A risk-adjusted CUSUM chart for monitoring multi-outcome surgeries: a case study in the kidney transplantation surgery

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Abstract: Risk Adjusted Cumulative Sum (CUSUM) control charts are powerful statistical tools for early detection making of process changes. Unlike other industries, healthcare systems are of a wide range of variability and different levels of inputs. However, since variability in the output of healthcare process may result from different factors including environmental factors, doctor's performance, or patient specifications; therefore, considering multiple outcomes facilitates and increases precision of the process control. Accordingly, in this paper, risk-adjusted CUSUM control chart with multiple outcomes is applied to monitor kidney transplantation surgery. It is assumed that transplantation surgery might result in full recovery of the patient, rejection of the organ, or after-surgery complications. Finally, the annual report of kidney transplant surgery in the U.K has been used to monitor 1779 surgeries between 2010 and 2011, and the associated CUSUM control charts have been presented.

Keywords: Process monitoring, Healthcare, Risk-adjusted CUSUM, Multiple outcomes, Kidney transplantation surgery

Introduction: Although statistical process monitoring methods were initially introduced for early detection of industrial and chemical process changes, soon Shewhart and Deming mentioned various applications of such methods including healthcare process monitoring. Cumulative sum (CUSUM) control charts are useful for rapid identification of tiny changes in process parameters (Montgomery, 2008; Altman & Royston, 1988). In this paper, the focus is on monitoring outputs of kidney transplantation surgery. Existing literature on monitoring surgery outputs indicates binary output as an assumption, i.e. failure or success for the process. However, there are possibly more than two outputs for a surgery. For example, kidney transplant surgery may lead to complete rejection of the kidney, infection or bleeding, deficiency of the organ, and acceptance of the kidney (Rossi et al., 2016). Furthermore, since each of the outputs may have a different origin, assuming multiple outcomes makes it possible to monitor the process more accurately. Therefore, in this paper a risk adjusted CUSUM chart is developed for monitoring kidney transplantation surgery assuming multiple outcomes for the process.

Methodology/approach: Three outputs are assumed for kidney transplantation surgery including: acceptance of the organ, complications, and full rejection. Then, a risk adjusted CUSUM chart is developed for monitoring surgery outputs based on the transplantation data of 1624 surgeries in U.K between 2008 and 2009 (Mumford & Brown, 2017). Then, the generated chart is used for monitoring 1779 transplant surgeries between 2010 and 2011 in the U.K.

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Findings and Discussion: Monitoring the results indicated multiple out-of-control results. However, systems came back to the controlled mode. This implied an unstable performance. Overall, 57 signals were received by the chart out of which, 19 signals were due to complications and 38 signals were due to rejection. The 99.5 confidence interval for receiving signal from the process was [0.020, 0.44]. Also, chi square statistic was used to test independence of output levels from time and there was no evidence for the rejection of the null hypothesis at 0.005 significance level.

Conclusions: Monitoring processes with multiple outcomes helps better identification and categorization of the effective factors and better control of the process. In this paper, a risk adjusted CUSUM chart was developed for monitoring kidney transplant surgeries. The developed chart seems to be easily applicable in other healthcare processes.

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