

# Application of financial analysis techniques to clinical laboratory data: A novel method of trend interpretation in the intensive care unit

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## ABSTRACT

Modern critical care medicine depends on constant flow of massive amounts of information. This information has limited usefulness unless it is appropriately gathered, stored, displayed, and interpreted. Despite such wealth of data in the modern intensive care units (ICU), intensivists often rely on very fragmentary 'snapshot' information to make important clinical decisions. In an attempt to improve the understanding of clinical data trends, application of financial analysis (FA) methods to clinical laboratory data samples was performed. Three randomly chosen, anonymized laboratory datasets of patients who spent at least 30 days in the ICU were retrospectively examined. Regularly obtained laboratory values were retrieved and recorded for each patient. Variables examined included white blood cell count, hemoglobin level, platelet count, and blood glucose levels. These variables were then entered into specialized FA software and subjected to computer-based processing. Trends in the recorded data were examined using (1) the **Stochastic Oscillator (SO)**, (2) the **Relative Strength Index (RSI)** tool, (3) **Price Envelope (PE)** analysis and (4) **Moving Average** analysis. All clinical laboratory parameter analyses demonstrated that laboratory data could be successfully 'trended' using FA techniques. Not only was the laboratory data clearly readable and transparent when displayed in FA fashion, some trends that were not apparent on 'gross' inspection of the numeric data became very apparent after FA. Much like with financial patterns and vital sign data, trends noted within laboratory parameters appeared to be more significant when more than one indicator identified or 'confirmed' them, utilizing the concept of a **confirmatory variable**. Laboratory data, much like financial and vital sign data, were subject to trend reversals. Such reversals in laboratory parameters appeared to follow patterns similar to those followed by financial vehicles and markets. This report demonstrates that laboratory data can be subjected to the same manipulations as financial market data. Furthermore, FA tools appear to provide the interpreter with means to define, confirm, and possibly predict trends and trend reversals. Assumptions for use of FA methods in biologic parameter analysis are also presented.

**Cite as:** Stawicki SP. OPUS 12 Scientist 2007;1(2):1-4.

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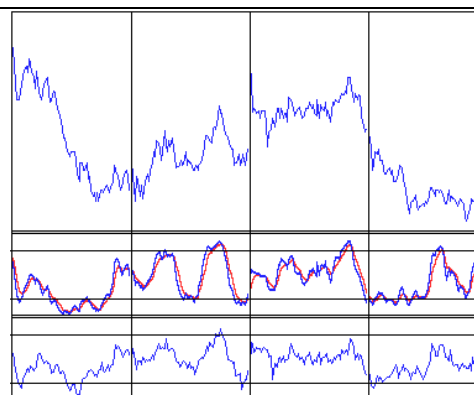
**Keywords:** Wall Street, Technical indicators, Trending methods for stocks and bonds, Laboratory data, Financial analysis software, Intensive care unit.

The success of modern critical care medicine is largely dependent on contemporary research and technological advances that bring about an increasingly greater flow of clinical information. This information includes vital signs, laboratory values, pressure measurements (arterial pressure, central venous pressure, pulmonary artery pressure, intracranial pressure, bladder pressure, etc), various types of input (intravenous, enteral, etc) and output

(urine, suction drains, etc) parameters. Every conceivable device in the modern ICU provides the intensivist with certain amount of information, although utilization of this information tends to be largely episodic and fragmentary.<sup>1</sup> It is well known that the ubiquitous clinical information requires significant amount of interpretation before it truly becomes clinically useful.<sup>1</sup> The ICUs have not capitalized on the huge amount of streaming data. Unlike the financial market specialists, intensivists still rely only on cursory data and trends analyses. An examination of analytic methods previously used by the author to 'trend' vital sign data was conducted on clinical laboratory variables in an attempt to find ways to improve the poor data-trend utilization in the ICU.<sup>1</sup>

Technical indicators have long been used in analyzing past trends and patterns in an attempt to predict future financial market events. It is also well established that nearly all variables in biology are non-stationarily stochastic.<sup>1-2</sup> Numerous complicated approaches have been used in the past to describe vital sign trends.<sup>2-3</sup> For example, Fourier spectral analysis has been shown to work well for strictly periodic or stationary random time functions and a stochastic exponential dispersion model was shown to describe regional animal organ blood flows.<sup>2-3</sup>

Various indicators are used to signal potential financial market trend reversals, and when used in conjunction with other information (such as company earnings, sector earnings, or stock market 'sentiment') can contribute to the overall decision-making process regarding purchase or sale of a given security. Some of the most commonly used stock market technical indicators include the relative strength index (**RSI**) and the stochastic oscillator (**SO**).<sup>4-5</sup>

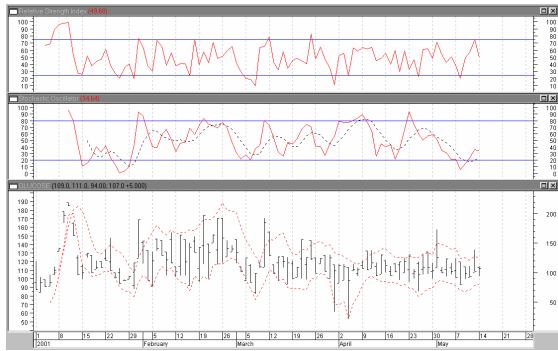


**Figure 1.** Example of SO and RSI indicators used in short-term (minute-to-minute) analysis. Each vertical bar represents one calendar day.

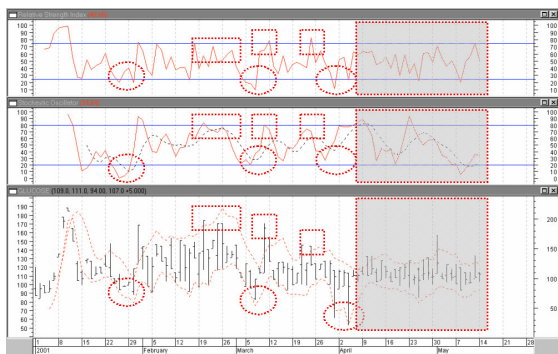
The advantage of indicators used in this study is that their understanding requires only a rudimentary knowledge of mathematics. In addition, all of the indicators used in this report (**RSI**, **SO**, **PE**, and **MA**) can be used equally well in both second-to-second (**Figure 1**) and month-to-month data analyses, making

them applicable across a broad range of clinical variables and data ‘resolution’ ranges. Moreover, these indicators work just as well for small measurement units (fractions and decimals) as they work for large measurement units. **Figure 2A** demonstrates financial-like graphical representation of serum glucose levels. **Figure 2B** demonstrates how **FA** indicators can be used to demonstrate trend reversals.

**Figure 2A** (below). Graphical representation of serum glucose levels, with the various trends indicated by **FA** software indicators. Note the **RSI** indicator in the upper field, with the **SO** indicator in the middle field, and the stock bar graph of serum glucose levels in the bottom window, along with **PE** dashed lines.



**Figure 2B** (below) shows the graphical representation of serum glucose levels with parts of the graph highlighted according to trend interpretation. Please note the ovals indicating lower trend reversals and the boxes indicating upper trend reversals in serum glucose levels. The shaded area towards the latter part of the recording period indicates relative lack of trending due to stabilization of glucose levels within the desired range. Such ‘obliteration’ of the trend indicates lack of significant change either on the upside or on the downside and points to clinical ‘stability’.



Much like the author’s previous examination of trends in vital sign data, it was hypothesized that use of **RSI**, **SO**, **MA** and **PE** can effectively describe trends in clinical laboratory parameters, and open a possibility that these indicators could be used in conjunction with vital sign data trends and clinical findings to improve global patient care and clinical decision making.<sup>1</sup> The goal of this report is to describe the use of existing and proven methods of financial data ‘trending’ in a novel way.

Laboratory data were obtained retrospectively from three randomly selected, completely anonymized, ICU datasets. Clinical laboratory data were recorded at least twice daily, over a period of weeks. Laboratory information was then transformed into the open-high-low-close (**OHLC**) format used in **FA**. In order for this format to be used, the data had to be arranged into 24-hour **epochs**. For each **epoch**, the opening value (the first value in the **epoch**), the high and low values, as well as the closing value (the

last value in the **epoch**) were ascertained over each 24-hour period. Data were then entered sequentially for each epoch into MetaStock™ (Equis International, Salt Lake City, UT, USA) financial analysis software. Following data entry, a graphical interpretation, much like a stock price graph, emerged. Data analysis included observational inspection of the stock-like charts, examining for the presence or absence of variability and/or trends.

A definitive trend was defined as one with the **stochastic oscillator** and the **relative strength index** indicator moving in tandem and one indicator ‘confirming’ the trend demonstrated by the other. **Envelopes** were added at times as secondary confirmatory trending tools. In addition, two **moving averages** were used to see whether the ‘trended’ variable was above or below the overall ‘long-term trend’ indicated by the moving average. Ordinary stock market parameters of ‘oversold’ and ‘overbought’ were used with respect to **SA** and **RSI**. The ‘oversold’ state represented a potential trend reversal on the low side, while the ‘overbought’ state represented a potential trend reversal on the high side. Detailed description of stock trending methods was discussed by the author previously.<sup>1</sup>

Three ‘public-domain’ indicators used mainly in stock and bond market analysis were utilized in this study. The first one, called **relative strength index (RSI)**, developed by J. Welles Wilder, signals overbought and oversold conditions.<sup>6</sup> The **RSI** is a very useful and popular momentum oscillator. It compares the magnitude of a security’s recent gains to the magnitude of its recent losses and turns that information into a number that ranges from 0 to 100. Generally, numbers less than 20 indicate ‘oversold’ condition and numbers over 80 indicate ‘overbought’ condition. The formula for **RSI** has several parts, and is derived as follows:

$$RSI = 100 - (100 / (1 + RS))$$

$$\text{Average gain} = (\text{Total gains} / n)$$

$$\text{Average loss} = (\text{Total losses} / n)$$

$$\text{First RS} = (\text{Average gain} / \text{Average loss})$$

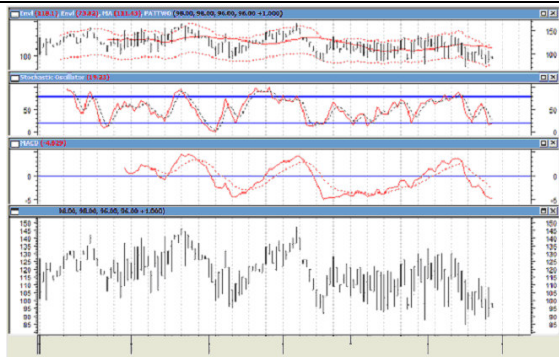
$$\text{‘Smoothed’ RS} = \{[(\text{previous Average gain}) \times 13 + \text{Current gain}] / 14\} / \{[(\text{previous average loss}) \times 13 + \text{Current loss}] / 14\}$$

where **n** = number of **RSI** periods

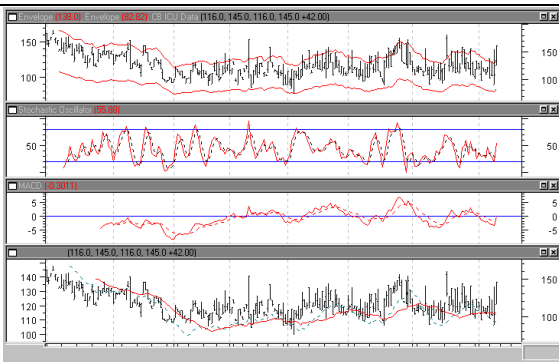
The **SO**, **MACD**, **PE**, and **MA** parameters were discussed previously.<sup>1,7-9</sup> All of these investment tools can be used to attempt identification of stock or bond price trend reversals. In addition, these indicators can be applied to ‘bundles’ or ‘baskets’ of stocks and/or bonds, wherein they help to identify the overall trend of the entire group (or **index**) of securities just as accurately as they do for an individual stock or bond.

As one can see, the graphs in **Figure 1** and **Figure 2** are not much different from heart rate (**Figure 3A**) and blood pressure (**Figure 3B**) charts processed with the same **FA** software. In fact, nearly identical reversal patterns can be seen in both types of graphs, and temporal patterns that would be difficult to detect by examining

the purely numerical representation of vital sign or laboratory data emerge.

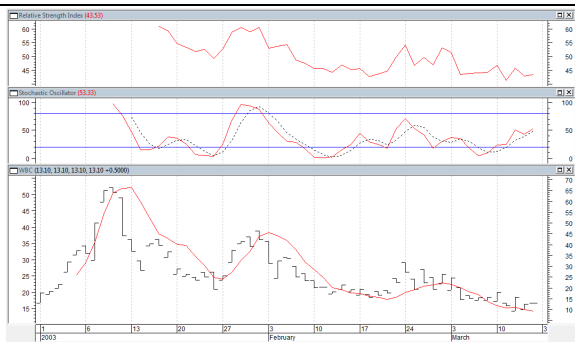


**Figure 3A** (above). Heart rate data shown in the format of a stock chart. The lower field shows heart rate in the open-high-low-close (OHLC) format grouped in 4-hour intervals (each bar). Above the bar graph are, from bottom to top: moving average convergence-divergence (MACD), stochastic indicator (SO), and envelope indicators (uppermost).



**Figure 3B** (above). Blood pressure data shown in the format of a stock chart. The lower field shows systolic blood pressure in the open-high-low-close (OHLC) format grouped in 4-hour intervals (each bar). Above the bar graph are, from bottom to top: moving average convergence-divergence (MACD), stochastic indicator (SO), and envelope indicators (uppermost).

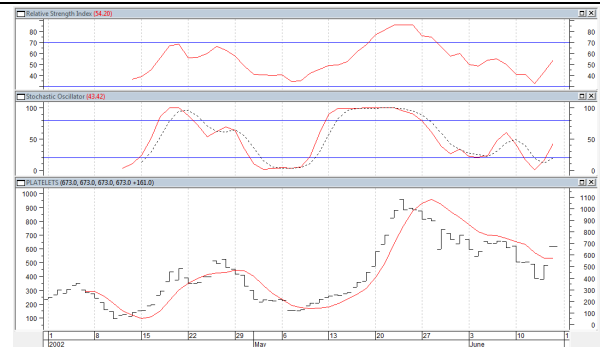
Good ‘trending’ characteristics can also be seen with white blood cell count (Figure 4), platelet count (Figure 5), and hemoglobin concentration data (Figure 6). Here, the stock-type charts very nicely demonstrate both short-term and long-term trends in laboratory parameter trends and trend reversals.



**Figure 4** (above). White blood cell count data displayed using the stock chart-like OHLC format. Again, note the excellent ‘trending’ characteristics of the data, as well as the normalization of white blood cell count leading to trend ‘obliteration’.

Based on this limited application of stock trending techniques to clinical laboratory variables, it appears that these simple and easy-

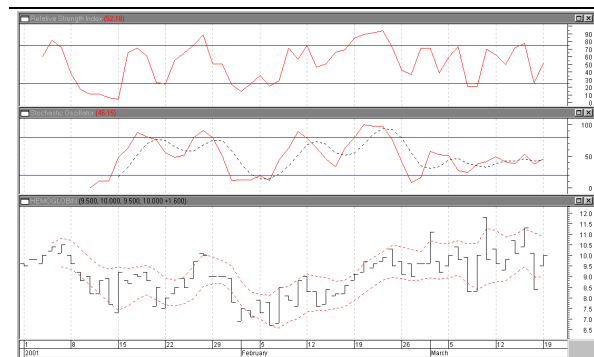
to-use investor tools (SO, MACD, RSI, MA, and PE) may be useful in analyzing a broad range of clinical variables. Similar analyses using vital sign data, intracranial pressure data and bladder pressure data have been previously performed by the author, with good results.<sup>1</sup>



**Figure 5** (above). Platelet count data displayed using the stock chart-like OHLC format. Note the excellent ‘trending’ characteristics of the data.

What is the usefulness and relevance of such charting trends and their interpretation? Quite frankly, the answer to this question is unclear. Certainly, application of these charts and trends to financial market data does not guarantee excellent investment results. In order to elucidate the full extent of any potential benefits to biologic data interpretation and/or eventual patient care, one must proceed with extreme caution and the overall patient clinical picture has to be taken into consideration first.

While graphs and trends of individual variables (i.e. white blood cell count, heart rate or hemoglobin) may be valuable from the standpoint of clarity of the graphical representation of these variables, the most useful clinical information will most likely come from ‘indices’ of multiple variables, much like the stock indices. In such arrangement, multiple components of a biologic ‘index’ would be used to create a ‘composite index’. Based on certain assumptions (see Table 1 below) this ‘composite index’ would then be used to estimate the overall patient ‘physiologic-economic’ condition, and it could be analyzed for significant trends and trend reversals much like its individual components. In a way, we would be estimating the overall state of the ‘physiologic economy of the patient’. These assumptions are partially based on the Dow Theory, formulated from a series of Wall Street Journal editorials authored by Charles H. Dow from 1900 to 1902.<sup>10</sup>



**Figure 6** (above). Hemoglobin data displayed using the OHLC stock chart format. Please note the ‘obliteration’ of trend as the hemoglobin level stabilizes.

**Table 1.** Physiologic economy of the patient – model assumptions

- The human body discounts all events and stimuli – direct and indirect – that affect its functioning.
- The ‘overall state’ of the human body is reflected instantaneously through various vital signs, laboratory values, input/output values, and pressure-based data (catheter-derived, ultrasound-derived, etc).
- Common types of trends describe dynamic changes in all measured biologic variables. These trends can be followed temporally using simple models based on basic mathematical equations.
- The presence of a trend in a biologic system may indicate a significant clinical change, which has to be correlated with the overall patient clinical picture.
- The disappearance or ‘obliteration’ of a trend indicates clinical ‘stability’ of that particular parameter.
- Combinations of multiple biologic variables are used to create a ‘biologic variable index’ – a reflection of the overall ‘physiologic economy of the patient’.
- In major trends, multiple components of the ‘biologic index’ must confirm each other.
- Each major trend remains in effect until clear trend reversal occurs. Confirmatory indicators may be useful when confirming such trend reversals.

## CONCLUSIONS

Indicators used in this manuscript provide a new way of describing and interpreting clinical laboratory data. When a trend was present, these indicators tended to demonstrate it quite well. When no trend was present, the indicators tended to ‘wonder around’ until the next trend was clearly identified. Further research on this topic is necessary in order to determine the usefulness (if any) of this model in clinical applications. Minimizing the subjective component of patient data interpretation and maximizing the objective component may

provide us with a better way of assessing patients and, when correlated with clinical data, may provide useful adjunctive confirmatory or possibly even predictive value. In addition, the author proposes that multiple biologic parameters, when used in conjunction and combined into ‘patient physiologic indices’ could offer a glimpse into the overall ‘economy’ of the human body.

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Published – October 8<sup>th</sup>, 2007 – 21:05 ET – King of Prussia, PA, USA.  
OPUS 12 Scientist, a Quarterly publication of OPUS 12 Foundation, Inc.

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