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# Does Every Blood Gas Need Co-oximetry?

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Arterial Blood Gas (ABG) analysis is used to assess both the acid-base balance and oxygenation of a patient's condition. In an effort to assess the oxygenation of a patient, there are a minimum of three (3) basic tests needed. They include the partial pressure of oxygen ($PO_2$), the oxygen saturation ($SO_2$) of hemoglobin, and the total hemoglobin (tHb). It is the combination of the tests and others that provide clinicians with an accurate understanding of a patient's oxygenation status.

Whole blood is comprised of both plasma and hemoglobin. Oxygen diffuses into the plasma and can be measured using the partial pressure of oxygen ($PO_2$). The $PO_2$ often represents a significant understanding of the alveolar diffusion of oxygen into the blood stream. The $PO_2$ is usually measured on a blood gas analyzer with the pH and partial pressure of carbon dioxide ($PCO_2$). Once oxygen diffuses into the plasma, it can bind to hemoglobin for transportation to the cells. The $O_2Hb$ represents the amount of oxygen that is bound to hemoglobin for transport to diffuse through the cellular walls and into the cell. The $O_2Hb$ can only be measured using wave lengths of light and is preferred on a co-oximeter that tests for hemoglobin.

What is co-oximetry? Co-oximetry is not a test but a methodology, also known as spectrophotometry. Co-oximetry provides a means of measuring several different tests using light emission and absorption based on Lambert-Beer's law. In an ABG assessment, co-oximetry is used to determine the total hemoglobin (tHb), hemoglobin derivates, and sometimes bilirubin test values. Hemoglobin derivatives are commonly known as Oxyhemoglobin ($O_2Hb$), Deoxyhemoglobin (HHb) or Reduced Hemoglobin (rHb) , Methemoglobin (MetHb), and Carboxyhemoglobin (COHb). Occasionally, there is a clinical need to evaluate other hemoglobin derivates including Sulfhemoglobin (SulfHb) or Fetal Hemoglobin (HbF). These parameters are a result of using co-oximetry to identify the test value for clinical assessment.

Oxygen saturation can also be measured by co-oximetry. However, the means used to determine oxygen saturation vary. Oxygen saturation is a percentage value indicating the amount of hemoglobin that is saturated with oxygen. There are three (3) different ways to determine oxygen saturation. They are the fractional oxygen saturation, the function oxygen saturation, and the calculated oxygen saturation measurements.

The first method of determining oxygen saturation is by measuring the $O_2Hb$ and comparing it to all the hemoglobin measured. This method is common for fractional oxygen saturation measurements ($FO_2Hb$) from co-oximetry. The equation for which is: $FO_2Hb = O_2Hb / 100$

The second method of determining oxygen saturation is by measuring the $O_2Hb$ and rHb/HHb only. This is referred to as functional hemoglobin saturation and can only be determined by using co-oximetry. This allows clinicians to assess how much of the hemoglobin capable of carrying oxygen is actually saturated with oxygen molecules. The equation for this measurement is: $SO_2 = O_2Hb / O_2Hb + HHb$.

The third method of determining oxygen saturations is by calculating the oxygen saturation ($SO_2c$) using an equation or algorithm using a measured $PO_2$, pH, $PCO_2$, and a calculated/ default hemoglobin. The challenge with the calculated oxygen saturation is that clinicians must often assume normal hemoglobin values in their critically ill patients that receive a blood gas and that there are no other inhibitors such as MetHb or COHb.

When comparing the three (3) different means of obtaining the oxygen saturation measurement, only $O_2Hb$ and $SO_2$ measured by co-oximeter provides direct measurement information to assess the oxygenation of hemoglobin. The use of $SO_2c$ (calculated oxygen saturation) restricts the clinician's ability to make a true determination of a patient's oxygenation status by only assessing the oxygenation of the blood plasma and often assuming normal or default hemoglobin values in a patient. Therefore, in order to make an accurate assessment of a patient's oxygenation statues, the $PO_2$ measurement is needed in conjunction with the $O_2Hb$ measurement from a co-oximeter.

Understanding the intent of an ABG is to measure both the acid-base balance and the oxygenation of a patient is fairly simple. However it is important for clinicians to understand the need to measure both the $PO_2$ and $O_2Hb$ (by co-oximetry) in order to perform an accurate patient assessment of oxygenation. Once clinicians understand the need for co-oximetry with all ABG tests, the accuracy of a patient's oxygenation will be assured.

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# Effects on Management and Outcome of Severe Sepsis and Septic Shock Patients Admitted to the Intensive Care Unit After Implementation of a Sepsis Program: A Pilot Study

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## Abstract

**Introduction:** The application in clinical practice of evidence-based guidelines for the management of patients with severe sepsis/septic shock is still poor in the emergency department, while little data are available for patients admitted to the intensive care unit (ICU). The aim of this study was to evaluate the effect of an in-hospital sepsis program on the adherence to evidence-based guidelines and outcome of patients with severe sepsis/septic shock admitted to the ICU.

**Methods:** This prospective observational cohort study included 67 patients with severe sepsis/septic shock admitted to a multidisciplinary ICU at a University Hospital from January 2005 to June 2007. Compliance to 5 resuscitation and 4 management sepsis interventions and in-hospital mortality were measured following an educational program on sepsis for physician and nurses of all hospital departments and hospital implementation of a specific protocol for recognition and management of patients with severe sepsis/septic shock, including an early consultation by a skilled sepsis team.

**Results:** During the study period, the compliance to all 9 interventions increased from 8% to 35% of the patients ($P < 0.01$). The implementation of resuscitation and management interventions was associated with a lower risk of in-hospital mortality (23% vs 68% and 27% vs 68%, $P < 0.01$). In the latter 2 semesters, after activation of the 'sepsis team', in-hospital mortality of ICU septic shock patients decreased by about 40% compared with the previous period (32% vs 79%, $P < 0.01$).

**Conclusions:** In our experience, an in-hospital sepsis program, including education of health-care personnel and process-changes, improved the adherence to guidelines and the survival rate of patients with severe sepsis/septic shock admitted to the ICU.

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## Introduction

The high incidence, costs and mortality rate of patients with sepsis in the recent years has led the critical care scientific community to develop specific strategies aimed to improve the outcome of these patients.[1-4] In 2004, the Surviving Sepsis Campaign (SSC) guidelines[3] recommended a series of diagnostic and therapeutic interventions whose implementation was expected to lead to a survival benefit in patients with severe sepsis/septic shock. Afterwards, to facilitate the application of these guidelines in clinical practice, the Institute for Healthcare Improvement (IHI) proposed the severe sepsis resuscitation (6-hours) and management (24-hours) bundles, that integrate the interventions described above. Nevertheless, the application of these bundles so far has been demonstrated to be quite poor in most surveys, confirming the difficulty of transferring evidence to the clinical practice.[4-12]

The main purpose of our study was to evaluate the effects of a "surviving sepsis" in-hospital project, including specific educational program and operative protocols, on the adherence to evidence-based guidelines. Moreover, we sought to assess if such a project could improve the outcome of patients with severe sepsis/septic shock admitted to an intensive care unit (ICU).

## Materials and Methods

Design, setting and population: This prospective observational study enrolled consecutive patients with a diagnosis of severe sepsis/septic shock admitted to an ICU of the 780-bed University Hospital of Modena from January 2005 to June 2007. The study was approved by the local ethical committee and the need for informed consent was waived in view of the observational and anonymous nature of the study. The ICU consists of nine beds and approximately 800 adult patients are admitted annually (70% surgical patients). Staffing at any time consists of one attending physician, one resident physician and three to four nurses.

The inclusion criteria were: a) documented or suspected infection; b) two or more systemic inflammatory response

**Table 1**

**Number, age, sex, primary site of infection, grade of sepsis, severity scores, length of stay and mortality of patients subdivided for semesters**

| Parameters | Total | January to June 2005 | July to December 2005 | January to June 2006 | July to December 2006 | January to June 2007 |
|---|---|---|---|---|---|---|
| Patients (n) | 67 | 13 | 11 | 10 | 13 | 20 |
| Age (years; mean ± SD) | 63 ± 16 | 65 ± 9 | 69 ± 13 | 66 ± 18 | 58 ± 17 | 61 ± 20 |
| Female (n, %) | 23(46) | 1 (8) | 3 (27) | 4 (40) | 6 (46) | 9 (45) |
| ED admissions (n, %) | 16 (24) | 1 (8) | 2 (18) | 3 (30) | 4 (31) | 6 (30) |
| Surgical admissions (n, %) | 38 (56) | 8 (61) | 8 (73) | 4 (40) | 7 (54) | 11 (55) |
| Primary site of infection | | | | | | |
| *Pneumonia(%)* | 36 | 38 | 36 | 40 | 31 | 35 |
| *Intra-abdominal (%)* | 27 | 15 | 18 | 40 | 38 | 25 |
| *Blood (%)* | 15 | 15 | 27 | 0 | 15 | 15 |
| *Urinary tract(%)* | 10 | 8 | 9 | 10 | 8 | 15 |
| *Surgical wound(%)* | 5 | 8 | 0 | 0 | 8 | 5 |
| *Other (%)* | 7 | 15 | 9 | 10 | 0 | 5 |
| Septic shock (n, %) | 50 (75) | 11 (85) | 10 (91) | 7 (70) | 9 (69) | 13 (65) |
| Blood lactate > 4 mmol/L (n, %) | 28 (42) | 4 (31) | 8 (73) | 3 (30) | 6 (46) | 7 (35) |
| SAPS (mean ± SD) | 53 ± 21 | 50 ± 15 | 53 ± 29 | 61 ± 24 | 47 ± 19 | 55 ± 21 |
| SOFA (mean ± SD) | 9.7 ± 3.9 | 12.3 ± 4.0 | 10.1 ± 4.6 | 10.1 ± 4.0 | 8.4 ± 3.4 | 8.4 ± 2.9 |
| ICU LOS (days; mean ± SD) | 16 ± 19 | 24 ± 33 | 24 ± 10 | 16 ± 24 | 16 ± 17 | 14 ± 9 |
| H LOS (days; mean ± SD) | 44 ± 38 | 53 ± 34 | 31 ± 38 | 38 ± 49 | 56 ± 42 | 42 ± 25 |
| H mortality overall (n, %) | 33 (49) | 9 (69) | 7 (64) | 7 (70) | 3 (23) | 7 (35) |
| H mortality septic shock (n, %) | 30 (60) | 9 (82) | 8 (80) | 6 (86) | 2 (22) | 5 (38) |

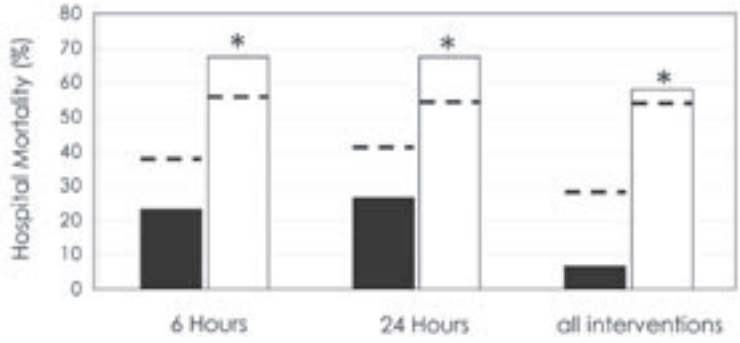
ED = emergency department; ICU = intensive care unit; H = hospital; LOS = length of stay; SAPS = simplified acute physiology score; SD = standard deviation; SOFA = simplified organ failure assessment.

syndrome criteria[13] and c) the onset of an organ dysfunction related to infection: gas exchange impairment (partial pressure of arterial oxygen ($PaO_2$)/fraction of inspired oxygen ($FiO_2$) < 250 mmHg), mean arterial pressure (MAP) below 65 mmHg, acute renal dysfunction (1.5-fold baseline creatinine increase or urine output < 0.5 ml/Kg/h for two hours), total bilirubin above 4 mg/dL, platelet count below 80,000 cells/$mm^3$ (or a 100,000 cells/$mm^3$ decrease) or lactate blood concentration above 4.0 mM. Patients with persistence of MAP below 65 mmHg after an adequate fluid infusion (see below) were classified as having septic shock. Patients with severe decompensated chronic liver disease included in the waiting list for liver transplantation were excluded from the study.

Data collection: Data collection began one month after the start of an in-hospital educational program on sepsis (see below) and only the first episode of severe sepsis/septic shock was considered in each patient. The management of patients was evaluated by analysis of interventions and sepsis bundles.[3] We identified five resuscitation (6-hours bundle) and four management (24-hours bundle) interventions: blood cultures collection before antibiotic administration; empiric antibiotic therapy within three hours from diagnosis; control of infection source within six hours; adequate fluid resuscitation before vasopressor administration; central venous oxygen saturation ($ScvO_2$) above 70% within six hours; blood glucose median below 150 mg/dL in the first 24 hours; low-dose hydrocortisone administration in association with vasopressor support; recombinant human activated protein C (rhAPC) if administration indicated; plateau inspiratory pressure below 30 $cmH_2O$ in patients with acute lung injury (ALI)/adult respiratory distress syndrome (ARDS). The term adequate fluid resuscitation indicates a central venous pressure above 6 mmHg (above 8 mmHg if mechanically ventilated) or a global end-diastolic volume by trans-pulmonary thermodilution (PiCCO system, Pulsion, Germany) above 700 ml/$m^2$.

Two of the authors (LR and LD) not involved in the clinical management of the patients, collected the above interventions by analysis of clinical charts and any uncertain data was audit with the attending physician. The interventions were classified as completed and not completed. An intervention not applied because not applicable (eg low plateau inspiratory pressure in patient without ALI/ARDS) was defined as completed. The time zero for bundles timing was the time in which the three study inclusion criteria were documented by clinical notes. Type of admission, grade of sepsis, primary site of infection, simplified acute physiology score (SAPS) II and simplified organ failure assessment (SOFA) score the day of sepsis diagnosis,[14,15] ICU and hospital length of stay, and hospital mortality were also recorded for each patient. Predicted hospital mortality was calculated by SAPS II score.

**Figure 1**




Mortality of patients with (black column) and without (white column) implementation of 6-hours bundle, 24-hours bundle and all interventions. For each group of patients the predicted mortality by simplified acute physiology score (SAPS) II is also reported (dotted line). * $P < 0.05$ comparing patients with and without bundles compliance.

Hospital program: The education phase of our hospital program named "Sopravvivere alla Sepsi nel Policlinico di Modena" (Surviving to Sepsis in Policlinico Hospital of Modena) started on November 2004 and continued throughout the study period. It included basic, advanced and refresh courses with conference lectures and practice training for nurses and physicians of all hospital departments. From November 2004 to June 2007 almost 250 physicians (out of 400) and 300 nurses (out of 950) of our hospital participated in educational courses. A specific protocol for early recognition and management of patients with severe sepsis/septic shock was prepared, approved and promoted (eg specific meetings, hospital intra-net, poster displayed in the staff working area) in all hospital wards (June 2006). The protocol includes: i) clinical data needed for severe sepsis/septic shock identification; ii) instruction for sepsis team activation; iii) detailed instructions for early goal directed resuscitation, collection of microbiological samples and antibiotic therapy; and iv) special recommendations on bicarbonate use, low-dose dopamine and glycemia control. The sepsis team is available 24 hours per day and is formed by two attending physicians: an intensivist and an infectious disease specialist. The team is activated by and collaborates with the attending physician and the nursing department staff in providing the interventions required for each patient with severe sepsis and septic shock (e.g. placing central venous line, measuring central venous pressure, providing non-invasive ventilation, assessing for antibiotic strategy and other specific therapy). After the activation by a dedicated telephone number, the time period for team sepsis consultation should be shorter than 60 minutes in patients with severe sepsis and 30 minutes in patients with septic shock. The sepsis team activity (eg frequency and percentage of appropriate activation, mean time before consultation, percentage of ICU admission, patient outcome) is regularly recorded and discussed with members of the "Sopravvivere alla Sepsi" group and with the hospital administrators.

Statistical analysis: The outcome measurements included intervention compliance, ICU and in-hospital length of stay

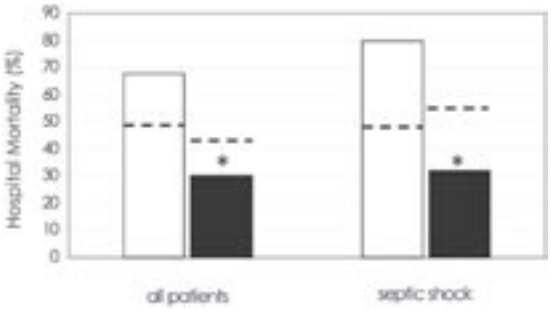
**Table 2**

**Percentage of patients with completion of interventions and bundles subdivided for semesters of analysis**

| Intervention | Total | January to June 2005 | July to December 2005 | January to June 2006 | July to December 2006 | January to June 2007 |
|---|---|---|---|---|---|---|
| Blood cultures collection* | 83 | 77 | 73 | 80 | 92 | 95 |
| Antibiotic therapy (3 hours)* | 95 | 92 | 82 | 100 | 100 | 100 |
| Infection source control* § | 86 | 85 | 82 | 70 | 92 | 100 |
| Adequate fluid resuscitation | 98 | 92 | 100 | 100 | 100 | 95 |
| $ScvO_2$ optimization* | 61 | 46 | 45 | 50 | 92 | 70 |
| Glycaemia control | 93 | 92 | 100 | 100 | 92 | 80 |
| Low-dose hydrocortisone* | 73 | 31 | 82 | 80 | 85 | 90 |
| rhAPC* | 66 | 54 | 45 | 70 | 77 | 85 |
| PiP < 30 $cmH_2O$* | 79 | 46 | 82 | 80 | 85 | 100 |
| 6-hours bundle | 45 | 38 | 9 | 20 | 77 | 60 |
| 24-hours bundle | 45 | 8 | 36 | 50 | 62 | 60 |
| All interventions | 22 | 8 | 0 | 10 | 46 | 35 |
| Sepsis team admissions* | 33 | 0 | 0 | 0 | 85 | 55 |

Data are expressed as percentage of patients. * $P < 0.05$ comparing the semesters; § Source control details: 38 surgical patients: 21 control by surgery, 3 radiological drainage, 8 control not necessary, 6 control not achieved within 6 hours. 29 medical patients: 6 radiological drainage, 6 central venous line removal, 13 control not necessary, 4 control not achieved within 6 hours
PiP = plateau inspiratory pressure; rhAPC = recombinant human activated C protein; $ScvO_2$ = central venous oxygen saturation.

**Figure 2**




In-hospital mortality before (white columns) and after (black columns) 'sepsis team' activation (June 2006) in all population and in septic shock patients. For each group of patients, the predicted mortality by simplified acute physiology score (SAPS) II is also reported (dotted line). * $P < 0.05$ before and after sepsis team activation.

and in-hospital mortality. For data analysis, the study period was divided: in semesters, in order to assess the progression of learning process and in two periods, before and after June 2006, in order to assess the impact of sepsis team on patient outcome. Students' t-test, chi-squared, Fisher's exact test, and analysis of variance single-factor analysis were used when appropriate. Univariate and multivariate logistic regression were performed, with hospital mortality as dependent variable and individual interventions, bundles and sepsis team admission as independent variables. Variables with $P < 0.20$ from univariate analysis were included in the backward logistic regression model that was also corrected for possible confounders such as age, SOFA and SAPS II scores, the presence of shock, lactate blood concentration (first data after study inclusion) and sepsis team period. The goodness of fit was assessed by the Hosmer-Lemeshow test. A value of $P < 0.05$ was considered significant. The statistical software package SPSS 15.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

## Results

From January 2005 to June 2007, 87 patients met criteria for study inclusion, but 20 patients were excluded because they were affected by chronic decompensated cirrhosis and were on the waiting list for liver transplantation. Comparing the five semesters of the study period, no differences were observed in the number of patients, age, gender, type of admission (i.e. surgical and emergency department), primary site of infection, SAPS II and hospital length of stay. Percentage of septic shock patients, SOFA score, ICU length of stay and in-hospital mortality decreased ($P > 0.05$) during the study period (Table 1).

The interventions compliance increased ($P < 0.05$) from January 2005 to June 2007 for all but the glycemia control and adequate fluid resuscitation. In the same way, the compliance with 6-hour resuscitation and 24-hour management bundles as well as with all interventions increased ($P < 0.01$) (Table 2). The implementation of bundles was associated ($P < 0.01$) with a decrease of in-hospital mortality (Figure 1). The characteristics of patients with and without all interventions compliance were similar, except for age (55 ± 12 vs 65 ± 13 years), sex (60 vs 27% female) and SAPS II (44 ± 13 vs 56 ± 21; $P < 0.05$). Nevertheless, the differences between observed mortalities and expected mortalities by SAPS II were favourable ($P < 0.05$) in patients with bundles and all interventions compliance (Figure 1).

In-hospital mortality decreased by about 40% ($P < 0.01$) during the past two semesters (ie after sepsis team activation, July 2006 to June 2007) compared with the previous ones (January 2005 to June 2006; Figure 2). Patients of these two study periods were similar in age, type of admission, primary site of infection and SAPS II, but in the two latter semesters SOFA score (8.4 ± 3.1) and percentage of septic shock patients (66%) were lower ($P < 0.05$) than in the earlier three semesters (10.9 ± 4.2 and 82%). Considering only septic shock patients in the two study periods, no differences were observed in demographic characteristics whereas the in-hospital mortality decreased ($P < 0.01$) in the two latter semesters (Figure 2).

The univariate logistic regression showed that odds ratio (OR) for in-hospital mortality was reduced ($P < 0.05$) by compliance to infection source control, $ScvO_2$ optimisation, rhAPC administration, 6-hours and 24-hours bundles, all interventions together and team sepsis. Multivariate logistic

**Table 3**

**Univariate and multivariate logistic analysis for in-hospital mortality**

| | Odds ratio | 95% confidence interval | *P* value |
|---|---|---|---|
| **Univariate analysis** | | | |
| Infection source control | 0.12 | 0.02 to 0.89 | 0.031 |
| $ScvO_2$ optimization | 0.30 | 0.10 to 0.83 | 0.025 |
| rhAPC | 0.18 | 0.06 to 0.58 | 0.004 |
| 6-hours bundle | 0.17 | 0.06 to 0.50 | < 0.001 |
| 24-hours bundle | 0.19 | 0.05 to 0.65 | 0.004 |
| All interventions | 0.05 | 0.01 to 0.31 | < 0.005 |
| Team sepsis activation | 0.28 | 0.10 to 0.79 | 0.015 |
| **Multivariate analysis** | | | |
| 6-hours bundle | 0.15 | 0.03 to 0.63 | 0.010 |
| 24-hours bundle | 0.12 | 0.02 to 0.52 | 0.005 |

Hosmer-Lemeshow test: $P = 0.819$.
rhAPC = recombinant human activated C protein; $ScvO_2$ = central venous oxygen saturation.

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analysis with adjustment for possible confounders indicated that 6-hours bundle implementation as well as 24-hours bundle were independently ($P < 0.05$) associated with lower in-hospital mortality (Table 3).

## Discussion

The main findings of our study were that an in-hospital program dedicated to sepsis, including healthcare personnel education and specific process changes, improved not only the adherence to evidence-based guidelines in clinical practice, but also the survival rate of patients with severe sepsis and septic shock admitted to the ICU. Also, the adherence to international guidelines provided more appropriate blood cultures, optimization of $ScvO_2$ and adherence to indications for rhAPC, steroids and protective ventilation.

In accordance with the indications of IHI for the local implementation of the SSC, a few months after the publication of the international guidelines[3] our hospital program started with an educational phase. It involved a large number of physicians and nurses, particularly from those wards implicated in the management of patients with severe sepsis/septic shock. The early establishment of a working group on sepsis, including reference nurses and physicians from all the hospital departments, was a key point in motivating the department staff to an active collaboration. Nevertheless, the high turn-over of residents and nurses led to a progressive impoverishment of skilled personnel. To overcome this problem, since 2006 a continuous educational program has been planned as a form of required education for health-care personnel at the hospital.

The compliance to evidence-based interventions at the beginning of the hospital program was very similar to that reported by others in emergency departments (ED).[9-11] Unfortunately, so far, few data have been reported on the implementation of sepsis bundles in ICU. Ferrer and colleagues[12] recently reported a very low compliance to resuscitation (5.3%) as well as management (10.9%) bundles before an education program in Spanish ICUs. On the other hand, Gao and colleagues[8] observed in ICU patients a rate of satisfaction of 6-hours sepsis bundles (59%) higher than that observed in our study. However, in the study by Gao and colleagues the 6-hours resuscitation bundles did not include the assessment and optimization of $ScvO_2$, that is the intervention was more frequently uncompleted in our patients as well as in other studies.[9,11,12]

The compliance to evidence-based guidelines increased during the study period and led mainly to an increase of blood culture collection before antibiotic therapy, optimization of $ScvO_2$, steroid use in shocked patients, adherence to indications for rhAPC and protective ventilation. Indeed, adherence to glycaemia control in our experience slightly decreased during the study period probably because of a great concern of the ICU staff for hypoglycemia-related complications originated by preliminary results of clinical trials.[16]

In the latter two semesters, the adherence to 6-hours resuscitation bundles suddenly improved (Table 1). This can be attributed to the activation of process changes in the hospital management of patients with sepsis that provided an early identification and appropriate treatment of patients with organ dysfunction both before and after ICU admission. Nevertheless, also in the last period of the study we were able to complete all the sepsis bundles only in 35 to 40% of the patients. Numerous activities, besides continuous educational programs, have been put in action to further improve this result: departmental audit on specific sepsis cases, procalcitonin measurement 24 hours per day and a sepsis dedicated laboratory panel including lactate and the parameters needed for organ dysfunction assessment.

Many studies have indicated that the implementation of interventions recommended by evidence-based guidelines are associated with outcome benefits in severe sepsis patients.[5,10-12] However, the majority of these studies were carried out in EDs including out-of-hospital patients with community acquired infection. Very few data are available about the effectiveness of this strategy in ICU patients with different provenance (ie ED, surgical or medical wards) and type of infection (ie community or hospital acquired).[7,8,12] Our data also indicated that in such a setting the compliance to evidence-based interventions improve the outcome of patients with severe sepsis/septic shock. Furthermore, the multivariate analysis including a correction for SAPS II and SOFA scor-, showed that the complete adherence to 6 hours and 24-hours interventions is associated with a significant OR reduction for in-hospital mortality.

As far as single interventions are concerned, the association between $ScvO_2$ of 70% or more and improved outcome in patients with severe sepsis/septic shock has been widely demonstrated in EDs,[5,10,17] but this is the first time that the same figure is reported in ICU patients. Van Beest and colleagues[18] recently reported that the incidence of low $ScvO_2$ in acutely admitted septic shock is very low in Dutch ICUs. In our centre, despite changes in management processes, the incidence of patients with low or unknown $ScvO_2$ within six hours from severe sepsis diagnosis was still around 20% in the past year. Risks and benefits of rhAPC in patients with severe sepsis/septic shock have been largely discussed and a further discussion on this issue is certainly beyond the aims of this paper. However, we observed that the adherence to the SSC guidelines[3] for the use of rhAPC was associated with a significant decrease in mortality. However, it must be underlined that the number of patients was low and that in the multivariate analysis none of the single interventions was associated with a significant change in OR for patient mortality.

As discussed above, the institution of a specific team for early sepsis management led to a significant improvement in outcome. This improvement regarded also the septic shock patients, already referred to the ICU before sepsis team institution. One can argue that the improvement could be due to an increased adherence to 24-hours bundle. However, after the sepsis team institution we observed a more remarkable improvement in 6-hours bundle. This suggests that the adopted process changes facilitated a quicker management of shocked patients.

Our study has some limitations. First, the study design (non-randomized) and the low number of patients involved so far do not allow us to draw any firm conclusions on the effect of single interventions, bundles and process change on sepsis outcome. Second, it has to be considered that the sepsis management model provided and analyzed in our study was according to the 2003 version of the SSC guidelines[4] and, therefore, is in some aspects different to that proposed by the more recent ones.[19] Third, as sepsis team institution and increased bundles compliance occurred simultaneously, we are not able to differentiate the actual role of one in respect to the other on the mortality reduction observed in the past year.

## Conclusion

In conclusion, our single-centre experience demonstrated the importance of specific program addressed to whole hospital departments for improving evidence-based practice and survival rate of patients with severe sepsis/septic shock admitted in ICU. In our model, a multidisciplinary approach and a specific team played a key role for education and for providing an early and appropriate sepsis management. A large number of patients and a more detailed assessment of sepsis team activity before ICU admission appears mandatory for a better understanding of this relevant issue.

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# Model for Predicting Short-Term Mortality of Severe Sepsis

Christophe Adrie, et al

Severe sepsis remains a leading cause of death in industrialized countries, and the number of deaths caused by sepsis is increasing despite improved survival rates. The objective of this study was to design a prognostic model for predicting death within 14 days of severe sepsis onset at any time during the first 28 days of the ICU stay. The model was to be based on variables collected at admission and on the day the sepsis episode was diagnosed. Up to four sepsis episodes per patient were included. We compared our model with other, widely used scores. Our model may prove useful for designing future studies.

We conducted a prospective observational study using data entered into a multicenter database from November 1996 to April 2007. The database contains data on admission features and diagnosis, daily disease severity, iatrogenic events, nosocomial infections and vital status. Data were collected daily by senior physicians in the participating ICUs. For each patient, the data were entered into an electronic case-report form. Severity of illness was evaluated on the first ICU day using the Simplified Acute Physiology Score (SAPS II), Logistic Organ Dysfunction (LOD) score, Sequential Organ Failure Assessment (SOFA) score, Mortality Probability models II0 score (MPM0 II score), and Acute Physiologic and Chronic Health Evaluation (APACHE) II score. Patients were followed until the end of the hospital stay in order to record the vital status 14 days after sepsis onset. Severe sepsis was defined as sepsis associated with at least one [major] organ dysfunction, and septic shock was defined as sepsis-induced hypotension persisting despite adequate fluid resuscitation together with organ dysfunction. The outcome variable of interest was death within 14 days after the diagnosis of an episode of severe sepsis (up to four) acquired in the community, hospital or ICU.

## Results

Among the 7,719 patients in the base, 2,268 experienced 2,737 episodes of severe sepsis, including 674 patients who had 793 episodes of septic shock. Of the 2,268 patients, 1,458 patients with 1,716 episodes of severe sepsis were included in the training cohort and 810 patients with 1021 episodes of severe sepsis were included in the validation cohort. Factors that were significantly associated with early death included worse SAPS II and LOD scores at ICU admission, septic shock (eg requiring either inotropic therapy or vasoactive agent support), multiple organ failure (which showed the strongest association) and co-morbidities (immunodeficiency, chronic heart failure, chronic hepatic failure, acute respiratory failure and acute heart failure). On the day of the diagnosis of severe sepsis, factors significantly associated with early death included the use of invasive procedures and a need for vasoactive agents and/or inotropic support. Escherichia coli, Pseudomonas species, methicillin-resistant Staphylococcus aureus, Candida species, bacteremia and multiple sources of infection were also associated with early death in the univariate analysis.

We found that predicting death within 14 days after the onset of severe sepsis during the first 28 days in the ICU was feasible in patients with no to three previous episodes of severe sepsis. By adjusting for confounders, we were able to build a predictive model in a training cohort that performed well in the validation cohort. If used in randomized trials, this prognostic model might help to include patients with similar disease severity and to improve adjustment for confounders. We chose to study short-term mortality, despite the current trend among researchers to focus on long-term mortality. Most studies of sepsis used 28-day all-cause mortality as the primary end-point. However, life-limiting disease is a common risk factor for sepsis and may cause death shortly after successful treatment of the septic episode. Sepsis is an acute event and its main manifestation, acute organ dysfunction, does not seem to be associated with long-term mortality in patients who survive the original insults. Furthermore, many studies failed to adjust appropriately for treatment-limitation decisions such as DNR given less than two days or later during the ICU stay. Moreover, treatment-limitation decisions were found to be independently associated with ICU deaths.

Severe infections per se are associated with a decrease in life expectancy. Short-term survival may need to be viewed as a surrogate measure, because it is desirable only when followed by long-term survival with an acceptable quality of life. On the other hand, focusing on very long-term mortality, which is extremely relevant to healthcare-cost issues, may mask beneficial effects of drugs used to treat sepsis if the patient dies later on as a result of an underlying chronic illness associated with a risk of sepsis. High death rates due to underlying diseases may explain why many therapeutic trials in patients with severe sepsis failed to detect benefits related to the experimental treatments. Therefore, when designing large trials of treatments for severe

*Continued on page 15…*

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# Epidemiology of Neonatal Bacteremia in a South Bronx Hospital

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## Abstract

**Background:** Bacteremia in neonates increases risk for morbidity and mortality. The objective of this study was to evaluate the incidence of neonatal bacteremia and identify any trends in an inner-city teaching hospital in the South Bronx.

**Methods:** Medical records of neonates age <28 days with positive blood and/or cerebrospinal fluid cultures admitted to nurseries (normal newborn and intensive care), pediatric inpatient and intensive care units between Jan 2000 and Dec 2006 were reviewed retrospectively using data obtained from logbooks and medical record charts.

**Results:** 136 (0.75%) positive blood cultures were identified, out of 18,307 births. 72 (53%) of 136 were considered contaminants and the remaining 64 (47%) represented true bacteremia. The combined incidence of early and late bacteremia was 3.4 per 1000 live births. Our study showed an early onset group B streptococcus bacteremia incidence of 0.76 per 1000 live births. Nearly half (46%) of early onset bacteremia was due to non-GBS organisms. 84% of late onset bacteremia occurred in low birth weight premature infants who required invasive procedures and prolonged hospital stay. These infections were caused by commensal species.

**Conclusions:** Bacteremia due to GBS in our population is 2-3 times higher than nationally reported rates. Racial differences continue to exist. The population served by our hospital is primarily Hispanic and Black of low socioeconomic status. Close monitoring of maternal infection and treatment, strict hand washing, aseptic precautions for all invasive procedures and avoidance of overcrowding are essential preventive measures. Continued surveillance is warranted to assist in strategy formulation to decrease morbidity and mortality.

## Introduction

Newborns have increased risk of bacteremia, which varies with weight and gestational age. Important risk factors include: maternal infections, prematurity, Black or Hispanic race, invasive procedures, indwelling lines, prolonged hospital stay, inappropriate antibiotic use, improper hand washing, and overcrowding. Bacteremia in newborns is associated with signs and symptoms of clinical sepsis and/or meningitis. However, symptomatology can be subtle and laboratory tests are required for diagnosis. Blood culture remains the gold standard test for diagnosis. Neonatal bacteremia is divided into two distinct groups based on presentation. Early-onset sepsis (EOS) is described as infection occurring within the first seventy two hours of life as per the NICHD network [11,12] and less than seven days of life as per CDC and AAP.[1,2,4] In our study we have used the definition of less than seventy-two hours. These are perinatally acquired infections from mother-fetus-infant through vertical transmission. Most of the organisms implicated in early-onset infection are due to group B streptococcal infections (GBS). The majority manifest with symptoms within 24 hours.[1,2] Late-onset sepsis (LOS) is horizontally transmitted and manifest as focal infections, including meningitis. Such infection may occur during hospitalization or may be acquired from the community after the infant is discharged home.

Trends are changing in the epidemiology of neonatal bacteremia. Studies have shown a decline in bacteremia caused by group B streptococcus following the implementation of intrapartum chemoprophylaxis guidelines.[5,8] Additionally, other microorganisms have been responsible for this type of infection and its consequences.[11] In addition, with increasing survival of extremely low birth weight preterm infants, late-onset infection is a challenging complication with some studies showing that the incidence of late-onset bacteremia is increasing.[3,12] Racial differences have been identified in the incidence as well as mortality caused by certain bacteria in neonates.[5] The objective of this study was to evaluate the incidence of bacteremia and identify any trends in an urban hospital in the South Bronx.

## Materials and Methods

This is a retrospective, epidemiological and descriptive study. We reviewed medical records of neonates with positive blood and/or cerebrospinal fluid cultures, admitted to the normal newborn nursery and NICU during the seven-year period from January 2000 to December 2006 to Lincoln Medical and Mental Health Center, a 347 bed community teaching municipal hospital serving the South Bronx. Our patient population is approximately 70% Hispanic, 20% Black and 10% others. We examined and abstracted data reflecting maternal risk of infection, delivery characteristics, gestational age, birth weight, time of onset of infection and its clinical features, blood culture reports,

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procedures and management performed during inpatient stay and the outcome. The data was obtained from nursery logbooks, medical record charts, and infection control and bacteriology lab. Only neonates who were born and admitted in our hospital were included. Those neonates who were discharged home and later readmitted for possible sepsis were not included.

Positive blood cultures were considered contaminants if they fulfilled the following criteria 1. infant's clinical status as documented in the medical record, 2. negative repeat cultures within 24 hrs, 3. normal complete blood counts, 4. type of microorganism and 5. no antibiotics were given. Contaminants will be discussed in detail under the discussion section.

## Results

18,307 neonates were born during the study period. A total of 79 positive blood cultures were identified. Of these, 20 (25%) were considered as contaminants. Of the remaining 59 cases of bacteremia, 24 (41%) were early onset and 35 (59%) were late onset. The overall incidence of bacteremia in our population was 3.2 per 1000 live births: early onset was 1.3 per 1000 live births and late onset 1.9 per 1000 live births.

The total hospital neonatal unit mortality rate during the study period was 3.9 per 1000 live births. Neonatal mortality due to sepsis was 0.5 per 1000 live births. Early onset bacteremia related mortality was 0.27 per 1000 live births and late onset bacteremia related mortality was 0.27 per 1000 live births. The cause of death was multifactorial as shown in table 2.

Our study showed an early onset GBS-bacteremia incidence of 0.76 per 1000 live births. Nearly half (42%) of early onset bacteremia was due to non-GBS organisms, predominantly E coli. Late onset bacteremia was observed particularly in very low birth weight premature babies (94%) who required invasive procedures and prolonged hospital stay (figure 1 and 2). Commensal organisms were responsible for 62% of the hospital acquired late-onset disease as shown in table 1, predominantly coagulase negative staphylococcus and candida.

## Discussion

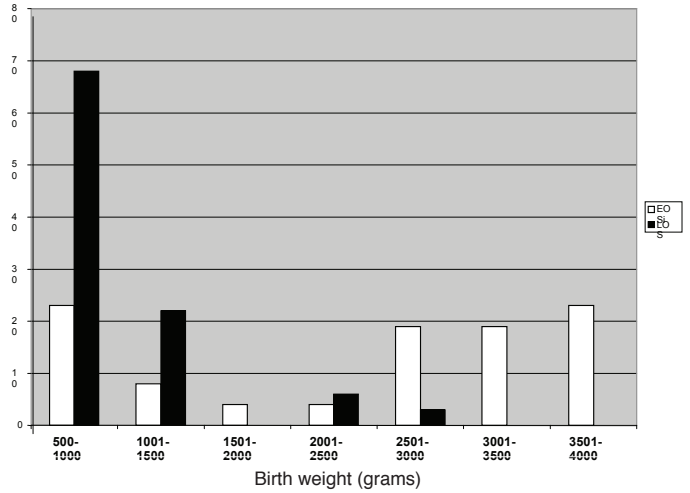
The maternal genital tract is a common source of bacterial pathogens that cause EOS. For many years, group B streptococcus (GBS) was the leading organism in early-onset sepsis.[3,4] In 1996, after several clinical trials and intensive research, the American College of Obstetricians and Gynecologists (ACOG), the Centers for Disease Control and Prevention (CDC) and the American Academy of Pediatrics (AAP) issued guidelines for risk-based approach or culture-based screening and intrapartum antibiotic prophylaxis as prevention of perinatal GBS invasive infection.[4,5] As a result of the implementation of chemoprophylaxis guidelines, a significant decrease of over 70% was observed in the incidence of EOS due to GBS infection, thus reducing GBS sepsis-related mortality rates.[7] In 2002, these strategies were modified to broaden culture-based screening methods and management algorithms, emphasizing chemoprophylaxis regimens.[4]

In our study, the combined incidence of early and late onset bacteremia was 3.2 per 1000 live births of which the incidence of early onset GBS disease was 0.76 per 1000 live births. Though this seems to be greater than that determined by the Active Bacterial Core (ABC) Surveillance system, United States, 2004 (0.34 per 1000 live births),[5] it is noteworthy to add that in the same study significant racial differences were identified.

**Table 1.** Microbiology of non-GBS organisms causing early-onset vs late-onset bacteremia.

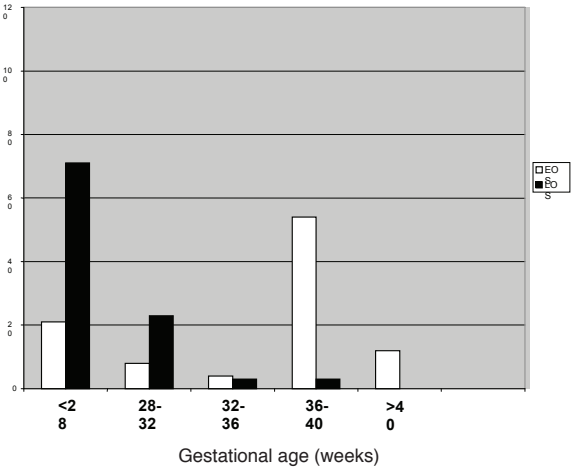
| NON GBS ORGANISMS | EOS N=10 | LOS N=35 | TOTAL N=45 |
|---|---|---|---|
| E.coli | 5 | 3 | 8 |
| C.albicans | | 8 | 8 |
| S.epidermidis | | 8 | 8 |
| K.pneumoniae | 1 | 4 | 5 |
| E.faecalis | | 6 | 6 |
| S.aureus | 1 | 4 | 5 |
| S.marcescens | | 1 | 1 |
| S.pneumoniae | 1 | | 1 |
| H.influenzae | 1 | | 1 |
| E.cloacae | 1 | | 1 |
| P.aeruginosa | | 1 | 1 |

**Figure 1.** Correlation of early-onset vs late-onset neonatal bacteremia with birth weight




EOS: percentage of early onset bacteremia
LOS: percentage of late onset bacteremia

**Figure 2.** Correlation of early-onset vs late-onset neonatal bacteremia with gestational age




EOS: percentage of early onset bacteremia
LOS: percentage of late onset bacteremia

Table 2. Neonatal Bacteremia and Mortality

| S.No | Gestational age (weeks) | Birth weight (g) | Problems | Organism | Day of onset of infection | Day of death |
|---|---|---|---|---|---|---|
| 1. | 23 | 526 | Severe RDS | Candida albicans | 16 | 21 |
| 2. | 23 | 554 | Severe RDS | Candida albicans | 11 | 15 |
| 3. | 24 | 550 | RDS | Candida albicans | 13 | 24 |
| 4. | 24 | 627 | NEC | Enterobacter cloacae | 1 | 9 |
| 5. | 24 | 643 | RDS, Severe hypovolemia due to placental abruption | E.coli | 1 | 1 |
| 6. | 24 | 774 | Staphylococcal scalded skin syndrome, septic shock | MSSA | 13 | 17 |
| 7. | 25 | 680 | RDS | Pseudomonas | 6 | 8 |
| 8. | 27 | 1210 | RDS vs pneumonia | GBS | 1 | 10 |
| 9. | 32 | 14480 | RDS vs pneumonia | GBS | 1 | 1 |
| 10. | 40 | 3175 | Pneumonia | GBS | 1 | 2 |

The rates per 1000 live births for early onset GBS disease were 0.73 for black infants and non-white infants and 0.2 for white infants. Between 2003 and 2005, a steady decrease in the incidence of early-onset GBS disease among white infants was reported, but there was a 70% increase among the black infants. This disparity in the incidence of early onset sepsis between black and white races is thought to be due to high maternal colonization among blacks, higher incidence of preterm births, a risk factor for infection and poor prenatal care that decreases the opportunity for universal GBS screening between 35-37 weeks.[15] Moreover, nearly a third of the patients who deliver in our hospital have their prenatal care in other prenatal clinics where documentation of adequate GBS screening is not available. Our higher incidence can be explained by predominance of blacks and Hispanics in our population. In our study, 57% of early onset GBS bacteremia occurred among Hispanics, 35% among blacks and 7% Asian population. Although Healthy People 2010 objectives have been achieved for early-onset infection, the fact that racial differences exist is disturbing.[5] In a population like ours, one should look into measures for overcoming the barriers of missed opportunities for GBS screening. Under such conditions, risk assessment, culturing and prophylaxis during the intrapartum period must be strictly adhered to.

There was no significant annual difference in the incidence of early-onset GBS bacteremia during the study period between the years 2000 and 2006. However, there was significant decrease in GBS related mortality. There were three neonatal deaths (of which one occurred in a full term infant) due to early onset GBS before 2003 and none after 2003, also seen nationally. This is due to improved perinatal surveillance and management because until 2003, universal maternal GBS screening was not instituted.

Of the total neonatal deaths during the study period, 10 had positive blood cultures. The incidence of neonatal deaths associated with bacteremia was 0.5 per 1000 live births, whereas the incidence of neonatal death due to any cause was 3.9 per 1000 live births. As shown in table 2, the cause of death was attributable to various factors such as extreme prematurity, less than 27 weeks gestational age and less than 750g birth weight with related complications, high-risk pregnancy and prolonged hospital stay in extremely low birth weight babies. There was one full term baby who died of fulminant GBS pneumonia.

Some studies have shown an association of intrapartum antibiotic exposure and increased EOS caused by non-GBS species, including E coli, other Gram-negative organisms or ampicillin-resistant pathogens,[11] and others have not.[6,10] In our study, the incidence of EOS caused by non-GBS organisms was nearly 42%. The non-GBS organisms causing early onset bacteremia are summarized in table 1. E coli was the most common non-GBS etiologic agent of early onset bacteremia.

Despite a decline in the early onset sepsis, similar studies have reported that late onset sepsis rates remain constant or increased.[3,4,5,12] This trend might be a result of extensive use of antibiotics or prolonged hospital stay with invasive procedures among infants that require NICU admission, especially preterm, very low birth weight infants. Prolonged intravascular access, parenteral nutrition, mechanical ventilation and the effects of prematurity contribute to infection onset, complications of the disease and fatal outcome.[5,11,14] The same was reflected in our study. All with late onset disease had undergone invasive procedures and 71% were < 28 weeks gestation and 68% weighed less than 1000g as shown in figure 2a and 2b. As also observed in table 1, 62% of outcomes were caused by nosocomial commensal organisms, including, Candida albicans and Staphyloccus epidermidis being the most common. We do not give antifungal prophylaxis in our hospital.

A large number of contaminants was identified in our study. This was a function of procedural and technical issues. These blood cultures were drawn from asymptomatic babies whose mothers had a risk factor for infection and were not adequately treated. Most were pregnant women who had prenatal care in other clinics without documentation of adequate GBS screening. There is no single definition for a contaminant and the criteria for considering a positive blood culture as a contaminant varies from institution to institution. In our study, we used the criteria mentioned above under the materials and methods section.

Limitations of this study include the retrospective nature of the study. We also do not have data about babies who were born and discharged healthy from our nursery, and who might have been

admitted in other hospitals. As a result, late onset community acquired infections are not completely represented in our study.

## Conclusions

Bacteremia continues to be a major determinant of neonatal morbidity and mortality when it is associated with sepsis with or without meningitis. Racial differences in the incidence of early onset disease continue to exist.[5] More studies are needed to clearly understand the reasons for the racial differences. At present, universal culture-based GBS screening between 35 and 37 weeks and intrapartum antibiotic prophylaxis for high risk as well as mothers with unknown GBS status is the most effective method for prevention of early onset GBS disease in neonates. The incidence of late onset disease is related to infants with prematurity and very low birth weight who require invasive procedures and it continues to increase.

We recommend close monitoring of maternal cultures and prophylaxis, strict hand washing and aseptic precautions for all invasive procedures, avoiding overcrowding in the nursery, adequate staffing, close monitoring for signs and symptoms of clinical sepsis, early discharge of stable infants home and appropriate use of antibiotics. Careful attention to technique in obtaining cultures is indicated in order to decrease the rate of contamination. Continued surveillance is needed to identify the changing trends in the epidemiology of neonatal bacteremia to assist in strategy formulation to decrease the morbidity and mortality.

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*Model…continued from page 11*

sepsis, it may be appropriate to select candidate treatments in preliminary trials that use short-term mortality as the primary endpoint.

We found that mortality from severe sepsis could be predicted based on variables associated with the PIRO concept (P: co-morbidities, McCabe; I: multiple-site infection, number of severe sepsis episodes; and R and O: organ dysfunction and vasoactive drug use). These findings are in accordance with a recent report of a PIRO-based score designed to predict 28-day mortality from sepsis, thus focusing on a nearer time horizon than many recent studies evaluating longer term outcome.

We developed a model for predicting death within 14 days after the diagnosis of the first, second, third or fourth episode of severe sepsis occurring within 28 days after ICU admission. The model is based on a few readily available variables. It may help to evaluate the effectiveness of new drugs or treatment strategies in reversing severe sepsis. In contrast, long-term mortality may be a better marker for the efficacy of treatments directed against sepsis, because recovery from sepsis may be followed by death due to underlying illnesses.

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Doug Wilder, RRT

## Case

A 19 year old female presented to the hospital with increasing labor pains and delivered an otherwise normal 3 lb neonate. The neonate was placed under an infant warmer with an Oxyhood at 100% $O_2$.

After a period of one hour the patient's respiratory rate increased to 60 with mild retractions noted.

A blood gas was ordered and run on the Roche cobas b 221 blood gas system.

The following results were reported:

| Parameter | Reported Value | Neonatal Normal Ranges |
|---|---|---|
| pH | 7.331 | 7.35 – 7.50 |
| $PCO_2$ | 44.3 | 35 – 45 |
| $PO_2$ | 225.0 | 50 – 80 |
| $HCO_3$ | 22.9 | 22 – 26 |
| tHb | 20.5 | 13 – 22 |
| $SO_2$ | 99.5% | < 90 |
| Glu | 60 | 80 – 120 |
| Lac | 6.2 | < 2.0 |

## Assessment

The patient had a normal $SO_2$ of 99.5% normal $PCO_2$, normal $HCO_3$, and all electrolytes were in normal range. Based on ABG values and physical appearance, the patient appeared normal with increased respirations attributed to its premature condition. Upon closer review of the ABG results along with the lactic acid level of 6.2 mmol which is three times the upper limits of the normal range, the patient was diagnosed with Infant Respiratory Distress Syndrome. This syndrome increases the breathing rate in response to incomplete lung development characterized by reduced amounts of lung surfactant, cyanosis, the formation of a glassy membrane over the alveoli and pulmonary collapse. As respiration increases inspiratory muscles work harder to provide oxygen. The increased muscle activity results in utilization of glucose and increase in lactic acid in the bloodstream due to the inefficiency of the neonatal liver to convert the lactic acid to pyruvic acid.

## Treatment

The patient was transferred to the NICU, administered bicarbonate, glucose, surfactant and placed on nasal CPAP overnight. The nasal CPAP was removed the next day.

## Conclusion

Lactic acid and glucose as part of a neonatal ABG panel provides greater diagnostic capabilities in assessing and treating Infant Respiratory Distress Syndrome and related conditions.

## Recommendation

All NICU blood gas analyzers should have the ability to run lactic acid and glucose like the Roche cobas b 221 system. All neonatal blood gas panel should include lactic acid and glucose as a standard of care in the neonatal setting.

# The Clinical Utility of Lactic Acid Trending with ABGs in the Critical Care Setting: A Case Study

Doug Wilder, RRT

## Introduction

With today's blood gas technology such as the Roche cobas b 221 blood gas system healthcare providers can trend any four of the eighteen parameters including metabolites such as glucose and lactic acid. This provides a diagnostic platform for a number of clinical applications. For example trending lactic acid gives the clinician the ability to not only monitor the level of lactic acid but also the ability to intervene early on in cases of tissue hypoxia, sepsis and the onset of myocardial infarction. The following study is a case in point.

## Case

A 65 year old female presented to ED with the following clinical findings: shortness of breath, evaluated temperature 101, blood pressure 110/70, swollen ankles. The patient also has a history of COPD and CHF. The patient was given bronchodilator therapy, diuretics, chest x-ray and a blood gas was drawn at 14:39 with the following results:

| | |
|---|---|
| pH | 7.31 |
| $PaCO_2$ | 50 |
| $PO_2$ | 55 |
| $HCO_3$ | 28.8 |
| Lac | 1.2 |

The patient was admitted to the hospital and placed on oxygen, bronchodilator therapy, treatment for CHF and antibiotic therapy. A second blood gas was drawn at 20:55 on LPM with the following results:

| | |
|---|---|
| pH | 7.32 |
| $PaCO_2$ | 48 |
| $PO_2$ | 74 |
| $HCO_3$ | 14.2 |
| Lac | 8.8 |

After the results were called to the physician the patient was placed on non-invasive ventilation overnight. At 07:59 another blood gas was drawn with the patient 40% $O_2$ with the following results:

| | |
|---|---|
| pH | 7.35 |
| $PaCO_2$ | 45 |
| $PO_2$ | 80 |
| $HCO_3$ | 16.1 |
| Lac | 7.4 |

At this point the patient seemed to be responding to the therapy. At 12:30 the patient's oxygen saturation started to drop and another blood gas was run with the following results:

| | |
|---|---|
| pH | 7.31 |
| $PaCO_2$ | 55 |
| $PO_2$ | 60 |
| $HCO_3$ | 10.1 |
| Lac | 13.3 |

Following this blood gas, the patient was moved to the intensive care unit placed on 100% oxygen via mask and another blood gas was drawn to 13:52 with the following results:

| | |
|---|---|
| pH | 7.30 |
| $PaCO_2$ | 65 |
| $PO_2$ | 59 |
| $HCO_3$ | 15.3 |
| Lac | 13.8 |

Now the patient was placed on a ventilator and an infectious disease physician was consulted. At 15:15 another blood gas was drawn with the following results:

| | |
|---|---|
| pH | 7.35 |
| $PaCO_2$ | 50 |
| $PO_2$ | 80 |
| $HCO_3$ | 10.2 |
| Lac | 15.1 |

At 18:30 a final blood gas was drawn with the following results:

| | |
|---|---|
| pH | 7.35 |
| $PaCO_2$ | 50 |
| $PO_2$ | 84 |
| $HCO_3$ | 14 |
| Lac | 18.9 |

The patient was transferred to another facility.

## Treatment

At the new facility the patient was placed on the ventilator for several more days and treated for a septic pulmonary infection and finally discharged 2 weeks later.

## Conclusion

The respiratory staff had received several in-services on lactic acid prior to the admission of this patient. This knowledge and training was instrumental in providing the physicians with trending data that improved patient care and resulted in a positive patient outcome. Any critically ill patient should have blood gases with electrolytes and a direct measurement of lactic acid. Trending should be considered in cases where sepsis, tissue hypoxia and myocardial infraction are suspected. The hospital should consider blood gas lactic acid testing and trending as a standard of care when dealing with critically ill patients.

# Point-of-Care Lactate Testing as a Predictor of Mortality in a Heterogeneous Emergency Department Population

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**Background:** Point-of-care (POC) lactate testing has been shown to correlate with serum measurements of lactate. In certain disease states, early lactate measurement is recommended.

**Objective:** To demonstrate that addition of POC lactate testing predicts mortality better than traditional clinical and laboratory markers.

**Methods:** This was a post-hoc analysis of a data set from a prospective, double-blind cohort study involving a convenience sample of heterogeneous patients presenting to an urban emergency department (ED). Patients presenting in cardiac arrest were excluded. POC lactate level R4 mmol/L (POC4) was compared with several clinical and biological values. Using descriptive statistics, we analyzed the impact of systemic inflammatory response syndrome (SIRS) criteria and POC4 on mortality rates. Logistic regression for mortality analysis was performed on POC4, systolic blood pressure, shock index, anion gap, base excess, and serum bicarbonate concentration. A composite score (the lactate-SIRS product, or LSP) involving the cross-product of the number of SIRS criteria (#SIRS) and POC was calculated. Likelihood ratios for in-hospital mortality were also calculated for #SIRS, LSP (R8), and POC4.

**Results:** Data were collected from 116 patients. Mortality for the entire population was 15%. POC <4 mmol/L mortality was 7.1% and POC4 mortality was 36.7%. Patients with 3 and 4 SIRS criteria had mortality rates of 16% and 33.3%, respectively. With the addition of POC4 to 3 and 4 SIRS criteria, mortality increased to 33.3% and 100%. Logistic regression demonstrated the POC4 to be the only variable to predict mortality independently ($p = 0.049$). Calculated positive likelihood ratios (LRs) for R2 SIRS criteria, LSP, and POC4 were 1.2, 2.25, and 3.3, respectively.

**Conclusions:** POC lactate testing is more useful than other clinical or laboratory results for predicting death in a heterogenous ED population. POC lactate added to SIRS criteria defines a population with a greater mortality than SIRS criteria alone.

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