100 years of blood gas and acid base analysis in clinicalmedicine

Oct 2012

J Kofstad

The term acidosis was first mentioned in the medical literature in 1898 in connection with the description of diabetic ketoacidosis. Alkalosis was first used in human medicine in 1922 by the English physiologist J. S. Haldane; it had been used in veterinary medicine somewhat earlier.

In 1870, the Norwegians C. M. Guldberg and P. Waage formulated the law of mass action, which applies to chemical equilibria, and which the American L. J. Henderson used for carbonic acid/bicarbonate balance in 1907. He expressed the mathematical balance as:

$cH^+ = K(cH_2CO_3 / cNaHCO_3)$. K is the equilibrium constant.

As the concentration of free H^+ ions in blood is as low as 40×10^{-9} mol/L, the Dane S. P. Sørensen suggested applying logarithms to such low numbers and even using the negative value so that the number would become positive. This value was called pH. For “normal” blood, the pH value is 7.40 for the concentration 40×10^{-9} mol/L or 40 nanomol/L of free H^+ ions.

“Why not also a logarithm the low equilibrium constant values?” the Dane K. A. Hasselbalch suggested in 1917. This was done and Henderson’s equation then became:

$pH = pK + \log (cHCO_3^- / S \times pCO_2)$

pK is the negative logarithm for the equilibrium constant described above. S is a transition factor for H_2CO_3 from mol/L to partial pressure of pCO_2.

The Dane E. Warburg was the first person to use the term “the Henderson-Hasselbalch equation”. He got his doctorate in 1922 with the work “Carbonic Acid Compounds and Hydrogen Ion Activities in Blood and Salt Solutions”.

Up to about 1923, there had been no uniform definition of what an acid or a base was. In that year, the Dane J. N. Brønsted formulated his new acid-base theory, which has dominated the field of acid-base since that time. An acid is a substance that forms H^+ ions in solutions or, in other words, an acid is a proton donor. A base is a proton acceptor. Acid = Base + H^+.

THE VAN SLYKE TECHNIQUE

In 1917, Donald D. Van Slyke (from the Rockefeller Institute for Medical Research) introduced the gasometric method for determining the total CO_2 and the total O_2 of blood. He first worked out the method using the volumetric technique, and, 7 years later, the method was improved, and he then used the manometric measuring principle. With this method, oxygen was released with ferricyanide, and carbon dioxide was released on adding an acid. Volume and pressure of the released gas were then measured and, using the general gas equation, the volume percentage of oxygen and carbon dioxide were calculated. As the dominant part of total CO_2 is made up of bicarbonate, and these ions "buffer" H^+ ions, the total CO_2 was later called the alkali reserve. Volumetric and manometric blood gasometry were routine procedures in many hospitals from the 1930s until well into the 1960s. Van Slyke also developed gasometric techniques for measuring total nitrogen, carbamide, glucose and lactic acid, etc.

In 1932, Van Slyke, together with internist John P. Peters from Yale University, published a two-volume edition of Quantitative Clinical Chemistry. The first volume was about interpreting laboratory answers, and the second volume dealt with methodology. This two-volume work continues to be one of the best-known reference works within clinical chemistry.

ASTRUP'S EQUILIBRATION TECHNIQUE

The Van Slyke instrument was gradually replaced by the Astrup equilibration technique regarding acid-base analysis. The polio epidemic that ravaged Northern Europe at the start of the 1950s gave Danish doctors the impetus to work out the genial technique, which the equilibration method turned out to be.

In Copenhagen, in 1952, the number of polio patients who suffered paralysis of the respiratory muscles was striking and these patients required artificial ventilation. The total CO_2 was determined and was found to be raised in the majority of the patients. This was interpreted as indicating that the patients had alkalosis. When pH was also determined, after a while, it turned out that the patients had low pH (acidosis).

The explanation was that respiratory acidosis with accumulation of CO_2 caused a low pH. During this period, it is true to say that acid-base analysis went from being a physiological laboratory practice to a clinical necessity. Measuring total CO_2 with the Van Slyke apparatus and pH with another instrument, however, gradually came to be considered cumbersome.

Professor Poul Astrup said that he volunteered to ventilate polio patients at the Blegdams Hospital in Copenhagen. The respirators were operated by hand, and while he sat and pumped he wondered: "Am I doing this too fast, too slow, or just right? Where can I get an easy answer to my question? I must know the patient's situation now, not in a few hours' time."

Astrup studied Van Slyke's work and used the knowledge that the titration line for CO_2 to pH was approximately a straight line in the physiological measurement area (pCO_2 from 1.5-15 kPa), presuming that pCO_2 was marked logarithmically. Capillary blood is taken in three capillary tubes (approximately 50 DL in each tube). Two of these samples are transferred to the equilibration chambers and equilibrated with special gas mixtures with known high and

relatively low pCO_2 for 3-4 minutes. For the third sample, there is no preprocessing of the equilibration stage. The pH should be measured for all three samples. The titration line can be drawn based on the pH measurements in the two equilibrated samples. After that, the pCO_2 is read from the titration line with the measured pH from the blood sample, which was not equilibrated. On a nomogram, which was later worked out by Professor Ole Siggaard-Andersen, it was possible to read base excess (BE), buffer base (BB) and standard bicarbonate parameters, which express the metabolic (non-respiratory) part of acid-base disturbance.

INTERPRETATION OF THE HENDERSON-HASSELBALCH EQUATION

In 1964, Lorentz Eldjarn from Norway created a box with a three-dimensional coordinate system. The pH was marked on the X axis. The pCO_2 was logged on the Y axis and the relevant bicarbonate level was marked on the Z axis. The graphic presentation was a double curved plane where the titration line for blood and spinal fluid was plotted. It was possible to project this complicated plane down or into one of the three main symmetrical planes. Projection down or into the plane with the X and Y coordinates was Siggaard-Andersen's curve nomogram where isobicarbonate lines were straight lines, projection into the plane with X and Z as coordinates became Davenport's nomogram with plotted isobars for pCO_2. The last projection with Y and Z as coordinates was called the Cohen and Kassirer nomogram with plotted iso-pH lines. A fourth nomogram with log pCO_2 on the X axis and BE on the Y axis was called the Grogono nomogram and was also intended to simplify the interpretation of acid-base disturbances. In recent years I have thought a lot about the extent to which these nomograms have contributed to the understanding of acid-base disturbances, but there is no doubt that they did help quite a bit.

DIRECT MEASUREMENT OF ELECTRODES

Throughout the 1950s and the 1960s there was a lot of international focus on creating electrodes that could directly measure pO_2 and pCO_2 in blood samples. It was successful, eventually, and the most practically usable electrodes were subsequently called Clarke for the pO_2 electrode and Stow/Severinghaus for the pCO_2 electrode. The three electrodes, pH, pCO_2 and pO_2, were then put together in one instrument, and analyzers for direct measurement of blood gases were available. Radiometer called its first analyzer of this type the Acid Base Laboratory 1 (ABL 1). This was the first fully microprocessor-controlled, fully-automated blood gas analyzer to become available commercially.

THE BIG TRANSATLANTIC ACID-BASE DEBATE

At the start of the 1960s, it could be said that Astrup and Siggaard-Andersen's major input regarding acid-base put Copenhagen on the world map, and after a while the term "The Copenhagen School" began to be used. When the acid-base status of a patient was required, an "Astrup" was simply requested. I have heard such an acid-base status being requested as recently as 2011 at a hospital in Norway! With the introduction of the metabolic parameters such as base excess (BE) and standard bicarbonate from "The Copenhagen School", articles soon started to appear in leading journals such as The Lancet and the New England Medical Journal, etc., criticizing these new parameters! Two internists in Boston, William Schwartz and Arnold Relman, were particularly critical of the two parameters mentioned and claimed that BE,

in particular, was not independent of pCO_2, especially in the case of hypercapnia. They pointed out that actual bicarbonate could well be used as the metabolic parameter. We call actual bicarbonate a mixed indicator that is present in both metabolic and respiratory acid-base disturbances. The presence of actual bicarbonate is most pronounced in metabolic acid-base disturbances

A few years later, BE was modified and called "base excess extracellular fluid" (BEecF). The basis for this was that in vivo O_2 and CO_2 do not just equilibrate with blood but with all the extracellular fluid space. The buffer capacity is much higher in blood with hemoglobin present compared to the interstitial space, which does not contain hemoglobin and subsequently has a much lower buffer capacity. It was then thought that the blood was diluted with extracellular fluid (fluid in the interstitial space). The concentration of hemoglobin in this diluted fluid would then be approximately one third of that of blood. Siggaard-Andersen had now worked out an "alignment" nomogram, where BE could be easily read. This meant, for example, that with a hemoglobin concentration of 15 g/dL or 9 mmol/L, you would use a hemoglobin concentration of 5 g/dL or 3 mmol/L when making your calculation and thus obtain the value of the BEecF.

Another element that led the Boston School, in particular, to not recognize BE, was that BE was a mystical, artificial parameter and was calculated from complicated algorithms. The various manufacturers of blood gas analyzers worked out their own algorithms for calculating BE. These algorithms contained pH, pCO_2 and hemoglobin. Some also included pO_2.

I was able to demonstrate, in 1980, that the calculation of BE varied quite a bit when analyzers from different manufacturers were compared, and this could have clinical consequences in some instances, particularly in metabolic alkalosis. Throughout the 1980s and the 1990s the calculation was standardized so that today Van Slyke's algorithm or modifications of it are generally used. pO_2 is not included in this calculation.

The Copenhagen School have subsequently admitted that it would have been better to call the BE parameter "titratable acid" but with the sign reversed. This was certainly a familiar term from the titration of urine for measuring the excretion of acids or bases.

STEWART'S APPROACH TO THE INTERPRETATION OF ACID-BASE DISTURBANCES

In 1981, the Canadian Peter Stewart introduced a new calculation method that he felt would improve our understanding of acid-base disturbances, particularly metabolic disturbances. The traditional definition of acids and bases was abandoned, and two new parameters were introduced: SID = strong ion difference, which in simplified form is $Na^+ + K^+ – Cl^-$, and A_{tot}, which is the total amount of weak acids present. Using these two parameters and pCO_2, he formulated six equations and created a "summation equation" that gave detailed information about the acid-base status. Furthermore, it may be mentioned that the SID was identical to Buffer Base that was introduced by Singer and Hastings in 1948.

Another feature, which should be mentioned with regard to Stewart's approach, was that there was greater focus on the role of albumin and chloride in the understanding of acid-base

disturbances. I include an example, which has led to discussion in international media: According to Stewart's theory an acute isolated hypoalbuminemia would be regarded as a mild metabolic alkalosis. The negative albumin charges will, due to a reduction of the albumin concentration, mean that these will have to be replaced to maintain electrical neutrality. This is primarily achieved by increasing the bicarbonate concentration, which is then interpreted as metabolic alkalosis. This is not an acid-base disturbance and should not be treated with acid therapies!

Stewart's method became popular among researchers, but was not very user-friendly in the busy everyday clinical setting due to complicated equations and the need for programmable calculators.

NEW ELECTRODES FOR MEASURING ELECTROLYTES INTRODUCED IN BLOOD GAS ANALYZERS

From the end of the 1960s, ion-selective electrodes were developed for the macro electrolytes in blood plasma. It was particularly electrodes for sodium, potassium, chloride and calcium that were used and that were found to be reliable. These electrodes were built into the blood gas analyzer. Simon's discovery in 1969 that valinomycin was a particularly suitable carrier substance in a potassium electrode was of major importance. With regard to calcium, two answers had to be reported as ionized calcium varied depending on the pH. When the pH was between 7.60 and 7.20, the "adjusted" calcium value was calculated to pH = 7.40. In this way, it was possible to distinguish between, for example, hypercalcemia, which was just secondary to acidosis, and actual hypercalcemia! After a while, several types of directly measuring electrodes were built into the blood gas analyzers, such as glucose and lactate electrodes.

SPECTROPHOTOMETRY AND OXIMETRY

Spectrophotometric determination of oxygen saturation was introduced at the start of the 1930s. During the Second World War the need to measure oxygen saturation increased due to the military needs of flying at high altitudes without stabilization of the hypobaric conditions.

During the 1970s and 1980s, there was a vast development in multiwavelength oximetry. Absorption spectra for hemoglobin derivatives, particularly within the wavelength area of 500-700 nm, were recorded. Measurements at over 100 different wavelengths were recorded to calculate the four common hemoglobin derivatives: oxyhemoglobin, deoxyhemoglobin, COhemoglobin and methemoglobin. It was also possible to measure sulfhemoglobin if this was present in the case of sulfa therapy.

Simultaneous measurement of oxygen saturation and partial pressure of oxygen soon became a clinical necessity for plotting the position of the oxyhemoglobin dissociation curve (ODC) and also the pO_2 50 %, which could tell about the hemoglobin's affinity for oxygen. With the introduction of oximetry to the blood gas analyzers, the blood sample had to be split; one part went to the electrometry measurements and one part went to the oximetry measurements so that the modern blood gas analyzer now gives at least 11 directly measured parameters, four from the oximeter and seven from the electrometer. In addition, glucose and lactate

measurements became possible, so that on the printout there are 13 directly measured values as well as a number of calculated parameters

QUALITY CONTROL

Many different test solutions have been prepared to control the quality of the measurements in the blood gas analyzers. What is common to them all is that the gases are very difficult to control, particularly low pO_2 (hypoxemia). The reason is that oxygen is not particularly watersoluble, and when the test ampoule is opened, oxygen in the air quickly diffuses into the solution. When using hemoglobin-containing solutions, it is difficult to produce these with deoxyhemoglobin, because this is immediately converted into oxyhemoglobin when it comes into contact with air. In major international quality control tests, where many types of instruments are tested, the total coefficient of variation can be up to 15 % for low pO_2 values of 7-8 kPa. Ranges for these results can be 6.0-9.5 kPa! The large variation is caused by both preanalytical and analytical factors! Tonometry has also proved to be a good method for carrying out quality tests on pCO_2 and pO_2

CONCLUSION

When you read the two-volume work by Peters and Van Slyke from 1934, it is surprising how much biochemical and physiological knowledge they had then! There has, however, particularly following the Second World War, been an incredible technological development resulting in today's blood gas analyzers playing a very important role, particularly within intensive care medicine.

Otherwise it may be pedagogically correct in the future to rename BE and call it hydrogen ion excess with the opposite sign!

AUTHOR

Johan Kofstad
Kalderaveien 9
1359 Eiksmarka
Norge

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译文（非专业人士翻译仅供参考）

血气和酸碱分析在 100 多年中在临床的应用

2012.10

J Kofstad

酸中毒术语第一次提到在 1898 年在糖尿病酮症酸中毒的描述的医学文献中。在人类第一次使用碱中毒于 1922 年由英国生理学家 JS 霍尔丹它已被用于在兽医药领域。

1870 年，挪威 CM Guldberg 和 P. Waage 制定的法律，它适用于化学平衡，和美国 LJ 亨德森用于碳酸/碳酸氢盐的平衡在 1907 年。他表示，这是数学平衡：

CH+：= K（cH2CO3/ cNaHCO3）。 K 是平衡常数。

随着浓度的游离 H+离子，在血液中是低至 40×10-9 mol / L 时的 DaneSP 索伦森提出申请到如此低的数字的对数，甚至使用负的值，这样的数量将成为正。这个值被称为 pH 值。对于“正常”的血，pH 值是 7.40 的浓度为 40×10-9 mol / L 或 40umol/ L 的游离 H+离子。

“为什么不能有对数的平衡常数的值吗？”丹麦 KAHasselbalch 公式中建议于 1917 年。这样做，Henderson’s 方程，然后变成了

$$pH = pK + \log (cHCO_3^- / S \times pCO_2)$$

PK 是上述平衡常数的负对数。 S 是 H2CO3 过渡到 mol / L 的因素 pCO2 是压力的一部分。

丹麦 E.，Warburg 是第一个人使用的术语“Henderson-Hasselbalch 方程“。他得到了他的博士学位，在 1922 年的工作“碳酸化合物和氢离子在血液和盐溶液“的活动。

至约 1923，一直没有统一的定义什么的酸或碱是。在这一年中，丹麦人 JN 的布朗斯台德提出了他的新的酸碱理论，自那时以来，占据了主导地位的领域酸碱。的酸是一种物质形成 H +离子在溶液中，或，换句话说，一种酸的质子给体。一个基础是质子受体。酸=的基础+ H+。

范斯莱克技术
1917 年，唐纳德·D.范斯莱克（从洛克菲勒医学研究所）介绍用于确定总 CO2 和 O2 的血液总气量法。他第一次工作该方法使用体积的技术，并且，7 年后，方法进行了改进，然后，他用压力计的测量原理。使用这种方法，被释放氧用铁氰化钾，并释放二氧化碳时添加酸。体积和压力的影响然后测定释放出的气体，并使用一般的气体方程，体积的氧气和二氧化碳的百分比计算。作为占主导地位的总 CO2 由碳酸氢钠，这些离子的“缓冲”H+离子，二氧化碳总量后来被称为碱储备。在许多的体积和测压的血液 gasometry 是例行程序，从 20 世纪 30 年代一直延续到 20 世纪 60 年代的医院。范斯莱克还开发气量用于测量总氮，尿素，葡萄糖和乳酸等的技术。

1932 年，范斯莱克，与美国耶鲁大学内科医生约翰·P·彼得斯一起，出版了一本两卷版的定量临床化学。第一册是关于如何解释实验室的答案，和第二卷的处理方法。此两卷本著作仍然是临床化学领域内最知名的参考作品之一。

阿斯楚普之平衡法
范斯莱克仪器逐渐被阿斯楚普平衡技术关于酸碱分析。脊髓灰质炎疫情肆虐北欧开始 20 世纪 50 年代推动了丹麦的技术，其中平衡的方法被证明。

在哥本哈根，1952 年，小儿麻痹症患者出现的呼吸肌麻痹是惊人的，而这些患者需要人工通气。总 CO2 确定和被发现在大多数患者提出。这被解释为说明患者有性碱中毒。经过了一段时间，当 pH 值确定原来，患者有低 pH 值（酸中毒）

呼吸性酸中毒的解释是，CO2 的积累造成的低 pH 值。在此期间，它是真实的，是一种生理酸碱分析说，从实验室操作规范的临床必要性。用范斯莱克装置测量总 CO2 和用其他检测仪器测量 pH 值，然而，这种方法逐渐被认为是繁琐的。

保罗·阿斯楚普教授说，他主动给小儿麻痹症患者进行通气。呼吸器手工操作，而他坐在那里泵气时他想：“我这样做有时太快了，有时速度太慢，还是刚刚好？我在哪里可以得到一个简单的回答我的问题？现在我必须知道病人的情况，而不是在几个小时的时间。“

阿斯楚普研究范斯莱克的工作和使用知识的 CO2 对 pH 值滴定线约为生理测量区域中的一条直线（pCO2 的从 1.5-15 千帕），假定，pCO2 的标记对数。采取三种毛细血细管（每管约 50 DL）。两个这些样品被转移到平衡室和平衡的特殊

气体混合物与已知的高相对较低的二氧化碳分压 3-4 分钟。对于第三个样品中，有没有预处理平衡阶段。应测量的 pH 值，可用于所有三个样品。滴定行两个平衡样品的 pH 值测量的基础上可以得出。之后，将二氧化碳分压是读取从滴定行与从血液样品中所测量的 pH，这是不平衡。列线图，这是以后工作由的奥莱 Siggaard 教授 - 安德森，它可以读出剩余碱（BE），缓冲碱（BB）和标准碳酸氢盐参数，它表达的酸碱平衡紊乱的代谢（呼吸）的一部分。

Henderson-Hasselbalch 方程的释义
在 1964 年，洛伦兹埃尔亚恩从挪威在一个方块，一个三维坐标系统。将 pH 值标示在 X 轴上。在 Y 轴上的记录的 pCO2 和有关碳酸氢盐水平被标记上的 Z 轴。图形演示是一个双曲面血液和脊髓液的滴定线所在平面作图。这是可能的项目这个复杂的飞机降落到的三个主要对称的平面。投影下降或成的平面的 X 和 Y 坐标的时间是 Siggaard-Andersen 的曲线的列线图，isobicarbonate 线是直的线，投影到平面上与 X 和 Z 坐标成为达文波特的列线图绘制等压线 pCO2 的。最后预测绘制与 Y 和 Z 坐标被称为的的 Cohen 和 Kassirer 列线图与异 pH 值线。与日志的 pCO2 Y 轴的 X 轴和 BE 的第四列线图被称为还打算 Grogono 列线图和简化的解释酸碱干扰。在最近几年中，我想了很多的程度，这些列线图已提供的酸碱紊乱的理解，但是这是毫无疑问他们做了相当多的。

直接测量电极
在整个 50 年代和 20 世纪 60 年代，有很多国际的焦点上创建电极，可以直接测量血液样本中的 pO2 和 pCO2。它是成功的，最终，最实际可用的电极随后调用氧分压电极和 pCO2 电极。这三个电极，pH 值，二氧化碳分压与 PO2，然后把一台仪器和分析仪直接测量血气。雷度的酸碱称为它的第一个这种类型的分析仪实验室 1（ABL）。这是第一个完全由微处理器控制，全自动血气体分析仪。

BIG TRANSATLANTIC ACID-BASE 辩论
在 20 世纪 60 年代开始的，它可以说是阿斯楚普和 Siggaard - 安德森的主要输入关于酸碱把哥本哈根，并经过了一段时间的“哥本哈根学派“，开始被使用。当病人的酸 - 碱的状态是必要的， “阿斯楚普”的根本要求。我听说过这样的酸碱状态请求最近于 2011 年在挪威的一家医院！随着引进的代谢参数如剩余碱（BE）和标准碳酸氢盐从“哥本哈根学派”，第很快就开始出现在领先的期刊，如新英格兰医学报“，”等批评这些新的参数！在波士顿的 William Schwartz 和两个内科阿诺德 Relman，特别重要的两个参数，并声称是这样，特别是，是不是独立的二氧化碳分压，尤其是在高碳酸血症的情况下。他们指出，实际碳酸氢盐，可以很好地用于作为代谢参数。我们把实际碳酸氢盐的混合指标是在两个代谢和呼吸性酸碱本干扰。实际碳酸氢盐的存在下，最明显的是在代谢性酸碱干扰。

几年后，被修改，被称为“基地过量的细胞外液”（BEecF）在体内 O2 和 CO2，这是不只是平衡了血，但所有的细胞外液的空间。缓冲区的容量远远高于血液中的血红蛋白目前的间隙空间，其中不包含血红蛋白，其后有一个低得多的缓冲器容量。这在当时认为，血液稀释外流体（流体的间隙空间中）。该稀释液中的血红蛋白的浓度然后将约三分之一的血液。 Siggaard - 安德森现在已经制定了一个 “对齐”列线图，可以很容易地读出。这意味着，例如，与血红蛋白浓度为 15 g

/ dL 或 mmol/ L 的，你可以使用一个血红蛋白浓度 5 g / dL 或 3 毫摩尔/ L 时，你的计算，从而获得值的 BEecF。

另一个因素，导致波士顿学校，尤其是不承认 BE，BE 是一个神秘的，人工计算参数，并计算方法复杂。各种血气分析仪制造商制定了自己的算法，计算 BE。这些算法包含了 pH 值，二氧化碳分压和血红蛋白。有些人还包括 PO2。

我能够证明，在 1980 年时，变化的计算相当多的分析仪，比较来自不同制造商的，而这可能具有临床后果某些情况下，特别是在代谢性碱中毒。在整个 20 世纪 80 年代和 20 世纪 90 年代，计算进行了规范，使今天范斯莱克的算法或修改通常使用的。氧分压，不包含在此计算内。
哥本哈根学派后来承认，这将更好地调用参数“可滴定酸”，但符号相反。这无疑是一个耳熟能详的名词用于测量的酸或碱的排泄的滴定。

STEWART的方法，酸碱失衡的解释
在1981年，加拿大的彼得·斯图尔特推出了新的计算方法，他认为酸碱失衡，特别是代谢紊乱，提高我们的认识。 “被遗弃的酸和碱的传统定义，和两个新的参数介绍：SID=强离子差，它以简化的形式是Na +的+，K + - 的Cl-，和Atot，这是存在的弱酸总额。使用这两个参数和pCO2，他制定了六个方程，并建立了一个“求和公式”，详细说明了的酸碱状态。此外，它可能被提到的SID是相同的缓冲碱，Singer and Hastings在1948年推出的。

另一特征，应提到关于 Stewart 的方法，是有，酸碱的理解，更加注重对白蛋白和氯离子的作用干扰。我有一个例子，它导致了国际媒体讨论：据斯图尔特的理论的急性孤立的低蛋白血症会被视为一种温和的代谢性碱中毒。负白蛋白的费用，由于减少的白蛋白浓度，意味着这些将必须被替换，以维持电中性。这是主要通过增加的碳酸氢盐的浓度，然后将其解释为实现代谢性碱中毒。这不是一个酸碱平衡紊乱，并且不应该被用酸处理治疗方法！

斯图尔特的方法成为研究人员之间流行，但不是非常用户友好的忙日常临床设置，由于复杂的方程式和需要可编程计算器。

推出新的电极测量电解质血气分析仪
从 60 年代末，离子选择性电极的宏电解质血浆中。这是特别是电极的钠，钾，氯和钙被使用和被发现是可靠的。这些电极被内置到血液气体分析仪。西蒙在 1969 年的发现缬氨霉素是一个特别合适的载体物质的钾电极是非常重要的。关于钙，两个答案被报告为钙离子浓度的 pH 值的不同而不同。当 pH 为在 7.60 和 7.20 之间，“调整”钙值计算至 pH= 7.40。以这种方式，有可能来区分的，例如，高钙血症，这只是二次酸中毒，而实际高钙血症！一段时间后，几种类型的直接测量建成的血液气体分析仪，如葡萄糖和乳酸电极电极。

分光光度法及血氧饱和度
分光光度法测定的氧饱和度被介绍了在开始的 20 世纪 30 年代。在第二次世界

大战期间由于需要测量血氧饱和度增加在高海拔地区的飞行，没有稳定的低压条件下军事需求。

在多波长血氧饱和度在 20 世纪 70 年代和 20 世纪 80 年代，有广阔的发展。吸收光谱的血红蛋白衍生物，特别是在波长区域 500 - 700 nm 时的记录。在超过 100 种不同波长的测量，记录到计算四个常见的的血红蛋白衍生物：氧合血红蛋白，脱氧血红蛋白，CO 血红蛋白，高铁血红蛋白。这是也有可能测量 sulfhemoglobin 如果这是磺胺治疗的情况下呈现。

同时测量血氧饱和度和氧分压很快成为临床用于绘图的氧合血红蛋白解离曲线（ODC）的位置的必要性，并也氧分压 50%，这可以告诉血红蛋白对氧的亲和力。随着引入到血液气体分析仪的血氧饱和度，血液样品以被分割;一个部分电极法测量，另一部分去的血氧饱和度测量现代血气分析仪现在给至少有 11 个直接测量的参数，从血氧饱和度和 7 的静电。此外，葡萄糖和乳酸测量成为可能，因此，在打印输出上有 13 个测量值以及作为计算出的参数的数目。

质量控制
许多不同的测试解决方案已编制，以控制测量质量血气分析仪。这是他们的共同所有的是，这些气体是非常困难的控制，特别是低氧分压（低氧血症）。原因是氧没有特别的水溶性，当测试安瓿被打开时，空气中的氧迅速扩散到的解决方案。当使用含血红蛋白的解决方案，它是很难产生这些与脱氧血红蛋白，因为这是立即转换成氧合血红蛋白时，与空气接触。在主要的国际质量控制测试，其中许多类型的仪器进行测试，总的变异系数可高达 15%的低氧分压值 7-8 千帕。这些结果的范围为 6.0-9.5 千帕！大的变化是由两个分析前和分析的因素！张力测量也被证明是一个很好的方法 pCO2 和 pO2 的质量测试。

结论
当你读彼得斯和范斯莱克从 1934 年的两卷本著作，令人惊讶的是当时，有许多生化和生理知识！有先后，然而，特别是第二次世界大战后，一直在一个令人难以置信的技术发展今天的血气分析仪发挥了非常重要的作用，特别是在重症监护室医学。

文献概述：血气和离子分析近一百多年来的临床进展，对于酸碱中毒等一些离子概念的提出，各种酸碱中毒、剩余碱的概念以及意义；以及近几十年来血气分析以惊人的发展在如今的临床中发挥着重大的意义。

关键词：血气、电解质、质量控制