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Quality Improvement Report

Improving Warfarin treatment - A study using the Six Sigma methodology

by

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INTRODUCTION

Warfarin is an oral anticoagulant (blood thinning) medication effective for the prevention and treatment of thromboembolic events in various clinical contexts; see Hylek and Singer (1994), Cannegieter et al. (1995), Odén and Fahlén (2002) and Levine et al. (2004) for more information about warfarin treatment. Since it is an extremely safety-critical medication, patients undergoing warfarin treatment should be monitored frequently by blood testing to ensure that the treatment yields desired results; The International Normalized Ratio (INR) defined by the World Health Organization (WHO) as

$$INR = \left(\frac{\text{coagulation time of patient plasma}}{\text{coagulation time of normal plasma}} \right)^{ISI}$$

is usually used to measure the effect of warfarin treatment. ISI is the International Sensitivity Index and the WHO reference ISI for Warfarin is equal to one. The standard INR range (also called the therapeutic range) for most clinical situations is 2.0-3.0.

There are about 100 000 patients (approximately one percent of the total population) treated using anticoagulant medications such as warfarin today in Sweden. The proportion of older patients (over 80 years old) has increased over the past decade and today it accounts for approximately 30 percent; see Läkemedelsverket (2006). There are reasons to believe that both the proportion of patients undergoing warfarin treatment and proportion of older patients will continue to increase at the same time as alternative treatment methods, possibly replacing warfarin do not seem to appear in the near future.
The improvement project presented in this paper was conducted at a unit responsible for warfarin treatment at Lidköping hospital in Sweden. The unit coordinates and monitors the

warfarin treatment of 1200 patients and consists of a cardiologist and five specially trained nurses. Lidköping hospital is situated in the Western Region of Sweden and is one of the four hospitals in the Skaraborg Group of Hospitals. It serves a population of around 85 000, and is an acute hospital having complete departments and with staff on-call. The care offered includes, among others, internal medicine, surgery, urology, orthopaedics, gynaecology and paediatrics. In total there are more than 160 beds and around 700 employees.

In the following sections we will provide the background of the study including the outline and context of the problem, assessment of the problem and strategy for change including the approach taken and recommendations proposed. Finally, we present the results of the study and elaborate on some of the lessons learned.

BACKGROUND

Outline of problem

Anticoagulant treatment has a well documented effect for the prevention of numerous medical conditions including atrial fibrillation, deep vein thrombosis, and pulmonary embolism. However, there are risks related to the warfarin treatment. According to statistics from the Swedish register for side effects of medication, during 1991 – 2001 approximately 120 patients died in Sweden as a result of bleeding caused by anticoagulant medications including warfarin; see Socialstyrelsen (2004).

Several studies indicate that there is a strong correlation between individual variation in the INR and patient morbidity/mortality in warfarin treatment; see e.g. Levine et al. (2004). Thus, the focus of the improvement project was to reduce variation in the INR value of patients undergoing warfarin treatment as a way to eventually decrease mortality and morbidity. Variation in INR values was continuously monitored throughout the project.

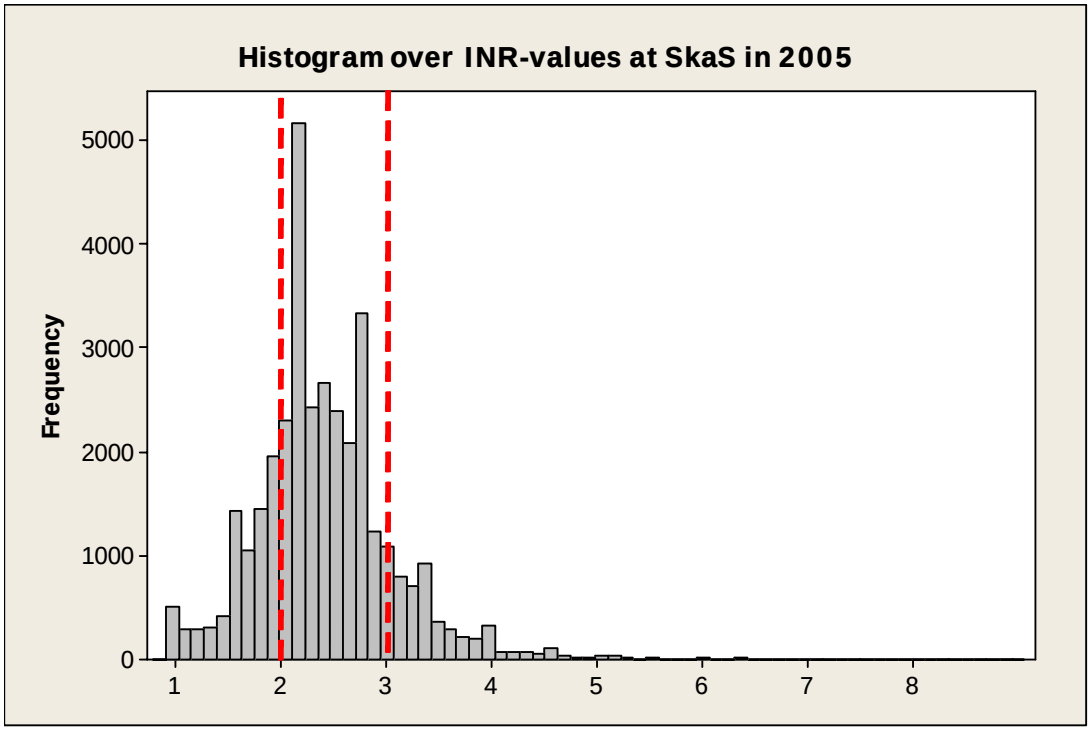

Figure 1. Variation in INR values before starting the improvement project

Figure 1 illustrates the situation before commencing the project. As seen from the figure, there is great variation in INR values whereby more than one third of the values are outside the therapeutic range of 2.0-3.0. Since decreased variation in INR values leads to reduced risk of morbidity and mortality of patients undergoing warfarin treatment, it was decided to start an improvement project with the goal to increase the number of patients with INR values within the therapeutic range.

Outline of context

The project started in the autumn of 2005 as an effort to improve the safety of the patients receiving anticoagulative therapy. An extended data collection showed that, although the numbers of patients suffering from complications in warfarin treatment could be assessed, the information would be difficult to use in an improvement project because of the limitations in continuous data monitoring. It would simply be too few observations (e.g. death cases) to monitor as well as the approach for improvement would be reactive. Therefore, the aim of the project was formulated as to reduce morbidity and mortality of patients undergoing warfarin treatment by reducing variation in the INR values.

The entire process of warfarin treatment comprises a decision to start such a treatment until the patient is in the stable condition. However, there is great variation in the basis on which the patient's responsible doctor makes the decision about starting a warfarin treatment. When a patient starts anticogulative therapy, the warfarin treatment unit takes over and provides all necessary care including warfarin medication to the patient. As a result, the patient's responsible doctor is not in charge for the daily ordination and monitoring, but is responsible for the length of treatment including the decision about finishing the treatment. This might be a drawback of the process as it might affect the decisions the responsible doctor will make in the future. As such, it is important that the patient's responsible doctor is well informed about the ongoing warfarin treatment.

Another critical aspect of the process is that the blood tests are analyzed in a number of different laboratories. This creates obvious risks for unwanted variation between tests sent to different laboratories and requires good administration to avoid undesired consequences.

ASSESSMENT OF PROBLEMS AND STRATEGY FOR CHANGE

Details of approach taken

Given the scope and complexity of the project Six Sigma methodology using the DMAIC (Define-Measure-Analyse-Improve-Control) roadmap has been chosen to address the problems outlined above.

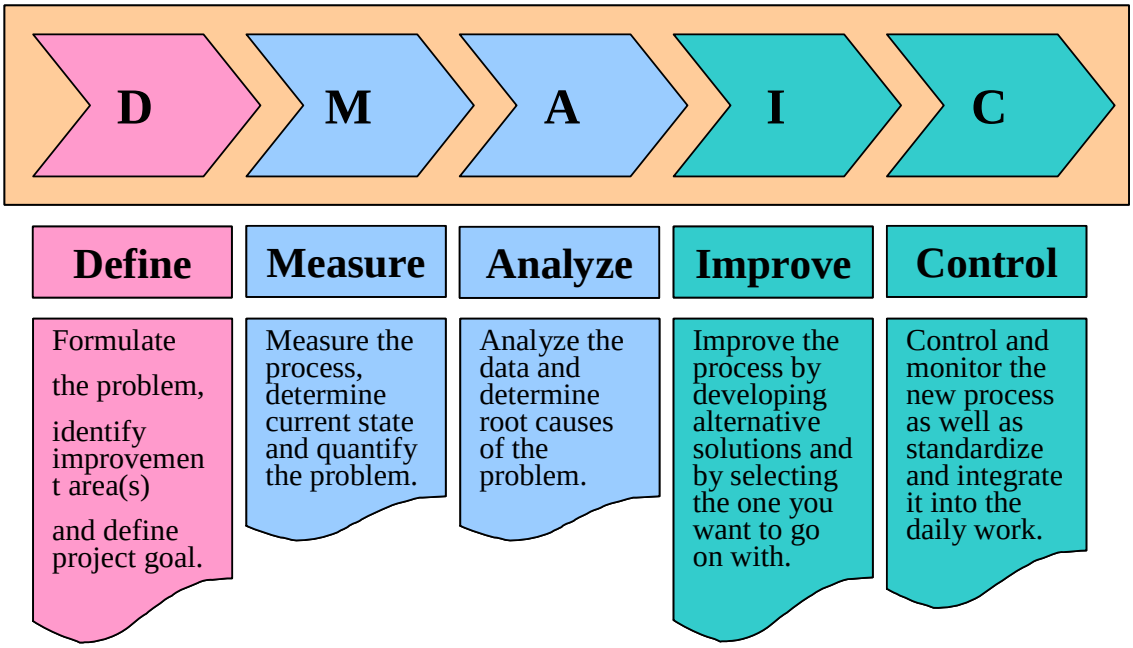

Figure 2. DMAIC roadmap at the Hospital Group of Skaraborg

Six Sigma is a rigorous, data-driven problem solving methodology developed to carry out larger, strategically important projects. The ultimate goal of Six Sigma is to improve bottom line performance and increase customer satisfaction by reducing unwanted variation. For more information on Six Sigma see Magnusson et al. (2003) and Bergman & Klefsjö (2003).
The Hospital Group of Skaraborg has previously implemented various improvement projects at a smaller scale using the so called Breakthrough Method, originally developed by Institute for Healthcare Improvement (IHI); see e.g. The Breakthrough Series (2003). In 2005 several Six Sigma projects have been launched in different medical areas of the hospital. As of today, Six Sigma methodology together with the Breakthrough Method is used as a way to carry out improvement projects at the hospital.

The following summarizes the five phases of the improvement project:

Define: undergoing warfarin treatment is safety-critical. A good care must be exercised to avoid complications and to keep the mortality/morbidity rates as low as possible. There is strong correlation between variation in the INR and patient morbidity/mortality in warfarin treatment. Before starting the improvement project over one third of the INR values taken from approximately 35 000 patients were outside the therapeutic range. The goal of the project was to reduce variation in the INR value of patients undergoing warfarin treatment (thus, increasing the proportion of patients with INR within therapeutic range) as a way to eventually decrease mortality/morbidity.

Measure: data regarding variations in INR measurements were collected and measurement system analysis (MSA) conducted to examine the relationship between the measurement variation and the process variation. The analysis showed that there was low variation in the INR of the tests taken in the same laboratory. However, there was considerable variation between different laboratories.

Analyze: in addition to the variations found between different laboratories, the data analysis reviled that there was great variation in the start up routines for patients starting warfarin treatment as well as in the INR values of patients with mechanical heart valves whose prescriptions were unnecessarily overadjusted. Furthermore, it was found that the interruptions in warfarin treatment affected patient's medical condition as well.

Improve: based on the data analysis, a number of suggestion for improvement were proposed including standardization of start-up routines, better information to patients as well as to and from wards at start-up, no overadjusting of prescriptions to patients with mechanical heart valves, and avoiding as long as possible interruptions in treatment.

Control: in order to put the proposed improvements for warfarin treatment into practice and control the process a monitoring scheme consisting of a number of control charts for proportion of INR within therapeutic range were constructed. This function is embedded in the database previously used to retrieve statistics on warfarin treatments. As of today, each unit responsible for warfarin treatment at the Hospital group of Skaraborg can access the control charts and see how their warfarin process is developing. The control charts are updated on a daily basis.

Recommendations for follow-up and improvement

Although the project did not elaborate general guidelines applicable for other hospitals administering warfarin treatment, there were a number of recommendations made with regard to follow-up and further improvement of the warfarin treatment process at the Hospital Group of Skaraborg. These recommendations included continuous monitoring of the proportion of INR within therapeutic range and further improvement of the process by additional reduction of INR variation. A PDSA-cycle based work procedures were suggested as a way of working with these improvements.

Intervention

The proposed improvements are now realized at different units responsible for warfarin treatment at the Hospital Group of Skaraborg and the results are monitored at a system level, i.e. per unit per day/week.

Measurement of problem

A combination of Six Sigma and Breakthrough methods for process improvement was used. Surveys, patient interviews, historical data from the warfarin treatment database and prospective, continuous data were collected in order to analyze the factors contributing to the overall variation in INR. The most probably causes were assessed by using VMEA (Variation Mode and Effect Analysis). For more information on VMEA see Johansson et al (2006).

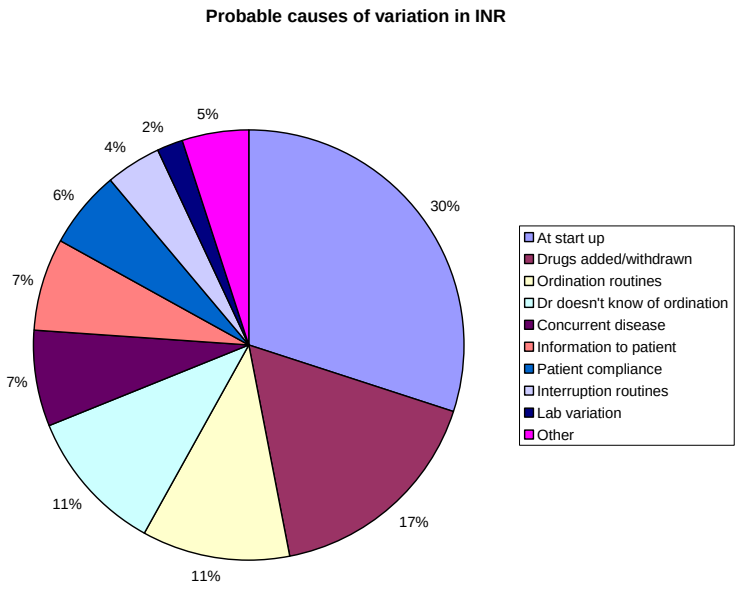

Figure 3. Probable causes of variation in INR

The data analysis showed that the warfarin-process was not in statistical control, thus not being predictable; see Figure 4.

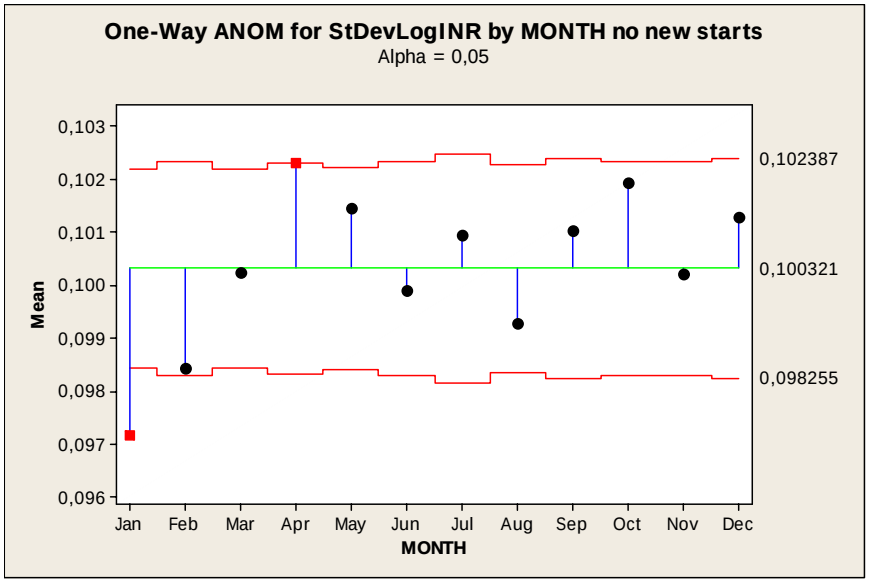

Figure 4. Variation in INR by month for 2005

Several special causes of variation that contributed to the overall variation in INR values were identified. One large source of variation was found when the reference blood test was processed/analyzed at a number of different laboratories. Figure 5 illustrates this variation the excess variation between different laboratories.

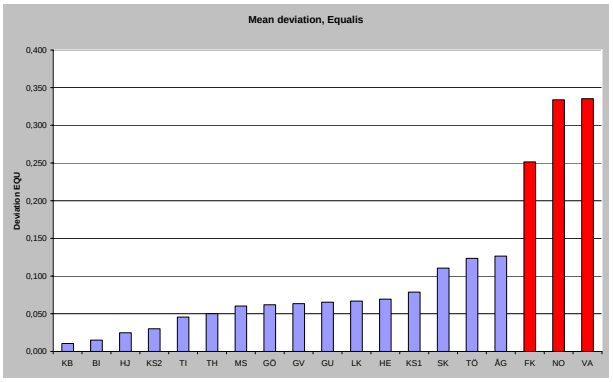

Figure 5. Mean deviation among different laboratories

RESULT OF ASSESSMENT

As a result of the root-cause analysis supported by extensive statistical data analysis several improvement suggestions were formulated. These improvement suggestions included but were not limited to:

- Standardized start-up routines
- Improved and standardized information to patients
- No overadjusting of prescriptions to patients with mechanical heart valves
- Information to and from wards at start-up
- As long as possible avoid interruptions in treatment

These suggestions were then spread among doctors and nurses throughout the entire hospital in small steps using iterating PDSA-cycles. The combination of fact-based decisions and everyone's involvement created a lot of enthusiasm for the project. In Figure 3 the results are illustrated

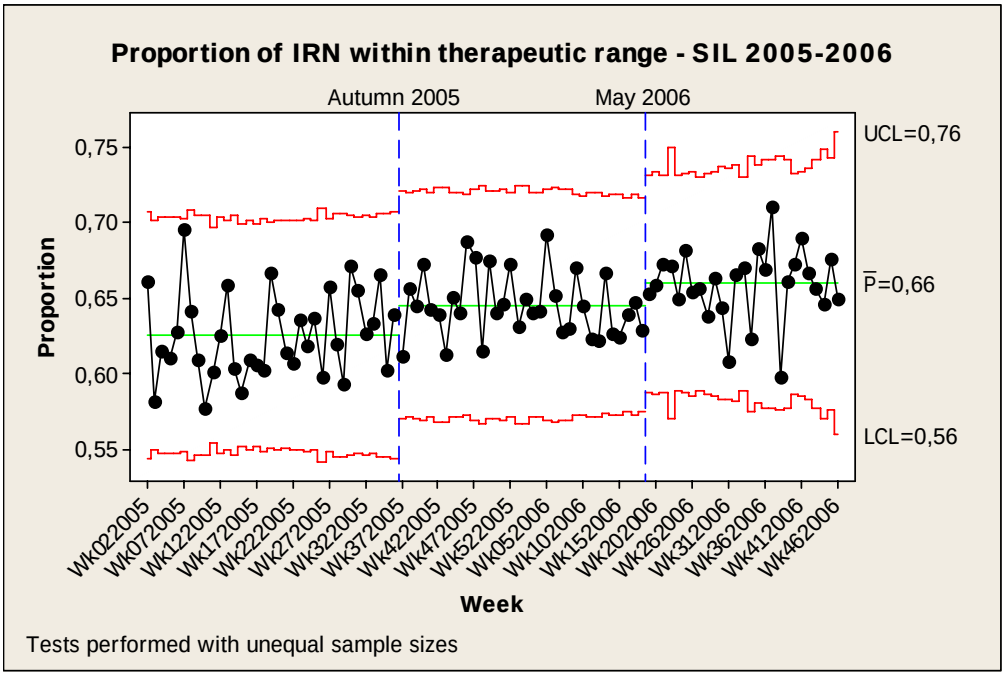

Figure 3. Proportion of INR within therapeutic range at Lidköping Hospital

As a result, the number of INR-values within therapeutic range increased from 63% (autumn 2005) to 66% May 2006 to 70% March 2007 (latest data, not included in the control chart).

All INR values are included in the data including values for new patients starting treatment and for planned interruptions in treatment. Mortality and morbidity in warfarin treatment is now continuously monitored.

LESSONS LEARNT AND NEXT STEPS

A combination of analytical and action-oriented approaches is necessary to reach "the high hanging fruits" in critical healthcare processes. This project shows that the combination of Six Sigma and Breakthrough methods has generated a considerable improvement in the treatment of warfarin patients. The project is now extended to comprise the four hospitals and all the fifteen primary care units in Skaraborg. The described improvement method is used at all hospitals in Skaraborg.

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