tHb by 1.39 (see "Oxygen Content" above for derivation of 1.39) provides the volume of oxygen capable of being reversibly bound and transported at the available hemoglobin concentration of the sample. The equation for oxygen capacity must allow for carboxyhemoglobin and methemoglobin concentration, to express the capacity based on available hemoglobin. The equation for oxygen capacity is:

$$02\ Capacity = 139 \times THb \times 1 - \frac{(\%COHb + \%\ MetHb\ )}{100}$$

Like oxygen content, results are expressed in milliliters of oxygen at STP per one hundred milliliters of blood (Vol%O2) and does not include physically dissolved oxygen. 02Cap can also be expressed in terms of mmol/L.

Measured Oxygen Saturation Percentage (%S02)

The amount of oxyhemoglobin in blood expressed as a fraction of the amount of hemoglobin able to bind oxygen (oxyhemoglobin plus deoxyhemoglobin), is termed hemoglobin oxygen saturation. Oxygen saturation based on available hemoglobin is mathematically different from oxyhemoglobin percentage (%02Hb) based on total hemoglobin. Since both carboxyhemoglobin and methemoglobin are present at varying levels in the blood, but are not available for binding oxygen, the denominator of the %S02 and %02Hb equations for a given sample can be substantially different. The greater the concentration of these alternate hemoglobin forms, the more divergent the two expressions. (see "Oxyhemoglobin Percentage" above for the %OzHb equation). Select the appropriate base for expressing the oxygen-hemoglobin relationship. Each satisfies a different requirement and a different property of the oxygen-hemoglobin relationship.

The measured oxygen saturation percentage equation is:

$$\%SO2 = \frac{\%O2Hb}{100 - (\%COHb + \%MetHb)} \times 100$$

Detected/Corrected Interferences Fetal Hemoglobin Correction (HbF)

The presence of fetal hemoglobin (HbF) causes changes in the absorbance spectra as the fetal hemoglobin species differ from that of the adult. Corrections are made for both % carboxyhemoglobin and % oxyhemoglobin, by means of the following equations:

COBb (corrected) = %COBb (measured) - %COHb (fictitious)

%O2Hb (corrected) = %O2Hb (measured) + %COHb (fictitious)

where:
%COHb (fictitious) = m x %O2Hb (measured) + 0.24%

$$m = 0.065 \frac{(\%HbF)}{100} + 0.005$$

The %HbF is entered by the operator through the keyboard.

Sulfhemoglobin detection

Sulfhemoglobin (SHb) is a form in which the hemoglobin iron molecules are combined with sulfur. SHb can reversibly combine with oxygen, but the affinity is only 1 % that of SHb. Because of spectral characteristics at the wavelengths used by IL 682, SHb can interfere with other hemoglobin measurements. Typically, the presence of SHb causes an apparent increase in MetHb and negative results for COHb. IL 682 detects the presence of SHb by measuring the ratio of absorbances. This procedure differentiates between actual high MetHb and the suspected presence of SHb. If this procedure detects SHb above a prescribed level, the operator is warned and the data are flagged. Samples with low SHb, but which have abnormal absorbance spectra, can falsely trigger the SHb indicator.

Turbidity Correction

Light scattering in analytical samples is caused mainly by the presence of lipids. This scattering can interfere with absorbance measurements and affect CO-Oximetry results. Background "absorbance" changes resulting from sample turbidity have been found to exhibit a predictable relationship to wavelength and concentration of turbid material. IL 682 uses a dedicated wavelength to measure and correct for possible interference by the addition of turbidity.

Below levels of turbidity corresponding to 3.0% Intralipid, the IL 682 corrects the results without indication. At levels of turbidity corresponding to the addition of 3.0% or greater Intralipid, the IL682 corrects the results and displays a warning to the operator that high turbidity may be present. 3.0% added Intralipid corresponds to approximately 1500 mg/dL triglycerides.

Equipment

GEM Premier 3000 Instrument (P/N 570001000)
IL 682 Co-oximeter
Cerner VT320 terminal and keyboard

Installation Dates: OR and Peds Cath Lab – Septmember 21, 2004
3264 Main Lab - November 2, 2004

Supplies

GEM Premier 3000 PAK® Cartridge

Cartridge Types

iQM: CVP (Calibration Verification Material) material is run immediately after cartridge warm-up to verify cartridge calibration. The instrument then handles quality control automatically, and external controls are not required.

Part Number				
iQM Cartridge	**non-iQM Cartridge**	**Analytes**	**Maximum Tests**	**Use-Life (Days)**

Part Number iQM Cartridge	non-iQM Cartridge	Analytes	Maximum Tests	Use-Life (Days)
24315089	24315009	pH, pO_2, pCO_2, Hct, Na^+, K^+, Ca^{++}, Glu, Lac	150	21
24330089	24330009	pH, pO_2, pCO_2, Hct, Na^+, K^+, Ca^{++}, Glu, Lac	300	21
24345089	24345009	pH, pO_2, pCO_2, Hct, Na^+, K^+, Ca^{++}, Glu, Lac	450	21
24360089	24360009	pH, pO_2, pCO_2, Hct, Na^+, K^+, Ca^{++}, Glu, Lac	600	14

Cartridge Storage

Room temperature: 15 to 25°C (59 to 77°F).

Cartridge Expiration

Shelf-Life Expiration: The cartridge may be used up to and including the expiration date shown on the packaging.

On-board Expiration: The GEM Premier 3000 PAK cartridge must be replaced when the maximum number of tests are run, or when cartridge use-life is reached, whichever comes first.

Calibration Validation Product (CVP) and Controls for iQM Cartridges

GEM CVP

Part Number	Description
24001587	Multipak, 20 ampules, 5 x 4 levels x 2.5mL

GEM CVP solutions are used for the verification of the iQM cartridges prior to to reporting patient results.

GEM CVP 1 and 2 ampules: Aqueous buffered bicarbonate solution containing inorganic salts and organic metabolites, equilibrated with precise concentrations of carbon dioxide and oxygen.

GEM CVP 3 and 4 ampules: Aqueous buffered bicarbonate solution containing inorganic salts and equilibrated with carbon dioxide and oxygen.

One set of GEM CVP consists of 4 ampules with the following configurations.

GEM CVP 1: low pH, pO_2, Na^+, K^+, glucose, lactate; high pCO_2 and Ca^{++} values
GEM CVP 2: high pH, pO_2, Na^+, K^+, glucose, lactate; low pCO_2 and Ca^{++} values
GEM CVP 3: low hematocrit values
GEM CVP 4: normal hematocrit values

Quality Control for iQM Cartridges

Once the iQM cartridge is validated with CVP, the quality control process becomes an automatic part of the iQM cartridge operation. Process Control solutions A, B and C incorporated within the iQM cartidge, along with other iQM process checks, continuously monitor operation of the entire testing process including sensors, fluidics, and electronics, thus eliminating the need to run external quality controls.

External Quality Control for the GEM 3000

The first twelve months external controls will be run on the GEM 3000 to validate IQM and the internal controls. The QC schedule for the first year is as follows:

First six months (November 2, 2004 – May 22, 2005)

OR instruments: Level 1,2,3 of Contril per instrument per week.

3264 Main Lab: Level 1,2,3 of Contril per instrument per day.

After May 30, 2005

OR instruments: Contril level 1,2,3 per instrument per week.

3264 Main Lab: Contril level 1,2,3 per instrument per week.

Within Laboratory QC Proficiency.

Performed daily.

A pooled patient sample is run on all OMNI's along with a spun hematocrit for comparison of blood gases, sodium, potassium, ionized calcium, CO-OX parameters, glucose, and hematocrit values.

Bi-weekly Between Laboratory QC.

For comparison of all blood gas parameters included above

IL Quality Control (ContrIL® 9)

Part Number	**Description**
24001418	Multipak, 30 ampules, 10 x 3 levels x 2mL
24001419	Level 1, 30 ampules x 2mL
24001420	Level 2, 30 ampules x 2mL
24001421	Level 3, 30 ampules x 2mL

ContrIL9 includes three different ampules of aqueous, tonometered buffers. Each ampule contains known quantities of analytes at low, normal, and high physiological levels. For QC of pH, pCO_2, pO_2, Na^+, K^+, Ca^{++}, glucose, and lactate.

Performance Verification Product

Part Number	**Description**
24001525	PVP set, multipak, 4 x 5 levels
24001526	PVP Crit set, multipak, 4 x 4 levels

GEM PVP for periodic use, as designated by some regulatory agencies, and can be used with any cartridge type.

Storage

ContrIL 7 and GEM critCheck QC material should be stored at room temperature and is stable for use until the vial is opened or until the expiration date. ContrIL 9 and Calibration Validation Product (CVP) are stored refrigerated at 2 to 8ºC and are stable until the expiration date on the box. Alternatively, ContrIL 9 and CVP may be stored for up to 12 months at room temperature (up to 28ºC), as long as the expiration date on the box is not exceeded.

IL 682 CO-OX Controls

Run two levels, rotating levels 1,2,3, of IL CO-OX controls once per day on the OR instruments and every eight hours in the main lab.

IL Multi-4TM CO-Oximeter controls level 1, 2 and 3 are purified suspensions of human hemoglobin in a physiologically buffered matrix. The following parameters can be monitored with this control: tHb, %O2Hb, %COHb, and %MetHb. A fourth level is available which is a stabilized preparation of lysed bovine erythrocytes fully saturated with carbon monoxide. For more details on these products refer to the package insert. Store IL Multi-4 controls at 2-8^{o}C

Cartridge Insertion and Warm-up

Cartridge Insertion

1. Unlatch the cartridge door on the instrument's right side by sliding the lock handle to the front and opening the door.
2. Check the label on the foil bag containing the GEM Premier 3000 PAK cartridge to be sure that the cartridge is not past its expiration date.

CAUTION: Do not use an expired cartridge. The GEM Premier 3000 will not except an expired cartridge unless that date is set incorrectly. Please refer to the Operator's Manual, page 2.7 for instructions on setting the date/time.

3. Open the foil bag, and remove the cartridge.
4. Check the inside of the foil bag to be sure that it is dry.

CAUTION: If there is any moisture inside the foil bag, DO NOT USE the cartridge. Open a fresh GEM Premier 3000 PAK cartridge and call Technical Support at Instrumentation Laboratory.

5. Grasp the tab end of the plastic protective cover. Pull firmly to remove the cover.

NOTE: The cartridge must be inserted into the instrument within one minute of removing the protective cover.

6. Align the cartridge according to the labels. Using a rapid, smooth, continuous motion, insert the cartridge into the instrument's cartridge compartment.

NOTE: The cartridge will not insert all the way into the compartment. A small lip of the cartridge will rest on the door.

7. When the instrument has successfully read and validated the barcode and the date/time has been accepted, it will prompt you to close the cartridge door. If the instrument displays a message that the barcode reader did not read the label, follow the directions on the screen to complete the insertion process. The instrument will make three attempts to read the barcode before prompting the operator to use the barcode wand. If the barcode cannot be read, contact IL Technical Support.
8. The instrument will prompt: *Is the date/time correct*? If correct, select YES to proceed with warm-up. Otherwise, select NO to correct the date/time. The instrument will prompt: *Remove cartridge*. Remove the cartridge (see "5.5 Cartridge Removal") to begin the process again, changing the date and time when prompted.
9. Close the door, and slide the lock handle toward the back of the unit.

The cartridge door will lock. The GEM Premier 3000 will display the Cartridge Warm-up screen.

Cartridge Warm-up

Cartridge warm-up requires approximately 30 minutes. Samples cannot be analyzed during cartridge warm-up, but the instrument does allow access to many of the menu commands.

During cartridge warm-up, the instrument brings the measuring chamber to the proper temperature and performs several rinses and calibrations. If an error occurs during warm-up, the instrument will prompt for removal of the cartridge (see "5.5 Cartridge Removal" for instructions).

The GEM Premier 3000 will also determine the type of cartridge during cartridge warm-up. If a non-iQM cartridge is inserted, the instrument will continue with warm-up. If an iQM cartridge is inserted, the instrument's response will depend upon how iQM Mode has been configured:

- If iQM Mode is ON, it will be left ON.
- If iQM Mode is OFF, the instrument will display the message: *Would you like to enable iQM? If you enable iQM, CVP material should be ready for analysis. YES/NO.* If YES is selected, iQM Mode will be turned ON. If NO is selected, iQM Mode will remain OFF, and the iQM cartridge will be treated as a non-iQM cartridge.

After iQM Mode has been configured (ON or OFF), the mode cannot be changed for the duration of the inserted iQM cartridge. After the cartridge is removed, iQM Mode will remain at its current setting but will be available for changing, if desired.

When cartridge warm-up is complete, the instrument will display the Ready screen.

If an iQM cartridge is inserted and iQM Mode is ON, the instrument will display a reminder to run all levels of CVP material, and the status of all analytes will be set to "Pending CVP." All levels of CVP material must be run and within range before patient samples can be reported (see "5.3.1 Quality Control for iQM Cartridges").

Quality Control for iQM Cartridges

When you are using an iQM cartridge, CVP material must be run immediately after cartridge warm-up prior to being able to report patient results. The instrument then handles quality control automatically, and you are not required to run external controls.

CVP Sampling

NOTE: CVP material must be predefined by the Key Operator prior to running CVP samples.

1. Touch CVP on the Ready screen.
2. Enter an operator ID by entering the appropriate characters on the keypad or with the barcode wand. Touch ENTER.
3. Identify the CVP material:
    a) Lift the door to the ampule spinner, and insert and release the ampule. The reader will spin the ampule and read the barcode.
    b) If the lot number is not found, the instrument will prompt for a different ampule or for selection of material from a list of defined material.
    c) If the lot number matches the lot number of a defined material, the instrument will prompt for sample aspiration. If the selected material only contains analytes that have failed calibration, the instrument will abort the sampling process.
4. Prepare the CVP material:

a) Mix the solution by vigorously shaking the ampule.

b) Tap the solution from the tip of the ampule to restore solution to the bottom part of the ampule. Allow bubbles to dissipate for at least 10 seconds.

c) Use the instrument's ampule breaker to snap off the ampule neck.

CAUTION: Analyze CVP solution within one minute of opening the ampule.

5. Position the ampule on the sampler when the screen instructs you to do so. Make sure the sampler is near, but not touching, the bottom of the ampule. Touch OK.

6. Remove ampule AFTER the instrument beeps four times and displays the message *Remove the sample.* The instrument will wait two seconds for removal of the sample before withdrawing the sampler.

7. Dispose of ampule in an appropriate waste container.

8. The instrument will take 85 seconds to process the sample and display results. During this time, a progress indicator will be displayed. The Sample Information screen will also be displayed to prompt for entry of sample information.

CVP Sample Information

9. Enter Operator ID as necessary:

   - If Operator Security is ON and an operator password was previously entered, the operator ID associated with the password will be displayed. This ID cannot be changed.
   - If Operator Security is OFF, no operator ID will appear, and the ID can be entered (up to 16 alphanumeric characters) or left blank as desired.

10. Enter an optional sample comment to record a short description with the sample. This comment, up to two lines of 24 characters each, will be saved, printed, and transmitted with the sample.

CVP Sample Results

Measured results will be displayed along with the expected results. If the measured values fall within the expected range, "Pass" will be displayed. If a measured value falls outside the expected range, the screen and print-out indicate a failure with the message "Fail" and a "F" on the hard copy print-out next to the analyte which has failed. CVP data is automatically downloaded into an on-board computer memory for future analysis and transferred to disk for record keeping.

NOTE: The instrument stores all data generated while a cartridge is in service and for at least 20 cartridges.

CVP Sample Disposition

If one or more of the CVP analytes failed and you select the ACCEPT or DISCARD button, the instrument will prompt with the message: *CVP failure. Perform 2-point calibration before repeating the failed CVP sample.* Touch OK, then initiate a 2-point calibration from the DIAGNOSTICS menu prior to repeating the CVP sample.

NOTE: The sensor status on the Ready screen will not change to Green/OK until all CVP materials associated with that analyte are run and passed. Sensor status will remain as either yellow/Pending CVP, or red/Failed CVP. CVP failures will be cleared when the failed CVP material is run and passed or when the cartridge is replaced.

- Touch the ACCEPT button after the sample has been reviewed and deemed satisfactory and after any user-entered information has been edited. No further editing of the sample will be allowed.

  When you accept a CVP sample, the instrument will:

  – Set the sample's disposition to ACCEPTED, and save the sample to the database.

  – Print a sample report.

  – Send the results to the LIS/DMS (if configured).

  – Satisfy the CVP requirement.

  – Return to the Ready screen.

- Touch the DISCARD button after the sample has been reviewed and deemed not valid for some reason. No further editing of the sample will be allowed, and **the sample's disposition cannot be changed from DISCARDED**. The instrument will prompt to confirm the disposition. If NO is selected, the discard request will be aborted. If YES is selected, the instrument will:

  – Set the sample's disposition to DISCARDED, and save the sample to the database.

  – Return to the Ready screen.

CVP Failure

If a measured value falls outside the expected CVP range for an analyte, the screen displays CVP FAIL and highlights any analyte that failed. To correct the failure:

11. Use 2-PT CAL on the DIAGNOSTICS menu to run a 2-pt calibration before trying to repeat the failed CVP run.
12. Repeat the CVP with freshly opened CVP material from the same CVP lot.
13. If the failure is corrected, ACCEPT the CVP results.
    - If the original failure is corrected but a new analyte fails, repeat the CVP with freshly opened CVP material from the same CVP lot one more time.
    - If the failure is corrected, ACCEPT the CVP results.
    - If the failure is not corrected, remove the cartridge and notify Technical Support.

NOTE: If a CVP failure persists, the analyte(s) will not be available.

IMPORTANT: Ensure that enough CVP material is on hand toward the end of a lot to clear any existing failure conditions. Only CVP material from the same lot can clear an error condition for that lot.

If a patient sample is run while an analyte is in the Pending CVP or Failed CVP state, the result will not be reported. On the screen, the result will be flagged with "V" and blanked out. The printed report will display "PENDING CVP" or "FAILED CVP" as appropriate.

Calibration

Cancellations from Calibrations

If an interruptible calibration is in progress, the instrument will interrupt the calibration and start the sampling process. The following calibrations cannot be interrupted:

- Two-point calibrations during the first four hours of cartridge life
- Two-point calibrations after the first four hours of cartridge life if the three previous two-point calibrations were interrupted for sample analysis
- Low O_2 calibrations
- The first one-point calibration after sample analysis

For more information about calibrations, see "5.4 Calibration."

Note: Do not interrupt a calibration unless it is absolutely necessary to analyze an urgent sample. If a calibration is interrupted, always allow the sample analysis to complete.

GEM Premier 3000 calibrations are automatic. During calibrations, the instrument internally checks each sensor's performance to verify correct operation. Calibration data is automatically downloaded into an on-board computer memory for future analysis and transferred to disk for record keeping.

The GEM Premier 3000 incorporates a two-point calibration for all parameters except hematocrit. Calibration values are read into the GEM Premier 3000 via the cartridge bar code. When you insert a cartridge, the instrument pumps Reference Solution B into the electrode chamber and hydrates the sensors for 15 minutes. One- and two-point calibrations are performed according to the schedules below.

Two-point calibrations last approximately 2.5 minutes (4.5 min within the first 6 hrs). During this time, the instrument will remain at the Ready screen (during a two-point calibration). The calibration progress indicator will appear at the bottom of the Ready screen. After calibration, a print-out is generated. If all sensors are operating correctly, the print-out includes a "No Errors" message. (Note: the content of the Calibration Report is determined by the option chosen during instrument configuration.) If a slope or drift error is detected, the analyte which has failed will be flagged with a "slope error" or a "drift error" message. The instrument will then withhold results for that analyte until sensor performance returns to normal.

One-point calibrations occur every 30 minutes, at a minimum, and after every patient sample.

Calibration Schedules

One-Point Calibration Schedule

Cartridge Life after Warm-up	Calibration Frequency
0.5 to less than 3 hours	every 2 minutes
3 hours to less than 6 hours	every 4 minutes
6 hours to less than 10 hours	every 6 minutes
10 hours to less than 20 hours	every 10 minutes
20 hours to less than 40 hours	every 15 minutes
40 hours to less than 80 hours	every 20 minutes
80 hours or greater	every 30 minutes

Between one-point calibrations, all sensor outputs are monitored every 30 seconds, and an automatic one-point calibration will be initiated if the instrument detects excessive drift in any channel.

Two-Point Calibration Schedule

Cartridge Life after Warm-up	Calibration Frequency
30 min. to less than 50 min.	every 20 minutes
50 min. to less than 80 min.	every 30 minutes
80 min. to less than 2 hours	every 40 minutes
2 hours to less than 8 hours	every hour
8 hours to less than 20 hours	every 2 hours
20 hours to less than 40 hours	every 3 hours*
40 hours or greater	every 4 hours*

* Or 20 samples, whichever comes first.

During the recovery following instrument restart, the instrument will perform a one-point or two-point calibration as needed before the Ready screen is displayed, then the calibration frequency will resume according to the previous schedule.

Low O_2 Calibration Schedule

Low O_2 calibrations occur once every 24 hours throughout cartridge life, after warm-up. Following the low O_2 calibration, the instrument will perform one-point calibrations every three minutes for 15 minutes, then return to the previous schedule. The exact time of the day for performing the low O_2 calibration is determined by the Key Operator during instrument setup.

Calibration Notes

Calibration Failure

If an automatic one-or two-point calibration fails, the GEM Premier 3000 will automatically initiate up to two additional one-or two-point calibration sequences in an effort to recover from a failure. If the sensor does not respond to the automatic two-point calibrations, then the appropriate error message will be printed on the calibration report, and the status indication on screen turns red.

There are three actions you may choose to take if these automatic calibrations fail to clear the error:

- Continue to use the cartridge and report only the results from the working sensors.
- initiate a manual two-point calibration.

NOTE: Because the instrument will automatically perform up to two one- or two-point calibrations after a calibration error has occurred, if you initiate a manual calibration, you may significantly delay sensor recovery.

- Contact Technical Support and replace the cartridge.

Calibration Interruption

Calibrations can be interrupted to analyze samples in certain circumstances. If a sample is run when the instrument is performing a calibration that cannot be interrupted, it will display the message *Calibration in progress* for non-iQM cartridges or *Process Control in progress* for iQM cartridges.

The following calibrations cannot be interrupted to analyze a patient sample:

- Two-point calibrations during the first four hours of cartridge life

- Two-point calibrations after the first four hours of cartridge life if the three previous two-point calibrations were interrupted for sample analysis
- Any low O_2 calibration
- The first one-point calibration after sample analysis

The following calibrations cannot be interrupted to analyze a QC or CVP sample:

- Any low O_2 calibration
- Any two-point calibration
- The first one-point calibration after sample analysis

NOTE: Do not interrupt calibrations in progress unless it is absolutely necessary to analyze an urgent sample. If a calibration is interrupted, always allow the sample analysis to complete.

Cartridge Removal

The cartridge must be replaced when its use-life or sample capacity has been reached (see "3.2.4 Cartridge Expiration"). A cartridge must also be replaced if the power has been off for more than one hour or off more than 20 minutes if blood has rested on the sensors or an "A" or low O_2 calibration is in progress. The instrument displays *Remove and discard the cartridge*, as well as a reason for the removal request.

The instrument saves the data from 20 to 40 cartridges. After 40 cartridges have been inserted, the instrument will prompt you to perform database maintenance. See "5.5.1 Copy Cartridge Data" for information about saving cartridge data.

1. Slide the handle on the right side of the instrument toward the front of the instrument and open the door.
2. Grasp the cartridge in the compartment, and pull it straight out.
3. Dispose of cartridge in an appropriate biohazard container.
4. Install a new cartridge when the instrument displays the Insert Cartridge screen. See "5.1 Cartridge Insertion and Warm-up."

Copy Cartridge Data

You can copy the data that the instrument has generated while a cartridge is in use whenever the instrument is at the Ready screen, or between instrument acknowledgment of cartridge removal and insertion of a new cartridge.

One data diskette must be used per cartridge, even if the cartridge has processed only part of its full capacity.

NOTE: If the disk already contains cartridge data, the instrument will give you the opportunity to replace the disk or overwrite the data.

5. Touch COPY CART. DATA on the DIAGNOSTICS menu.
6. Select the cartridge to be copied by touching its entry in the listing.
7. Touch COPY.
8. Insert a blank, PC-formatted, high-density 3.5" diskette, with its label facing the front of the instrument.
9. Touch OK. When copying is complete, the instrument will display a message stating so.

10. Remove the disk, and touch EXIT.
11. Write-protect the disk by sliding the square tab on the back of the disk toward the edge to expose the small hole.
12. Label and store the disk in a safe place.

Copy iQM Data

You can copy the iQM performance data stored by the instrument to a diskette with COPY iQM DATA on the DIAGNOSTICS menu. Copying iQM data does not remove it from the instrument. iQM data will be removed from the instrument only when the data is older than 1 year. At that point, the data from the oldest month will be automatically deleted.

1. Select COPY iQM DATA from the DIAGNOSTICS menu.
2. Insert a blank, PC-formatted, high-density, 3.5" , with its label facing the front of the instrument.
3. Touch OK. When copying is complete, the instrument will display a message stating so.
4. Remove the disk, and touch EXIT.
5. Write-protect the disk by sliding the square tab on the back of the disk toward the edge to expose the small hole.
6. Label and store the disk in a safe place.

SPECIMEN

1. Samples can be analyzed either from a heparinized (Li or balanced) syringe, capillary tube (220 uL), or ampoule adapter.
2. Arterial, venous or capillary blood anticoagulated with either Li heparin or modified heparins such as calcium-balanced, zinc-balanced, or low amounts of dispersed heparin are the anticoagulants of choice. Ammonium heparin, EDTA, citrate or oxalate is not recommended for electrolyte or hematocrit analysis. Green top vacutainer tubes are acceptable for Na/K, Ionized Calcium, Glucose, and body fluid pH only. Grey top tubes are acceptable for lactate only.
3. For hematocrit, whole blood is the only acceptable specimen.
4. While storage of blood in plastic syringes on ice may produce an artificially high PO2 (see Ref 6), whole blood samples must be stored on ice if they cannot be delivered to the laboratory within 10-15 mins. Once within the laboratory, ice storage is not necessary unless a delay is expected. When sending samples for blood gas analysis on the pneumatic tube system, storage of samples on ice is not recommended.
5. For ionized calcium specimens, the preferred specimen is at least 400 uL of whole blood collected anaerobically in a syringe that has no air bubbles, is at least 1/2 full and contains either a minimal amount of dry heparin or an electrolyte balanced heparin. If the sample cannot be analyzed within 1 hour, the syringe may be stored on ice for up to 4 hours.

   If the preferred anaerobic heparinized whole blood cannot be collected in a syringe, whole blood may be collected in a red top or green top container, providing the vacutainer is filled with blood leaving minimal air space. A minimum volume of 1 mL is required. For green top tubes the heparinized wholeblood may be aspirated directly.

If a red top tube is received, process as follows:

a. If not coagulated allow the blood to clot in the original closed container at room temperature for for up to 15 – 20 mins.
b. Centrifuge the blood in the stoppered container.
c. Remove serum with a plastic 1 ml tuberculin syringe and cap using a luer tip cap. Expel any air bubbles. Analyze the sample as soon as possible.
d. Anaerobic plasma or serum is stable in stoppered containers at refrigerated ($4^{o}C$) for up to 72 hours.

When to report the pH-corrected ionized calcium

Normally, the pH-corrected ionized calcium result should not be reported, as it will likely cause confusion in interpreting the ionized calcium result. However, pH-corrected ionized calcium is sometimes useful and may be required in some situations.

Use of the pH-corrected ionized calcium concentration is required when:

1. The sample (serum or whole blood) has obviously been exposed to air for more than 10-30 minutes. This is especially so for samples collected in standard vacutainer-type tubes. If the cap has been removed from a syringe containing whole blood collected with no air introduced into the syringe, the ionized calcium will probably not be affected for a longer period, perhaps as long as 60 min.
2. A relatively small volume of sample has been collected in a tube or syringe with a large air space also in the container.
3. Whenever the sample has been frozen.

The pH-corrected ionized calcium result may be useful when a properly-collected whole blood sample has sat at room temperature for over an hour. Many times, the ionized calcium will change very little under this circumstance. However, a pH below 7.30 would indicate changes have occurred that might significantly affect the ionized calcium result.

Ionized calcium corrected to pH 7.4 should be reported as a footnote as follows:

Ionized Calcium (7.4) = x.xx mmol/L reported due to specimen instability.

6. For pH body fluids such as Blood, Pleural fluid, CSF, Thoracentesis fluid, Chest drainage, etc:
   a. If the specimen appears to be free of clots and debris, no processing is necessary before analysis. If the specimen appears to have clots and debris, sample should be centrifuged using the Statspin centrifuge before analysis.

PROCEDURE

Sample Volume

The syringe or capillary that is used must be filled nearly to capacity to prevent excessive heparin concentration in the sample.

Minimum sample requirements for the cartridge in use are as follows:

GEM 3000 Sample Volume	Cartridge Analytes
150uL	BG/Hct/Lytes/Glu/Lac
145uL (capillary mode)	BG/Hct/Lytes/Glu/Lac

GEM 3000 Sample Volume	Cartridge Analytes
135uL	BG/Hct/Lytes
135uL	BG/Hct
IL 682 CO-OX Sample Volume	
65uL	CO-OX

CAUTION: All patient specimens should be treated as infectious. You should use personal protective equipment and techniques to avoid creating aerosols or contaminating yourself.

1. Obtain a properly collected sample (Syringe or Vacutainer Sampling (240 ul))
2. Expel any air bubbles. Mix the sample for 30 seconds by rolling the syringe in the palm of the hands for 15 seconds, then reverse the syringe and mix an additional 15 seconds using the same technique. Check for clots.
3. Check for the presence of clots: remove the cap, and expel a drop or two of the sample onto a gauze pad. If clots are suspected, obtain another sample.
4. Select analytes or panels to be tested by touching the panel or analyte on the ready screen. A check mark will appear in the analyte box on the Ready screen. To deselect analytes, touch the analyte box again to remove the check mark.
5. Specify the sample type by touching ARTERIAL, VENOUS, CAPILLARY, or OTHER at the Ready screen.
6. Touch OK after you have entered all patient information and user-entered analytes.
7. Analyze the sampe immediately. position the sample so that the sampler is near, but not touching, the bottom of the syringe plunger. For a capillary sample, attach the capillary tube or capillary and adapter to the sampler. Then touch OK.
8. Remove the syringe, capillary tube, or capillary and adapter from the sampler when the instrument beeps four times and prompts you to do so.
9. CAUTION: Care should be taken to remove the sample quickly so as not to bend the sampler.
10. If the sample analysis includes CO-Ox analytes, the instrument will prompt for introduction of the CO-Ox sample. Touch OK, and introduce the sample to the CO-Oximeter and press sample.
11. Dispose of sample in a biohazard waste container.
12. The instrument will take 85 seconds to process the sample and display results. During this time, a progress indicator will be displayed. The Patient Information screen will also be displayed to prompt for entry of sample information.
13. Enter or scan in the Pathnet accession number in the Patient ID and Accession number fields from the Pathnet label.
14. After results have printed, the data is transmitted to Impact and Pathnet.
15. At the Cerner terminal type C to log on and type username and password.

NOTE: EACH EMPLOYEE MUST USE THEIR OWN USERNAME AND PASSWORD. FAILURE TO DO SO WILL RESULT IN DISCIPLINARY ACTION.

16. Enter TSA at the select prompt and press RETURN.

17. Enter 350 for the Workcenter (WC) and Testing Site number (TS) and press RETURN.
18. At ACC # prompt, press RETURN to enter the Julian date of the accession number. Enter the last four digits of the accession number and press RETURN.
19. All patient results performed by the analyzer and successfully transmitted across the interface will be displayed. If the cursor stops at a line, then PathNet requests an answer to this field. Enter the results of each requested field.

QNS (Quantity Not Sufficient) AND TD(Technical difficulty) SAMPLES:
Press the Convert to Alpha Key (F12) and type in QNS or TD in the appropriate field. On the keybroad list expedite key codes that may be used to enter the listed codes as comments.

ENTERING FIO2 VALUES: FIO2 values are entered in Pathnet as a percentage. FIO2% values expressed in liters/min can be converted to FIO% by using the table below. If no values or given for either FIO2 or liters then enter an asterisk in the FIO2 field. To do this you must press the F12 (convert to alpha) key, then check for any footnotes already present. In many cases the FIO2 listed in liters will be displayed as an order level footnote.

Conversion of Liters of Oxygen to FIO_2 %

Liters/min	FIO_2 %
1.0	24
1.5	26
2.0	28
2.5	30
3.0	32
3.5	34
4.0	36
4.5	38
5.0	40
5.5	42
6.0	44

20. Footnotes can be entered at this time if necessary.
    Note: Footnotes should be entered only on parameters which cross to DHIS. Parameters that do not cross to DHIS are pH ins and analyzer #. All alert results should be footnoted with time, date, and initials of person to whom results were given.

ENTERING FOOTNOTES

To enter footnote return to the line with the alert parameter. Press the F11(Footnote Key). If there are any existing comments on the patient, Pathnet will offer to display them. Comments should be checked for important patient information. After viewing footnotes, press the (F8) "Home" key to restore the screen. Press the F11 key until you see the display "enter footnote after entering result". Enter correct result and press "Return". A window will open up. All footnotes to be placed on the patient's chart are to be entered above the

line. Footnotes for lab use only should be entered below the line. Press the "Home" key to close the window and save the footnote

NOTE: When results are outside of the reportable limits, footnote using the appropriate expedite key.

21. “Results correct (Y/N/R/D)" is displayed. Press Y if results are correct, N if results are not correct and you wish to change them, R if result was changed that is a component of a calculation, or D to enter dilution factor.
22. When Y is pressed, the system prompts for the lines to be verified. After these lines are entered, "Ver/Perf info correct?" is displayed. Pressing Y verifies the results and sends them to DHIS. "Results posting-please wait" is displayed by the system. Pressing N allows changes to be made in the lines verified or performed.

ENTERING RESULTS ON THE SAME SAMPLE WITH DIFFERENT ACCESSION NUMBERS:

23. Run sample and transmit data across interface of one accession number. Manually input data for the other accession numbers, Or change ID # to other acc # on the analyzer and retransmit. Then follow steps k-p if necessary.
24. Exit TSA by pressing PF3.
25. Exit PathNet by typing Q.

Interference/Micro Clot Checking

Flagging of Patient Results Off (Default Setting)

If the GEM Premier 3000 has not been configured to flag patient results when interference or micro clots are detected, then the instrument will begin the interference/micro clot check after the Patient Sample Results screen is displayed. Affected analytes will not be flagged in the displayed or printed patient results.

- If a micro clot is detected, the instrument will beep three times, display a message, and initiate a clot removal cycle.
- cartridges, the instrument will automatically check for micro clots again. If a clot is found, then the sensor will be disabled and given “iQM error” status.
- for non-iQM cartridges, the instrument will display a message recommending that an external QC be run to verify cartridge performance.
- If an interference is detected, the instrument will beep three times, display a message, and rinse the sensors. This happens for both iQM and non-iQM cartridges. The message will remain displayed until acknowledged by the operator.

For more information about setting the interference/micro clot option, see “Flag Patient Results for Interference and Micro Clots” on page 3.33.

Reporting of Results

The Patient Sample Results screen is displayed after:

- patient results are ready, and
- you have touched EXIT at the Patient Information screen (if that screen was presented), and
- interference/micro clot determination, if enabled, has been completed.

The Patient Sample Results screen will be displayed for 90 seconds. After 90 seconds,

- If Patient Sample Auto-Accept is ON, the sample will be given a disposition of ACCEPTED.
- If Patient Sample Auto-Accept is OFF, the sample will keep whatever disposition you have assigned it. If no disposition has been set, it will be given a disposition of PENDING.

The instrument returns to the Ready screen. Patient results are automatically downloaded into on-board computer memory for future review and documentation.

Temperature Corrections

1. Temperature corrections can be performed in the IMPACT Data Management System.
2. Bring up IMPACT CRITICAL CARE on the desk top if it is not already up.
3. Type in your **ID** and **PASSWORD**. Click on **X** at the **QC Message Reminder**
4. Click on the **Black Arrow** back button located in the right hand corner of the **Patient Sample Result** screen**.**
5. Click on **Sample** in the upper left hand corner and scroll down to select **Edit.**
6. Use the Patient **HISTORY NUMBER** to search for **PT. ID.** Then click on **SEARCH.**
7. Choose the sample that needs to be corrected by double clicking on it.
8. On the **Patient Sample Result Screen**, type in the correct temperature.
9. Click on the **SAVE** icon (disc on the right side of the screen).
10. Changes are not saved. Do you want to save now? Answer save.
11. No order associated with this sample. Would you like to send it? Answer yes. If results have not been verified, only the **pH** will be transmitted to Pathnet. The **pCO2** and **pO2** results must be entered using **ECR**. If the results have been verified, all results must be entered using **ECR**.
12. Click on the **Black Arrow** back button located in the right hand corner of the screen.
13. Minimize the screen to log on to Pathnet. Use **ECR** to enter necessary results.

Instrument Interface Setting

See configuration/interface set-up on the GEM 3000. Settings are also listed on a spread sheet posted on the cabinet above the Senior's desk.

Analyte Reportable Ranges

Measured Analytes	**Reportable Ranges**
PH	6.80 to 7.80
pCO_2	5 to 150 mmHg
pO_2	0 to 760 mmHg
Na^+	100 to 200 mmol/L
K^+	1.0 to 20.0 mmol/L
Ca^{++}	0.10 to 4.00 mmol/L
Glucose	20 to 500 mg/dL
Lactate	0.3 to 15 mmol/L
Hct	15 to 65%

CAUTION: A DASH (-) on the display or print-out appears when there is an error in the calculation of the derived parameter.

Derived Analytes	Reportable Ranges
HCO_3^-	3.0 to 60.0 mmol/L
HCO_3^-std	3.0 to 60.0 mmol/L
TCO_2	3.0 to 60.0 mmol/L
BE(ecf)	-30.0 to +30.0 mmol/L
BE(B)	-30.0 to +30.0 mmol/L
SO_2c	0 to 100%

CALCULATIONS

All calculations are done automatically on the GEM 3000

Limitations and Interferences

Limitations

Limitation	Description
Contamination with Room Air	Especially samples having a very low or high pO_2 content. Similarly, pCO_2 may be affected and subsequently pH and Ca^{++} results as well.
Metabolic Changes	Errors can occur due to metabolic changes if there is a delay in the measurement of the samples.
Elevated White Blood Cells or Reticulocyte Counts	Samples will deteriorate more rapidly, even when kept in ice water.
Improper Mixing	Errors will be introduced if the sample is not properly mixed prior to measurement.
Changes to Manufacturer's Instructions or Method Verification Protocols	Data obtained data may be compromised.
Improper Installation	The instrument must be installed per the manufacturer's instructions. Prior to initiating any method evaluation protocol, acceptable cartridge performance must be demonstrated by acceptable calibration (no slope or drift errors) and all levels of QC solutions within acceptable ranges for non-iQM cartridges; all levels of CVP must be run and within acceptable ranges for iQM cartridges.
Under-Heparinized Sample	Blood clot can form in the sensor chamber causing various sensor failures if sample is not properly heparinized.

Interferences

The following substances can potentially interfere with sample analysis:

- Severely abnormal plasma osmolarities or abnormal levels of proteins or lipids.
- Hematocrit values produced by the GEM Premier 3000 may differ significantly from the values produced by a cell counter. In general, abnormally high protein or lipid values may cause higher hematocrit values, and vice-versa.

- Benzalkonium Chloride (see Note 1, next section): Arterial lines and sampling devices coated with Benzalkonium Chloride cause falsely elevated sodium and ionized calcium readings.
- Benzalkonium Heparin (see Note 1, next section): Arterial lines and sampling devices coated with Benzalkonium Heparin cause falsely elevated sodium and ionized calcium readings.
- Thiopental sodium (see Note 2, next section): May interfere with the sodium, potassium, pCO_2 and ionized calcium readings (see Note 3, next section).
- The anesthetic halothane may produce unreliable pO_2 results due to interferences with pO_2 sensor.
- Ethylene glycol and its metabolite glycolic acid can show a severe interference to lactate measurement.
- The following compounds **did not** show noticeable interference with glucose and lactate determinations at the tested level:

Compound	**Test Level**	**High "Normal" Level**[1]
Ascorbic acid (vitamin C)	3 mg/dL	2 mg/dL
Uric acid	20 mg/dL	7 mg/dL
Dopamine	2 mg/dL	0.03 mg/dL
Dobutamine	2 mg/dL	0.03 mg/dL

The following tested drugs may interfere with glucose or lactate determination, causing falsely low readings:

Drug	**Interference Observed**	**High "Normal" Level**[2]
Flaxedil	? 2 mg/dL	1.4 mg/dL
Ethanol	? 350 mg/dL	100 mg/dL (toxic)

- The following tested drugs may interfere with glucose and lactate determinations, causing falsely elevated readings:

Drug	**Interference Observed**	**Maximum Therapeutic Level**[2]
Acetaminophen (Tylenol)	? 15 mg/dL	2 mg/dL
Isoniazide (Nydrazid)	? 2 mg/dL	0.7 mg/dL (toxic)
Thiocyanate	? 10 mg/dL	2.9 mg/dL
Hydroxyurea	? 0.5 mg/dL	2 mg/dL

- The following tested anticoagulants may interfere with glucose and lactate determinations, causing falsely low readings:

Anticoagulant	**Positive Interference**[2]
Sodium fluoride	? 1 g/dL
Potassium oxalate	? 1 g/dL

Interference Notes

Both iQM and non-iQM cartridges employ Failure Pattern Recognition (FPR) checks. One of the FPR checks that the GEM Premier 3000 recognizes is for the positively charged lipophilic compound Benzalkonium. Following sample analysis, and analysis of Process Control Solution B, if Benzalkonium Chloride or Benzalkonium Heparin patterns are detected, the following message will be displayed on the analyzer:

Sensor Interference Detected for Na and iCa on last sample likely due to Benzalkonium

The GEM Premier 3000 offers the operator the ability to enable flagging of patient results if an interference pattern is detected. In addition, this option, when enabled, delays the reporting of results until Process Control Solution B is evaluated for interference patterns, following sample analysis. If flagging of patient results for an interference is enabled (see page 3.33), the following message (plus progress bar) will be presented while the post analysis Process Control Solution B check is underway:

Checking for presence of interference and micro clots

This message will remain displayed until the Process Control Solution B, analysis is complete. If an interfering substance pattern is detected, the affected blood result(s) will be flagged. In addition, the analyzer will beep three times to alert the operator. The following message disappears only after operator acknowledgment:

Sensor Interference Detected for Na and iCa on last sample likely due to Benzalkonium

14. Another FPR check that the GEM Premier 3000 recognizes is for negatively charged lipophilic compounds, such as Thiopental Sodium. Thiopental Sodium is also known by other names, including: thiomebumal sodium, penthiobarbital sodium, thiopentone sodium, thionembutatal, pentothal sodium, nesdonal sodium, intraval sodium, traoanal, and thiothal sodium.

    Following sample analysis and analysis of Process Control Solution B, if the associated pattern is detected in Process Control Solution B, the following message will be displayed on the analyzer:

    Sensor Interference Detected for xxxxx on last sample (where xxxx is the analyte or analytes affected)

    The GEM Premier 3000 offers the operator the ability to enable flagging of patient results if an interference pattern is detected. In addition, this option, when enabled, delays the reporting of results until Process Control Solution B is evaluated for interference patterns. If flagging of patient results for an interference is enabled (see page 3.33), the following message (plus progress bar) will be presented while the post analysis Process Control Solution B check is underway:

    Checking for presence of interference and micro clots

    This message will remain displayed until the Process Control Solution B analysis is complete. If the associated pattern is detected, the affected blood result(s) will be flagged. In addition, the analyzer will beep three times to alert the operator. The following message disappears only after operator acknowledgment:

Sensor Interference Detected for xxxxx on last sample (where xxxx is the analyte or analytes affected)

NOTES AND PRECAUTIONS

1. Samples must be free of air bubbles.
2. Samples must be mixed for 30 seconds.
3. Samples must be free of clots.
4. Sample must be analyzed within 20 minutes after it is drawn.
5. An elevated potassium should be checked for hemolysis.
6. Samples containing air bubbles that are sent by pneumatic transport can have an altered PO_2. See reference 9. Footnote results if air bubbles were present in the sample when received.
7. PH may be measured on body fluids by the GEM 3000 analyzers and reported. The Blood Gas Laboratory subscribes to the CAP Body Fluid Survey that includes pH.

PRECISION

Data from whole blood sample.

	PH	**PCO2**	**PO2**	**NA**	**K**	**CA**	**GLU**	**LAC**	**HCT**
Mean	7.161	66.3	80.9	144.6	4.24	1.109	85.3	7.68	31.7
SD	.007	1.033	1.356	1.404	0.063	.022	2.289	.086	0.458
CV	.104	1.559	1.677	0.971	1.492	1.954	2.682	1.122	1.442
N	15	15	15	15	15	15	15	15	15

REFERENCE INTERVALS

	Arterial	**Venous**	**Capillary**
pH	7.35 - 7.45 units	7.32 - 7.42 units	
PCO2	35 - 45 mm Hg	39 - 55 mm Hg	
PO2	75 - 100 mm Hg	30 - 55 mm Hg	60-76 mmHg
Na	135 - 145 mmol/L		
K	3.2 - 4.8 mmol/L		
HCT	0.39 - 0.49 Male		
	0.35 - 0.45 Female		
HCO3	20 - 28 mmol/L		
TCO2	21 - 30 mmol/L		
BEb	-3.0 - 3.0 mmol/L		
Gluc	70 – 140 mg/dL		
Lac	0.5 – 1.6 mmol/L	0.5 – 2.2 mmol/L	
ICa	1.15 - 1.32 mmol/L		

ALERT VALUES

	Arterial		Venous	
	Below	**Above**	**Below**	**Above**
PH	7.25	7.60	7.33	7.58
PCO2	25 mmHg	65 mmHg	28 mmHg	65 mmHg
PO2	50 mm Hg	-	-	-
Na	120 mmol/L	155 mmol/L	-	-
K	2.8 mmol/L	6.0 mmol/L	-	-
HCT	0.15	-	-	-
THb	5.0 g/dL	-	-	-
Gluc	50 mmol/L	350 mmol/L	-	-
Lactate	-	5.0 mmol/L	-	5.0 mmol/L
%O2Hb	85 %	-	-	-
TCO2	6.0 mmol/L	-	-	-
CA	0.87 mmol/L	1.41 mmol/L	-	-

CLINICAL SIGNIFICANCE

Blood Gases

pH
Arterial pH indicates whether the acid-base status is acidemic, alkalemic, or normal.

PCO2
PCO2 represents the balance between cellular production of CO2 and ventilatory removal of CO2. It is sensitive indicator of hyperventilation or ventilatory failure.

PO2
Arterial PO2 indicates the oxygenation status, which is usually related to the ability of the lungs to oxygenate blood. PO2 measurements are used as a guide for initiating and/or monitoring oxygen therapy and/or ventilatory assistance.

SODIUM/POTASSIUM
Sodium is the major cation of extracellular fluid and is a major factor in regulating both the osmolality and volume of blood. Hormones such as aldosterone and ADH, and intake of water and salt have important effects in determining the sodium concentration of blood.

Causes of Hyponatremia:
1. Inappropriate ADH secretion
2. CHF or cirrhosis
3. Decreased secretion of aldosterone (as in Addison's disease) causing decreased reabsorption.
4. Diarrhea or vomiting with hypotonic fluid replacement.
5. Renal diseases: Nephrotic Syndrome, acute or chronic renal failure.
6. Polydipsia

Causes of Hypernatremia:

1. Defect in ADH production, secretion, or response.
2. Dehydration from inadequate fluid replacement.
3. Brain injury causing loss of thirst.
4. Diabetic coma after therapy with insulin
5. Excess treatment with sodium salts

Potassium is the major intracellular cation. It is important in neuromuscular excitability, cardiac rhythm, and acid-base balance.

Causes of Hypokalemia:
1. Thiazide diuretics, furosemide: increased urine flow
2. Hyperaldosteronism (causes decreased reabsorption in the proximal tubules)
3. Alkalosis - K+ movement into cell is matched by movement of H+ from the cell
4. Hypomagnesemia

Causes of Hyperkalemia:
1 Excess Dietary intake in patients with renal disease.
2. Insulin deficiency
3. Renal Failure
4. Aldosterone deficiency
5. Oliguria, anuria, or uninary obstruction.
6. Artifacts of improper collection: hemolysis, ice storage.

IONIZED CALCIUM

Ionized calcium is the form of calcium that is physiologically active. Approximately 50% of the total circulating calcium is ionized. Low calcium causes increased neuromuscular irritability, which can lead to tetany and convulsions. High calciums may cause nausea, vomiting, abdominal pain, and polyuria, stone formation in the bladder and urethra, and abnormal calcification of other tissues.

Causes of Hypocalcemia:
1. Hypomagnesemia
2. Vitamin D deficiency
3. Hypoparathyroidism
4. Pancreatitis
5. Pregnancy and lactation
6. Renal Diseases
7. Osteomalacia

Causes of Hypercalcemia:
1. Hyperparathyroidism
2. Neoplasms, especially of bone
3. Hypervitaminosis D
4. Milk-alkali syndrome
5. Sarcoidosis
6. Thyrotoxicosis

HEMATOCRIT

The hematocrit of a sample of blood is the ratio of the volume of erythrocytes to that of whole blood. A major use of hematocrit measurements is during and after major surgery, especially with cardiac bypass. The

hematocrit must be sufficiently high (usually > 20 %) to remove a patient from bypass. Anemias and hemolytic diseases result in a decreased hematocrit. An increase is seen in a relative polycythemia and sometimes absolute polycythemia.

CO-OXIMETRY

When hemoglobin is less than normal, the patient is anemic; when it is higher than normal, the patient may have polycythemia or erythrocytosis, a higher than normal concentration of erythrocytes in the blood.

Because a decrease in arterial oxygen saturation is physiologically abnormal and a saturation below 85% may be life threatening, such results should be reported immediately. This usually indicates severe pulmonary or cardiovascular disease. Chronic pulmonary disease is most common and can develop over a period of time. Cardiovascular disease is of a more urgent nature as this indicates severe heart failure or perfusion failure. Cyanosis and apparent bluish discoloration of the skin, lips, eyelids, and nail beds will be apparent to most when there are more than 5 g/ dL of reduced (deoxyhemoglobin) hemoglobin. Anemic patients will not usually show cyanosis. A patient with a high hemoglobin such as in erythrocytosis will more likely show cyanosis. A cyanotic patient should be investigated immediately for possible pulmonary and cardiovascular causes.

Carbon monoxide is present in smoke and automotive exhaust. City dwellers that are nonsmokers typically have carboxyhemoglobin values of less than three percent of the blood hemoglobin combined with carbon monoxide.

Methemoglobin (ferri-hemoglobin) is a derivative of hemoglobin in which the ferrous ion is oxidized to the ferric state. It is an "inactive" hemoglobin, it does not combine reversibly with oxygen or carbon monoxide. In addition, it shifts the oxygen dissociation curve and hinders the transfer of oxygen from the blood to the tissues.

GLUCOSE

In the fasting state the level of blood glucose is maintained by drawing upon the glycogen stores of the liver. As glucose levels usually increase following absorption of carbohydrates from the diet, glycogenolysis (glycogen to glucose) is replaced by glycogenesis (glucose to glycogen). A number of different hormones are important in regulating the levels of blood glucose and for this reason glucose levels are altered in different diseases. Tight regulation of blood glucose levels has taken on a far greater importance over the last few years.

Hypoglycemia is seen in:

1. Hyperinsulinism
   a. Islet cell tumor
   b. Non-pancreatic insulin secreting tumors
2. Early stage of Diabetes Mellitus
3. Hepatic diseases
   a. Reyes syndrome
   b. Hepatitis
4. Malnutrition
5. Pediatric anomalies
   a. Prematurity
   b. Infant of diabetic mother
6. Addisons disease

Hyperglycemia is seen in:

1. Diabetes Mellitus

2. Hemochromatosis
3. Cushing's syndrome
4. Pheochromocytoma
5. Stress (emotional, burns, shock)
6. Acute pancreatitis
7. ACTH (adrenocorticotropic hormone) administration
8. Acromegaly (a condition caused by hypersecretion of the pituitary growth hormone after maturity.

Lactate

Lactate is an intermediary product of carbohydrate metabolism, normally produced in the L-form
In healthy, resting individuals, approximately 1400 mmols of lactate are produced daily from pyruvate which results in a blood lactate level of <2.0 mmol/L,. In the human, lactate is produced solely from pyruvate and can only be converted back to pyruvate. An adequate supply of NAD promotes conversion of pyruvate to acetyl CoA, which eventually regenerates NAD and produces adequately large amounts of ATP via oxidative phosphorylation to sustain life. If oxygen is in short supply, NADH accumulates which favors the conversion of pyruvate to lactate. This produces a small amount of ATP, which cannot maintain adequate ATP for more than 30 to 60 min.
The commonest cause of increased blood lactate are type A causes in which there is overt evidence of hypoxia. Insufficient tissue oxygenation to meet the metabolic needs of the patient can arise due to; *poor tissue perfusion* such as in the shocked patient; or due to *reduced arterial oxygen content* such as in asphyxia or hypoxaemia. Extreme exertion can also cause increased lactate. Lactate is used as a marker for circulatory shock. Some of the other criteria used to indicate shock are: systemic hypotension (systolic blood pressure less than 90 mmHg), oliguria (urine output less than 20 mL/h), and coldness or purplish color in the toes.

Common types of cirulatory shock are: (1) hypovolemic shock due to dehydration, fluid loss, or blood loss, (2) cardiogenic shock due to decreased cardiac output from a variety of causes, (3) septic shock characterized by both “shunting” of blood from the arterial to the venous circulation. It is important to detect any of these shocks states early, so that therapy may be most effective. Appropriate therapy includes any of the following: fluid replacement, cardiotropic agents, vasoactive agents, and appropriate antibiotics in the case sepsis.

The less common *Type B* causes are those where there is no overt evidence of hypoxia. In these cases the mechanism may be impaired tissue oxygen utilization. Caused by *drugs and toxins* such as ethanol, methanol and phenformin; *predisposing diseases* such as respiratory alkalosis and diabetes mellitus, liver failure and sepsis; inborn or *congenital errors in* carbohydrate metabolism.

Dextro or D-lactic acidosis can occur when there is overgrowth of certain bacteria in a gut which has been shortened through surgery. The bacteria produce excessive quantities of D-lactate.

P50

P50 may be used as an indicator of shifts in the oxyhemoglobin dissociation curve. It may be an important parameter for providing valuable information relative to the oxygen carrying or more important, oxygen delivering capacity of the blood.

Increase values for P50 indicate displacement of the oxygen dissociation curve to the right (i.e. a decreased affinity of the hemoglobin for oxygen). Chief causes are hyperthermia, acidemia, hypercapnia, high concentrations of DPG, or the presence of an abnormal hemoglobin with decreased oxygen affinity. Low values for P50 signify displacement of the oxygen dissociation curve to the left (i.e. increased affinity of hemoglobin).

The main causes are hypothermia, acute alkalemia, hypocapnia, low concentration of DPG, or an abnormal hemoglobin.

Effects of:

1. Temperature - an increase of 10°C increases the P50 by a factor of 1.7, thus indicating a decrease in affinity of hemoglobin for O2 as temperature increases.
2. pH - Hydrogen ion activity affects the dissociation curve because hemoglobin is a buffer and HbO2 is a stronger acid than Hb. Increased pH tends to force O2 off the hemoglobin. A decrease in pH shifts the curve to the right and increases the P50. An increase in pH shifts the curve to the left.
3. CO2 - minor effect.
4. Hemoglobin - minor effect.
5. 2,3-DPG (2,3-diphosphoglycerate) is a small organic phosphate molecule. It is produced as a late intermediate in glycolysis, a by product of anaerobic metabolism. It is a highly charged anion that binds reversibly, mole for mole to deoxygenated hemoglobin but not to oxygenated hemoglobin. An increase in 2,3-DPG causes a shift to the right of the O2 dissociation curve and a decrease in 2,3-DPG causes a shift to the left.
6. Carbon Monoxide - CO combines reversibly with hemoglobin but about 210 times stronger than oxygen. As a result, carbon monoxide is not readily displaced from hemoglobin (except at high oxygen tensions). Initially, the curve shifts to the left until all the hemoglobin that does not hold carbon monoxide holds oxygen. At that point, a drastic shift to the right occurs, because of a decreased oxygen affinity of that hemoglobin bound to carbon monoxide.
7. Salts - In general, an increase in ionic strength increases P50. An increase in salts causes a shift to the right and a decrease causes a shift to the left.
8. Methemoglobin - Normally it is not a significant factor. It must be remembered that its presence will cause a shift to the left and a decreased P50.

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