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Continuous Monitoring of ICU Process Quality

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Management techniques already proven in commerce and industry are increasingly applied to health care. Professors Hiesmayr and Schmidlin provide an introduction to the application of industrial monitoring techniques to intensive care.

Introduction

Intensive Care can be seen as serial and parallel processes with the goal of reaching the best possible outcome for the largest number of patients. We present and evaluate the differences between intermittent and continuous methods of process monitoring and propose adapting some methods commonly used in the manufacturing world for application to medical activities (Berwick 1996).

Process Monitoring

Process monitoring (Hinckley 1997) started at the end of the 19th century and was originally based on judgement inspection. Skilled craftsmen reworked the products at the end of the production line until they considered them suitable for use. H. Ford introduced gage inspection, the comparison with a standard, (a first form of benchmarking), because he noted that variability between products was hindering continuous production. In the 30's Shewhart developed statistical process control with control charts, allowing detection of processes drifting out of control, using control limits at 3 standard deviations (SD) from the mean (Montgomery 1997). While this method is a compromise between detecting drifts and avoiding unnecessary warnings, it is ineffective for small drifts. Methods such as the cumulative sum chart (CUSUM) have therefore been introduced. Extremely efficient industries have introduced 100% inspection with source inspection and mistake proofing. This method is applicable to rare events, such as those occurring in intensive care, e.g. medication errors (Darchy et al. 1999), infections, failed extubations and death. This method is applied with checklists and has increased patient safety (Hinckley 2003). The major goal is prevention not observation and low investments in quality control are necessary.

Intensive care, with its large amount of data, is an attractive area in which to develop and refine various methods of process monitoring. Two factors are of major importance: events may be infrequent and it is highly desirable to detect deviations early (Harvey and Wensing 2003).

Definition of a Process

A process is a defined activity to transform a given input, typically in medicine the patient with his/her clinical condition, into a desired state. Thus a process can be defined by the task to perform, the various inputs such as patients, human resources and capital, and the output of the process including its side effects.

Typically a process is evaluated by comparing the actual result with the expected result. In the field of intensive

care, the inputs should also be monitored. A well known example is the relation between accepted mortality and physiological derangement early on after admission to ICU as defined by several scoring systems (SAPS II, SAPS III, MPM). Some inputs cannot be controlled easily and thus a risk adjusted evaluation of the process may be mandatory.

Monitoring of Process Quality

Two elements define quality: the difference between the mean value from the target and the variability of this mean. Variability is assessed with measurement of range or moving range, SD; for proportions a repeated determination is necessary. Deviations from the standard are not always symmetrical. An infection in the ICU necessitates many resources which are not compensated for by patients without infections. Losses have an irreversible character in medicine. In this sense many medical processes cannot be described by stock exchange processes, where losses are compensated by gains.

How to Monitor a Process

The information about a process is either a measurement or a count. Examples may be length of stay, duration of intubation, proportion of patients with nosocomial infections, proportion of patients with sufficient nutritional therapy or proportion of patients dying in hospital. Yearly intervals are the typical feature of many reports, but a similar mean value could represent different scenarios.

Thus a more detailed insight into the process over time is necessary. This can only be achieved by time series analysis.

Examples of Continuous Monitoring

Control Chart

The control chart is constructed from the mean of a measurement or the observed proportion of events. Typically confidence limits are added to the chart at 3 standard deviations (SD) from the centre line. In certain cases it may be helpful to introduce an early warning limit at 2 SD (Montgomery 1997).

As an example, Figure 1 illustrates monitoring with a target for nutrition care set at 22 Kcal/kg/day on the 5th day post admission in the ICU. The mean amount of nutrition given was derived from samples of 30 consecutive patients. The range was calculated as the mean absolute patient to patient difference for 30 consecutive patients. In 4 instances the lower 3 sigma limit was reached, often in conjunction with a higher patient to patient moving range. Corrective measures should first address the variability.

Cumulative Sum Chart with Risk Adjustment

The cumulative sum chart (CUSUM) is a sensitive instrument to detect small changes in process mean or proportions. The CUSUM detects shifts in performance smaller than one standard deviation of a sample. Each CUSUM starts with an estimation of the baseline event rate. When the event of interest (death, infection) does not occur, the difference between the predicted event rate and the observed event rate is equal to the predicted event rate. When the event of interest occurs, the difference between predicted and observed rate is the predicted rate minus one event. These values are now cumulated from one patient to the next. Figure 2 shows a baseline mortality rate set to 0.1; predicted survival = 1-predicted mortality; patient numbers 4 and 16 died and therefore have no predicted survival; encircled values are cumulated. The CUSUM also accommodates risk adjustment (Lovegrove et al. 1997; Sherlaw- Johnson et al. 2000).

Pitfalls & Challenges

We recommend starting from local data series to define the correct starting points. A data series from a sufficient duration should be used to determine a local standard. This standard should also be compared with external standards, if available. Thus new databases for quality control should include parameters with similar definitions to those already published, to allow external benchmarking. A major challenge is to choose control limits in such a way that a reasonable compromise between detecting drifts and avoiding unnecessary warnings is implemented.

Summary

Continuous process evaluation is a key element to guide improvements in health care. Continuous process control has the advantage of detecting deviations early and generating new information about the process, allowing learning from actual processes and outcomes. The vision is to evolve from the control of an isolated process to the integrated control of several processes so that information is presented as a common weighted risk management display, as applied in manufacturing and service industries.

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