Common cause Special cause vital signs charts

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ABSTRACT

This case is a simulation. It teaches the state of the art in model based vital signs charting. It changes the way that charts are used, viewed and interpreted. VMH is a large hospital. Traditional monitors are currently used to display the patient vital signs of pulse and oxygen saturation. These monitors help practitioners identify when a vital sign falls outside a specified one-size-fits-all range. Traditional charting is labor intensive, receiving low priority relative to immediate patient needs. This makes accuracy and timeliness very difficult. This case shows how to solve this problem by using *MyPulse* to create a computerized ultra intelligent monitor. Vital signs are separated into common cause (internal biological effect) and special cause (external environmental effect) charts. Also, the control limits are customized based on 1) absolute standards dependent on patient age group and sex, and 2) standard deviations from the mean established for each individual patient. The result is accurate advanced notification of unusual numbers and patterns, in real time, by color graphics, sound, print /caller ID phone alert, etc., to local and/or remote locations. *MyPulse* is the only system that will perform all these functions automatically.

CASE

The cardiac rehabilitation health care management planning meeting of VMH, a large hospital was convened to review the vital signs charting and quality control procedures. One of the systems under review is that for pulse oximetry. In that system, a pulse oximeter finger probe is clipped to the patient's finger. The pulse oximeter gives a read out of pulse and oxygen saturation every 5 seconds. A busy nurse reads and records the pulse and oxygen saturation values at irregular intervals. If there is time, at the request of the patient's physician, the nurse plots the values on a chart. Otherwise, the physician simply looks at the numbers. Based on the physician's knowledge of what is normal given the patient's age and sex, the numbers are interpreted. This becomes an important input into the physician's guidance recommendation for exercise.

Dr. Stafford (chief medical officer) appeared puzzled as he looked at the report on the number of misunderstood cases. "There were numerous cases when there was physician intervention that appeared to be unnecessary (false positives, one might say) in the final analysis. There was no harm done, except that it was an expensive way to spend a physician's time. Time that could have been spent elsewhere on more needy patient's." "Also," he continued, "it appears that there were about as many cases where there was no intervention, all because there were no vital signs data to suggest it (false negatives, one might say). So, we are left to wonder if there is more that we could have done."

"That's what I have been telling you," interjected Nurse Knightingale (Chief nurse), "there are so many variables that our nurses must respond to, how will we ever know if we are looking at the right ones at the right time anyway? Now, if you were to get me the additional nurses that I have been asking for, we will fix this problem once and for all." Dr. Stafford reassured Nurse Knightingale, "I understand your frustration Nurse Knightingale, but from the way that you describe the operating problems, there would not be enough nurses available for hire, even if we could afford it. All of your experiences are associated with this hospital. THM, another hospital in the city took the approach of hiring more nurses. I have arranged an exchange program in which you will be assigned to TMH for a month to observe their practices, after which time we will reconvene to discuss this matter further. You can report on your findings to us at that time. In the mean time, I urge the rest of you to give this matter serious thought. We must find an answer."

The next health care management planning meeting was convened one month later, right on time, except Nurse Knightingale was missing. "O.K., lets get started," said Dr. Stafford, "we can't wait for Nurse Knightingale. The purpose of this meeting is new and better ways of charting, and we know that she is agnostic on that subject anyway. Well guys, what do we have." "You were right Dr. Stafford," said Mr. Rosenburg (personnel director). It is as you said. We have a problem of low morale. This is so, even when we are not at fault." "We are following all of the same practices of other hospitals." "Oh," interrupted Dr. Stafford, "let me introduce Mr. Rosenburg, our new personnel director. We can't rule out the possibility that our

people require additional training. Stress levels are up," he warned. "Well what I was about to say," continued Mr. Rosenburg, "is that the only place to train them is right where they are working now. I tell you, they are doing exactly what we ask them to do. Most of them have prior experience at other hospitals anyway." "Good point," said Ms. deSilva (director of quality control). "However, I am running out of excuses for the visiting accreditation team. We could lose our accreditation this time around. I'm in favor of trying anything."

"Well maybe you won't have to try just anything, maybe management can try following its own policy of providing us with what we need to get the job done," Nurse Knightingale busted into the room. "You're late," said Dr. Stafford, "and once again, I am not hiring any new nurses until you can give good cause that that will solve the problem! "Who said anything about more nurses?" replied Nurse Knightingale. "I did my tour of duty as you ordered. Given our equipment, it's a miracle that we get anything at all done around here. TMH has completely automated all of its charting systems with ultra intelligent monitors. Our problems are as follows:

1) we ignore the large volume of available pulse oximerty data that our nurses had no time to record and chart,
2) our process is so labor intensive and therefore expensive that we would never be able to find or hire enough nurses. There will always be some other immediately pressing activity requiring the attention of our nurses.
3) in their present form our numbers are two few, and difficult to read and interpret, especially when the charts have not been updated and there is no picture of the data,
4) inaccuracies and missing numbers occur due to time pressured human error, and all these have lead to,
5) hurried evaluations.

"That is consistent with what I heard about TMH," said Mr. Andrews (Industrial engineer). "They did not hire more nurses, they just provided them with training on ultra intelligent monitors. The monitor is so very easy to use anyway. A smart nurse can learn it in 30 minutes. The *MyPulse* monitor (based on the Moving Window Spectral Method (MWS) [1][2][3]) will utilize all the data available from the pulse oximeter. It will automatically chart the values in real time, on a desk top or a portable note book computer. It can also download data stored in the pulse oximeter for subsequent analysis. The real time feature is the ultimate solution. The charts are labeled with upper and lower control limits based on absolute standards dependent on patient age group and sex [4][5]."

"That seems like what we need," said Dr. Stafford. "However, what if the patient does not fit well into the prescribed standards. Can the *MyPulse* predetermined standards be modified based on what we know about the particular patient?" "Yes," replied Mr. Andrews. "The upper and lower control limits can be edited in accordance with the physician's instructions. Having asked that question, I think you will also be interested to know that the charts are also marked in terms of standard deviations. The typical marks are +/- 3 standard deviations from the mean values established for each individual patient. Once again the physician can change the number of standard deviations. That is, *MyPulse* will customize itself to the individual patient!"

"It is my understanding that statistical quality control charts, a system with features similar to what we are doing when we use charts in the hospital, are based on independent observations on the data being monitored. Vital signs are highly sequentially correlated. So, what about the questions raised in [6] regarding the appropriate use of control charts, when the data are correlated," asked Dr. Stafford. "Good question," replied Mr. Andrews. "This system is designed to dynamically remove the correlation from the data before plotting the 'special cause chart.' This is so, even if the correlation is changing, due possibly to increasing or decreasing heart strength. Therefore, the 'special cause chart' is a chart of independent values. The upshot of all this is efficient detection of excessive variations from the norm, with no increase in the rate of false alarms (false positives) or the rate at which unusual values go undetected (false negatives)[7,8,9]. I think Nurse Knightingale made some observations on that too."

"I most certainly did. An outstanding concept," remarked Nurse Knightingale. "As if the history and standard deviation charts are not enough, there are many additional features. Vital signs are separated into common cause (internal biological effect) and special cause (external environmental effect) charts. If any of the upper or lower control limits are exceeded, that is, on either of these charts, in

absolute value or in standard deviations, there are automatic sound and color alarms. Collectively, these are difficult to overlook, even from a distance. The result is accurate advanced warning of unusual conditions. The principle is simple but very sound. A single breach of the control limits results in a blue screen and the breach point is marked for future reference. If the condition clears up, the screen returns to white. Two consecutive breaches will turn the screen yellow for caution, three breaches will turn it red to signal danger. The nurse is alerted to investigate the patient's condition. Once again if the condition clears up by itself or due to intervention, the screen returns to white. If the screen remains red for too long a period of time (specified by the physician*),* ***MyPulse*** will continue the color graphics and sound alarms. However, it will also print the chart, dial and send a telephone alert, and a caller ID, etc., to any local or remote location. This permits the physician to read the charts from anywhere in the world! A computer at the nurse's station can display the charts for several patients, simultaneously. ***MyPulse*** is the only system that will perform all these functions automatically."

Questions

The pulse oximetry patient data in Table 1 is for one of the cases under review at the meeting.

1) Plot a chart of the pulse oximetry data (should look like Figure 1.) Compare and contrast the hourly chart with the automatic real time ***MyPulse*** computerized charts in Figure 2 for the same patient (except that the computerized chart displays all of the most recent values of the last hour during which pulse was measured once every five seconds).
2) Why do the manual data exhibit no unusual values, except for the last pulse reading, while the computerized charts do?
3) Distinguish between absolute vital signs and standardized vital signs. Why are these important?
4) Distinguish between common cause and special cause charts. Why are these important?
5) What is the purpose of sound and color alarms?
6) What is the purpose of telephone alarms?
7) What is the purpose of email alarms?
8) What is the purpose of fax alarms?
9) What is the purpose of local print alarms?
10) Would the patient in this case have been better served if ultra intelligent real time charting with multifaceted alarms had been used?

TABLE 1: Hourly pulse oximetry data.

Time	SpO2%	PULSEbpm
02.00am	98	80
03.00am	94	82
04.00am	97	90
05.00am	98	88
06.00am	95	83
07.00am	95	85
08.00am	95	86
09.00am	96	87
10.00am	97	90
11.00am	94	80
12.00noon	95	76
01.00pm	98	60
02.00pm	97	20

Notes on Input Data

SpO2% - Oxygen Saturation in percentage. PULSEbpm - Heart rate in beats per minute

FIGURE 1. Plot of hourly Oxygen saturation and Pulse.

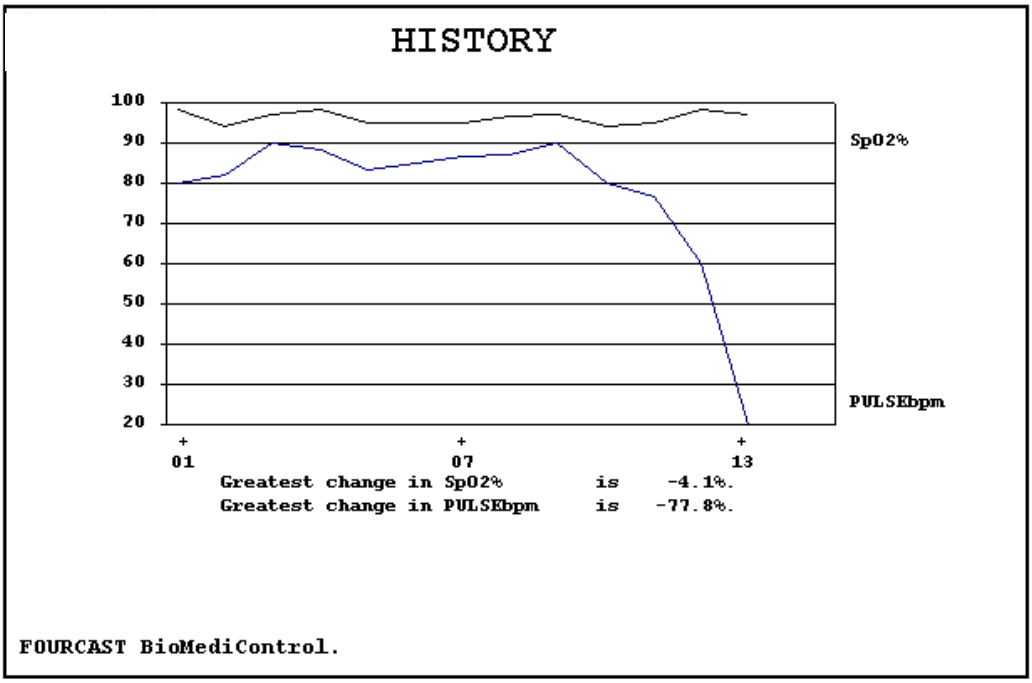


FIGURE 2a. Plot of Pulse during the last hour (original color: red).

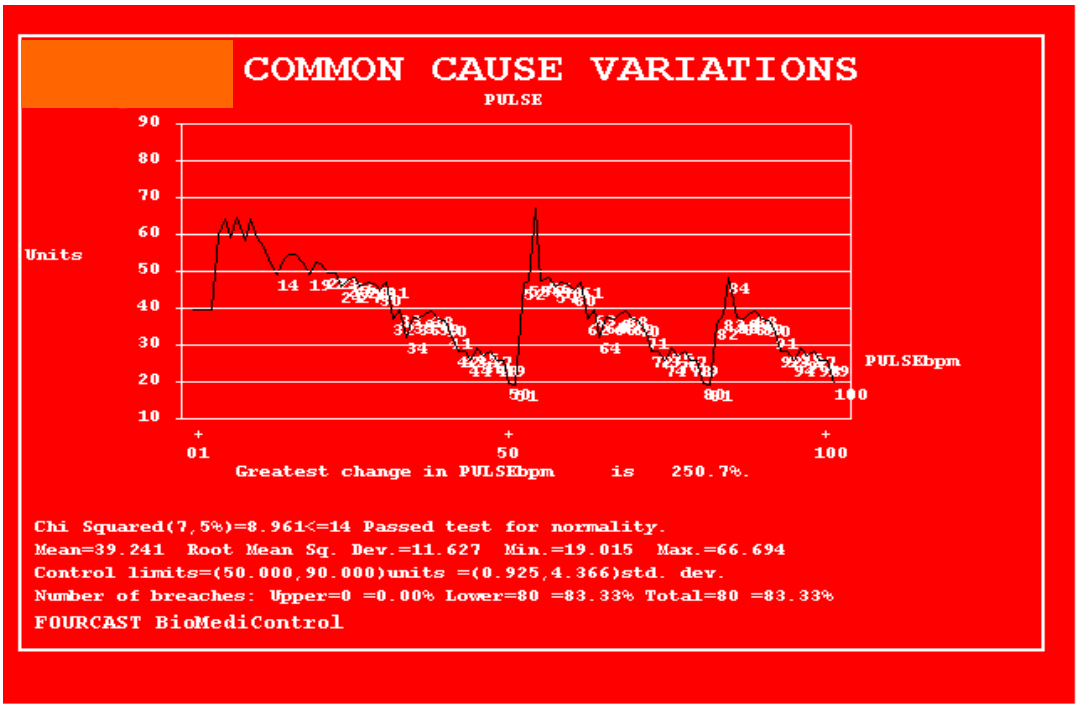


FIGURE 2b.

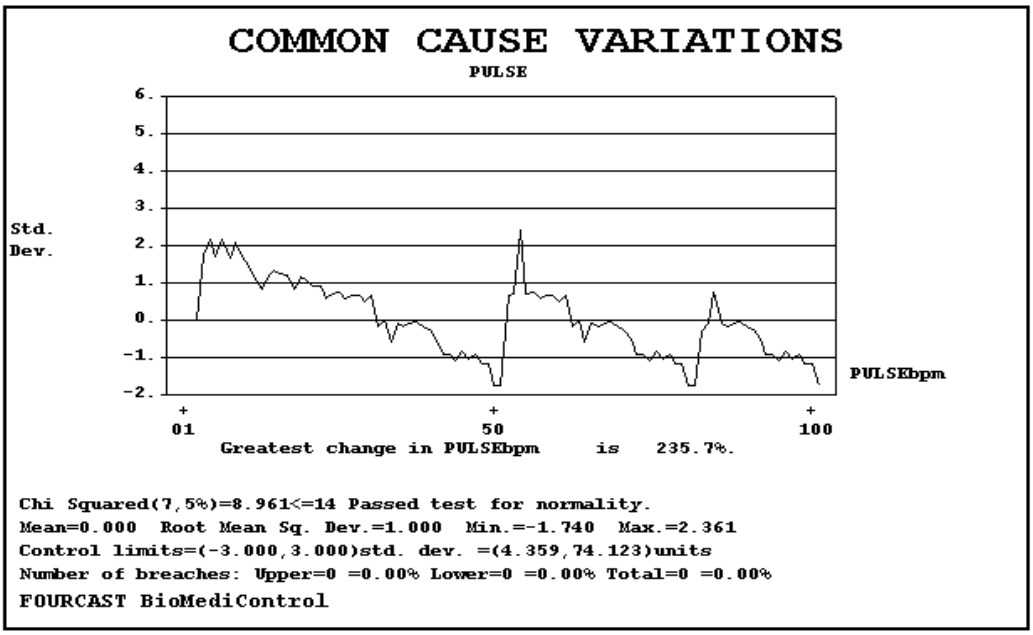


FIGURE 2c. (original color: red)

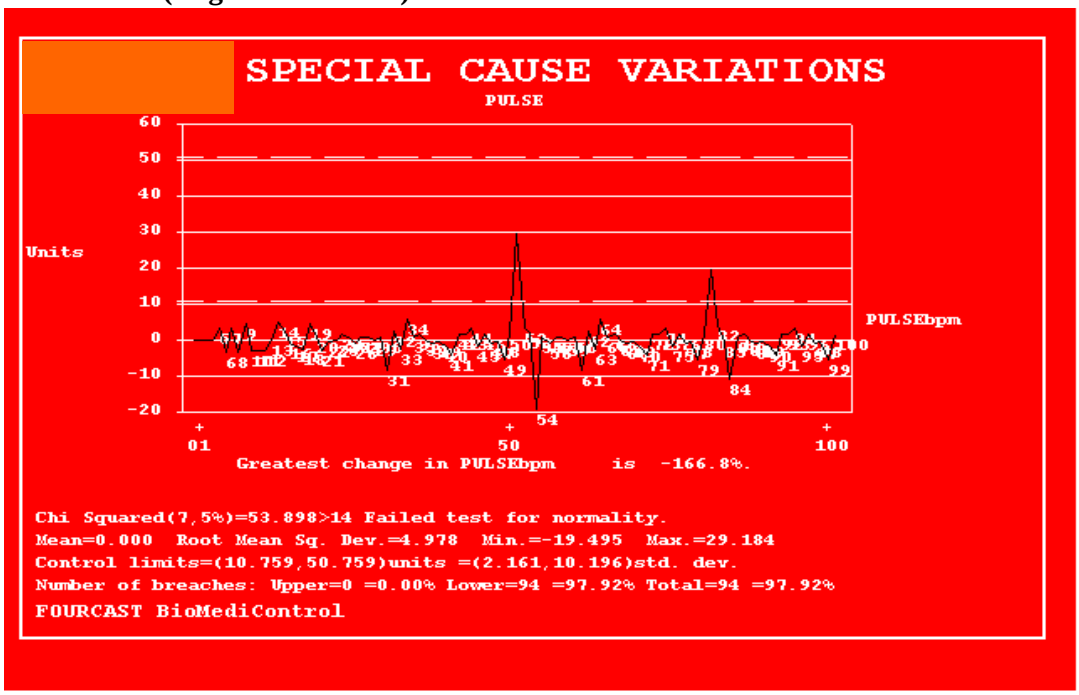
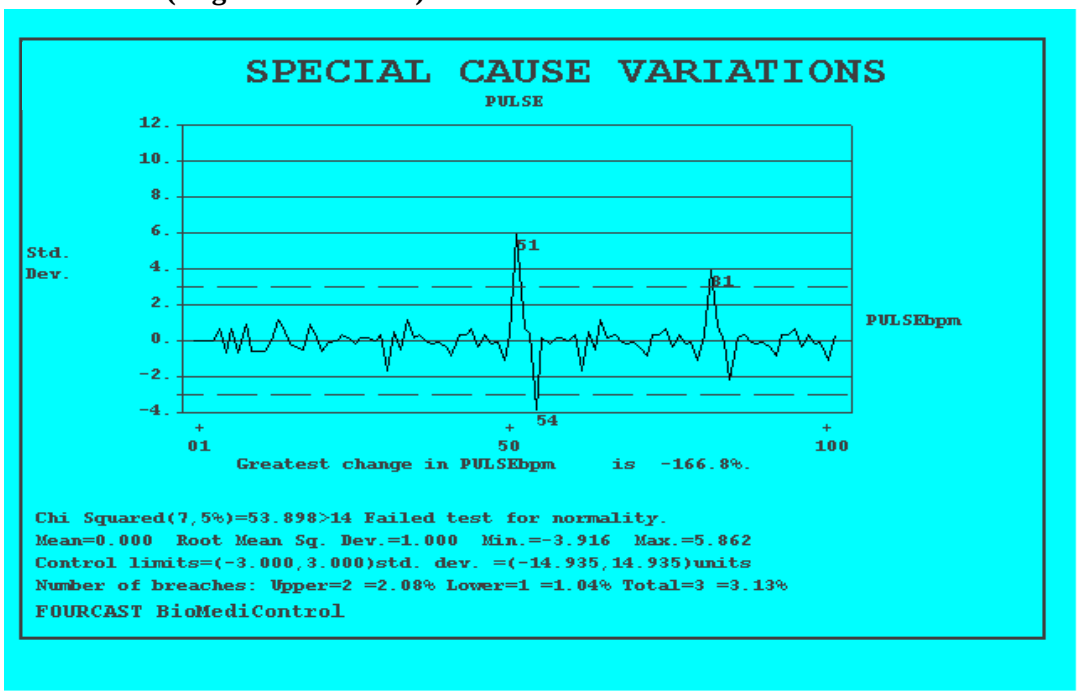


FIGURE 2d. (original color: blue)



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[8] _____, "Pulse Oximetry: an mws model," *Refereed Proceedings of the Industrial, Engineering & Management Systems conference,* Cocoa Beach, Fl., U.S.A., March 5-7, 2001.

[9] Ridley, A.D. "Single Versus Dual Process Control Charts," *Refereed Proceedings of the Priduction & Operations Management Society conference,* Savannah, Ga, U.S.A., 2003.

APPENDIX

Courses & Levels

This case is suitable for graduate & senior undergraduate courses for nursing and medical students, in service training for medical practitioners and for systems engineering, industrial engineering and engineering management practitioners providing services to the medical field.

TABLE 2: Standard range for Oxygen Saturation (percent) and Pulse (beats per minute)

Oxygen Saturation (SpO2%)	94-100 %
Pulse	50-170bpm

TABLE 3: Standard range for Pulse (beats per minute) by age group

	AGE GROUP	**PUSLEbpm**
1	Newborn	70-170
2	1 year old	80-160
3	1-2 years old	80-130
4	2-4 years old	80-120
5	4-6 years old	75-115
6	6-10 years old	70-110
7	10-12 years old (male)	65-105
8	10-12 years old (female)	70-110
9	12-14 years old (male)	60-100
10	12-14 years old (female)	65-105
11	14-16 years old (male)	55 - 95
12	14-16 years old (female)	60-100
13	Over 16 years old (male)	50 - 90
14	Over 16 years old (female)	55 - 95

End of Case