Financial analysis techniques in clinical practice: From 'micro' to 'macro'

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ABSTRACT
Improved methods of clinical data collection, storage, and processing are changing the way critical care practitioners examine and utilize the wealth of patient-related information available in the modern intensive care unit (ICU). The author of this report previously outlined general methods and principles of a proposed new biomedical parameter analysis system based on well-established financial analysis (FA) methods. The new system helps to define, confirm, and potentially predict trends and trend reversals in a number of traditional biomedical variables (vital signs, laboratory parameters, various catheter-derived pressure measurements, oximetry, temperature, and input/output variables). In order to examine the behavior of FA parameters and indicators across different temporal scales (i.e., minutes, hours, days, and weeks) the author analyzed trends in various biomedical parameters using different time scales and a standardized set of FA techniques, including: (1) the Stochastic Oscillator (SO), (2) the Relative Strength Index (RSI) tool, (3) Moving Average (MA), (4) Moving Average Convergence-Divergence (MACD); and (5) Price Envelope (PE) analysis. Randomly chosen and anonymized laboratory, urinary output, hemodynamic and intracranial pressure datasets of patients who spent at least 21 days in the ICU were retrospectively examined. Variables were entered into specialized FA software (MetaStock, Equis International, Salt Lake City, Utah, USA) and subjected to computerized processing methods. Analyses of the above clinical parameters demonstrate that laboratory, input/output, oximetry, and transduced pressure-based data can be successfully 'trended' using simple FA techniques. The data were easy to examine when displayed in FA fashion. In addition, some trends that were not easily apparent on examination of raw numeric data or basic non-FA graphs became more apparent after the application of FA methods. These findings suggest that biomedical parameters can be subjected to the same manipulations as financial market data. In addition, FA tools appear to provide the interpreting physician with means to examine biomedical parameters across different temporal scales and resolutions (from minutes to weeks per each measurement epoch). In fact, biomedical parameters tend to display similar trends regardless of whether the data is collected on the scale of minutes, hours, days, weeks, or months.

Keywords: Wall Street, Technical indicators, Trending methods for stocks and bonds, Biomedical parameters, Vital signs, Laboratory findings, Pressure-derived parameters, Financial analysis software, Intensive care unit, Directions for future research.

Modern critical care practice depends on acquisition, storage, advanced processing, and subsequent interpretation of large amounts of biomedical data. This information includes the following parameter groups and parameters: (a) vital signs – heart rate, respiratory rate, temperature; (b) laboratory values; (c) pressure measurements – arterial pressure, central venous pressure, pulmonary artery pressure, intracranial pressure, bladder pressure, etc.; (d) various types of input – intravenous, enteral; and (e) output – urine, suction drains, stool.

Every modern device in the contemporary ICU environment has the potential to provide the intensivist with a wealth of clinical information.1,2 However, the actual use of this information tends to be mostly episodic and fragmentary.1,2 It is well known that clinical information requires significant amounts of interpretation before it becomes clinically relevant.2 Furthermore, the major limitation of most ICU clinical data measurements is their relatively nonspecific nature and the very real potential for misinterpretation of this information.3 Because of these limitations, the ICUs have not fully capitalized on the huge amount of potentially useful streaming, real-time clinical data. Unlike financial market specialists, intensivists still rely mostly on cursory review of patient-related data and very basic trend analyses (Figure 1). In the current manuscript, an examination of financial analysis methods previously used by the author to ‘trend’ vital sign and laboratory data was conducted on biomedical variables collected over different time scales (i.e., minutes, hours, days, weeks) in an attempt to find ways to further improve the data-trend utilization in the ICU.1,2

Figure 1. Example of traditional (non-financial) representation of white blood cell (WBC) count trend over an extended period of time. Please note that the ‘busy’ appearance of the graphed data makes any short- or long-term trends difficult to interpret.

Technical indicators have long been used in analyzing past trends and patterns in an attempt to predict future financial market events. The periodic nature of the financial market’s ‘ups and downs’ and the resulting trends and trend reversals theoretically...
allow traders to make educated ‘guesses’ as to the most likely future direction of the stock, bond, or commodity price movements.

The word ‘stochastic’ is derived from Greek and indicates involvement of random variables, chance, probability, or guessing. In addition to the stochastic nature of the stock market, it is also well established that nearly all variables in biology are non-stationarily stochastic.\(^1\,^{4}\,^{6}\) Numerous complex approaches have been used in the past to describe vital sign and other biologic and biomedical variable trends.\(^2\,^{7}\) 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 accurately describe regional animal organ blood flows.\(^4\,^{7}\) In addition, recent research indicates that the use of pulmonary artery catheter waveform analysis during various pharmacologic interventions in an animal model may offer the potential to automate the use of the pulmonary artery catheter in the future.\(^3\)

In the traditional financial analysis (FA) system, various graphical 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) (Figure 2).\(^8\,^{9}\)

![Figure 2](image2.png)

Figure 2. Example of SO and RSI indicators used in short-term (minute-to-minute) analysis of stock price movement. Each vertical bar represents one calendar day. The patterns observed for financial or biomedical variables collected on minute-to-minute basis are very similar to patterns observed for biomedical variables collected on weekly basis (see Figure 3).

The two major objectives of this manuscript are: (a) to review the application of financial trending indicators to various biomedical parameters and (b) to examine the use of these trend indicators across different time interval scales – from data collected on minute-to-minute basis to information gathered on a weekly and even monthly basis.

LOGISTICS: DATA ORGANIZATION

Clinical variables were obtained retrospectively from four randomly selected, completely anonymized, ICU datasets. Clinical data were recorded over different temporal scales (i.e. every minute, hourly, daily or weekly) over a total period of weeks to months. Clinical information was then transformed into the open-high-low-close (OHLC) format used in FA, with certain exceptions applied to data collected on less frequent basis (see next section). In order for the OHLC format to be used, the data had to be arranged into equal time-interval epochs (i.e., minutes, hours, or weeks). 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.

![Figure 3](image3.png)

Figure 3. Graph of serum prealbumin level trends using FA techniques. Measurements were obtained once weekly for one year. Note the excellent ‘trending’ properties of prealbumin levels using RSI (top), SO (middle), and PE (bottom) indicators. Note that the graphing software utilized individual data points to construct the FA graphs and trends just as effectively as the traditional OHLC format.

Data for each epoch were then entered into MetaStock™ (Equis International, Salt Lake City, UT, USA) financial analysis software. Finally, a graphical interpretation, much like a stock price graph, was created. Subsequent analysis included visual inspection of the stock-like charts, examining for the presence or absence of variability, short-term, and/or long-term trends.

BIOMEDICAL PARAMETER TRENDING

The advantage of indicators used in this study is that their understanding requires only rudimentary knowledge of mathematics.\(^1\,^{2}\) In addition, all of the indicators used in this report (RSI, MACD, SO, PE, and MA) can be used equally well in both minute-to-minute (Figure 2) and week-to-week data analyses (Figure 3), making them applicable across a broad range of clinical variables and data ‘resolution’ ranges. Furthermore, FA indicators work just as well for small measurement units (fractions and decimals) as they work for large measurement units (Figure 4 and Figures 5A/5B). Figure 5A shows a financial graph of serum glucose levels. Figure 5B demonstrates how FA indicators can be used to demonstrate trend reversals.

In addition, the traditional open-high-low-close (OHLC, see above) representation of numerical values within each measurement epoch (i.e., one minute, one day, one week, etc.) does not seem to be absolutely necessary to establish valid long- and short-term trends, with both single-point or mixed (combination of single-point and OHLC) epoch representations being perfectly adequate (Figure 3).
During the author’s previous analyses of trends in vital sign and laboratory data, it was hypothesized that the use of RSI, MACD, SO, MA and PE techniques can effectively describe trends in other types of clinical/biomedical parameters (i.e., intake and output parameters, various vascular catheter-derived pressures, etc.) and open a possibility that these indicators could be used in conjunction with vital sign data and laboratory value trends to enhance the understanding of patient clinical status and provide an opportunity to improve global patient care and clinical decision making.\(^1\)\(^2\)

**Figure 4.** Graphical representation of serum pH utilizing FA trend indicators. Of interest, only the pH fraction (the value above 7.0 baseline) fluctuates in this example. Note the RSI indicator in the upper field, with the SO indicator in the middle field, and the OHLC stock bar graph of serum pH in the bottom window, along with PE (dashed lines). Each epoch represents a 24-hour period.

**SPECIFIC STOCK TREND INDICATORS**

Five ‘public-domain’ indicators used mainly in stock and bond market analysis were utilized in this exercise. The first one, called **relative strength index (RSI)**, developed by J. Welles Wilder, signals overbought and oversold market conditions.\(^3\)\(^-\)\(^\text{15}\) 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 values above 80 indicate ‘overbought’ condition. The formula for RSI has several parts, and was previously described in detail by the author.\(^1\)\(^2\) The SO, MACD (moving average divergence-convergence), PE, and MA indicators were also previously described/discussed by the author and by others.\(^3\)\(^-\)\(^\text{15}\)

All of these financial analysis tools can be used to help identify stock or bond price trends and/or trend reversals. In addition, these indicators can also 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. This may have important implications for biomedical variables because successful trend and trend reversal identification within a group of biomedical variables may potentially provide benefits similar to those provided by stock or bond indexing.

For the purposes of this analysis, 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 (Figure 5B). Price envelopes were added at times as secondary confirmatory trending tools. In addition, two moving averages were used selectively 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. Again, a more detailed description of stock trending methods was presented by the author previously.\(^1\)\(^-\)\(^2\)

As one can see, the graphical representations of laboratory variable trends in Figure 3 and Figure 4 are not much different from the graphs representing heart rate (Figure 6A) and blood pressure (Figure 6B) processed with the same FA software. In fact, nearly identical trend and trend reversal patterns can be seen with both types of data, and temporal patterns that would be difficult to detect by examining the purely numerical representation of vital sign or laboratory data become much easier to detect and interpret using FA methods. Of interest, pressure-based (Figure 7A/7B) and oximetry-based (Figure 8) parameters follow similar patterns as well.

**Figure 5A.** Graphical representation of serum glucose levels using FA techniques. Note the RSI indicator in the upper field, with the SO indicator in the middle, and the OHLC graph of serum glucose levels in the bottom window, along with PE (dashed lines). Each epoch represents 8 hours.

**Figure 5B.** Graphical representation of serum glucose levels with parts of the graph marked to highlight trends and trend reversals. Note the ovals indicating lower trend reversals and the boxes indicating upper trend reversals. The shaded area towards the end of the recording period indicates relative lack of trending due to stabilization of glucose levels within the desired range. Such ‘obliteration’ of the trend points to clinical ‘stability’.
Good ‘trending’ characteristics can also be seen with serum bicarbonate level (Figure 9), serum chloride (Figure 10), and ionized calcium data (Figure 11). Here, the stock-type charts very nicely demonstrate both short-term and long-term variations in laboratory value trends and trend reversals.

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Based on this preliminary application of stock trending techniques to various biomedical 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.\(^*\)\(^-\)\(^2\)

What is the usefulness and relevance of such charting trends and their interpretation? The answer to this question will have to await prospective validation of these techniques. Certainly, application of financial analysis charts and trends to financial market data does not guarantee excellent investment results. Likewise, the use of FA techniques may not guarantee improvements in data interpretation or clinical decision-making. Future applications of FA techniques in direct patient care may include automated monitoring systems with proactive monitoring capabilities – detecting early signs of potentially serious medical conditions before overt clinical symptoms appear.\(^*\)\(^-\)\(^6\) However, until we elucidate the full extent of any potential benefits or pitfalls of FA indicator applicability to biomedical data interpretation and/or eventual patient care, one must proceed with extreme caution and the overall patient clinical picture must be taken into consideration first.

While FA graphs and trends within individual variables (i.e. white blood cell count, central venous pressure, intracranial pressure, temperature, heart rate or hemoglobin) may be valuable from the standpoint of the clarity with which the graphical representation of these variables reflects the state of the corresponding body system, the most useful clinical information will most likely come from indexing of multiple variables, much like the various stock indices. In such system, multiple measured biomedical variables would be used to create a ‘composite index’. Based on certain assumptions (see Table 1 below) such ‘composite index’ would then be used to estimate the overall patient ‘physiologic-economic’ condition. Dynamic changes in this ‘physiologic-economic’ state could then be analyzed for significant trends and trend reversals, much like its individual components. In a way, one 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.\(^*\)\(^4\)

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

<table>
<thead>
<tr>
<th>Assumption</th>
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<tr>
<td>• The human body discounts all events and stimuli – direct and indirect – that affect its functioning at any given time.</td>
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<td>• This ‘overall physiologic state’ of the human body is reflected instantaneously through various vital signs, laboratory values, input/output values, oximetry, and pressure-based data (catheter-derived, ultrasound-derived, etc).</td>
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<td>• Commonly encountered types of trends and trend reversals describe dynamic changes in all measured biologic variables. These trends can be followed temporally using simple mathematical models.</td>
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<td>• The presence of a trend or a trend reversal in a biologic system may indicate a significant clinical change, potentially offering a glimpse of the ‘microeconomic’ state of the respective variable or body system. Any new trends or trend reversals have to be correlated with the overall patient clinical picture.</td>
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<tr>
<td>• The disappearance or ‘obliteration’ of a trend indicates clinical ‘stability’ within the corresponding parameter. Again, correlation with the overall patient clinical picture is indicated.</td>
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<td>• When a new major trend is suspected, multiple indicators must simultaneously indicate and confirm the presence of such a trend. An indicator that ‘confirms’ a trend demonstrated by another variable is said to be a ‘confirmatory’ indicator.</td>
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<td>• Each major trend remains in effect until clear trend reversal occurs and a new trend is established. Confirmatory indicators may be useful when confirming such trend reversals.</td>
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<td>• Combinations of multiple biologic variables (or their corresponding FA indicator values) may be used to form an ‘index’ – a reflection of the overall ‘physiologic economy’ of the patient.</td>
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<td>• Temporal changes within biomedical ‘indices’ may offer a glimpse into the ‘macroeconomic’ state of the patient.</td>
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STOCK TREND INDICATORS: THE 'MICRO' SCALE
After reviewing the principles of stock trending indicators and their applicability to biomedical parameter analysis, let us review an example of FA indicator use for variables collected on the time scale of minutes. Intracranial pressure OHLC graph below provides a nice example of biomedical parameter trending on such 'micro' scale.

STOCK TREND INDICATORS: THE 'INTERMEDIATE' SCALE
Below are some examples of FA trend indicators used for biomedical variables collected on hourly to daily basis. Laboratory and vital sign values collected on daily or twice daily basis provide good examples of FA indicator use on this 'intermediate' time scale.

STOCK TREND INDICATORS: THE 'MACRO' SCALE
Below are some examples of trend indicators used for biomedical variables collected on daily, weekly, and even monthly basis. As one can clearly see, even variables graphed on weekly and monthly scales can demonstrate very clear trends and trend reversals.

CONCLUSIONS
Financial analysis indicators used in this manuscript provide a new way of describing and interpreting trends and trend reversals within biomedical 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 of this model in actual clinical applications. Minimizing the subjective component...
of patient data interpretation and maximizing the objective component may provide healthcare practitioners with a better way of assessing and treating patients. Moreover, when correlated with clinical data, FA indicators may provide useful adjunctive confirmatory or possibly even predictive value with regards to the patient’s physiologic status. In addition, the author proposes that multiple biologic parameters, when used in conjunction and combined into ‘physiologic indices’ could offer a glimpse into the overall ‘economy’ of the human body.

Figure 16. Urinary output data displayed in FA fashion. Each point corresponds to 30 minutes. Note that despite the fact that the OLHC format has not been used to format data in this particular example, all of the indicators (SO, PE, and RSI) clearly demonstrate clinically useful trends within the data.

REFERENCES