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Simulation based alternatives for overall process improvement at the cardiac catheterization lab

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ABSTRACT

Cardiac catheterization is one of the critical procedures in patient care. It is pertinent for all process related issues in this department to be handled with due priority. This research is a cross-functional effort with a leading hospital that was in its planning stage to implement an overall process improvement at its cardiac catheterization lab department. It has been determined that significant process delays exist in this department. One of the identified key factors to process improvement was to reduce patient turnaround time. Process mapping was used to study the system and identify potential sources of delays in the system. A set of qualitative recommendations were put forward. These recommendations, include the reduction of wait time of outpatients and inpatients and the reduction of non-value-added times such as transfer time of patients, were evaluated using a discrete event simulation approach. The simulation study shows that the daily operating hours at the catheterization lab could be reduced, aiding to reallocate staff for discharging other duties, as the hospital may require.

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1. Introduction

Wilson Memorial Regional Medical Center (WMRMC) is a community hospital and a leading healthcare provider in Johnson City, New York. This 296-bed teaching hospital which falls under the umbrella of United Health Services (UHS) provides a wide range of medical–surgical services. Some of these services include cardiology, emergency medicine, nephrology and ophthalmology. The UHS is one of the 31 centers authorized to perform heart surgery in the New York State whereas the WMRMC is one of the ways through which it provides a comprehensive array of cardiac services to its patients. The hospital provided cardiac catheterization to approximately 1300 patients during the fiscal year of 2008. The catheterization lab was in the process of improving its overall performance to enhance patient satisfaction and increase revenue during the year 2009.

Cardiac Catheterization (CC) is an important procedure conducted by the catheterization lab. This procedure involves the insertion of a long, thin, flexible tube called a catheter into a blood vessel in the groin (upper thigh) or arm of the patient. The catheter is then threaded all the way to the heart. Diagnosis and treatment are performed through the catheter [24]. The heart and blood vessels are monitored using special dyes injected through the catheter that shows up on the X-rays. Any narrowing or blockages to the coronary arteries can then be identified and treated [24]. Electro Physiology (EP), a slightly different procedure, is a study of electric flow through the heart. A problem along this electric pathway, known as arrhythmia, needs to be treated if serious. Certain heart tissues could result in 'short-circuiting' the desired electric flow, causing arrhythmia in patients [12].

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The Cardiac Catheterization Lab (CCL) department at the WMRMC where continuous process improvement had to be initiated has two types of labs: CC lab and EP lab. These labs interact with a Cardiac Ambulatory Care Unit (CACU), a part of the CCL department, for outpatients coming into the department for undergoing a procedure. For inpatients, the interaction is with the inpatient ward. Each day the catheterization lab has a 'Doctor of the Day' who is an interventional cardiologist and takes care of the proceedings for that day. The CACU is a 13-bed unit with three resources available for taking care of the patients. The limited number of resources at the CACU coupled with its use by the radiology department patients poses a challenge to the catheterization lab system in turning patients around on a timely basis.

This study focuses on a systematic study of the catheterization lab department and identifying areas of improvement that will reduce the patient turnaround time. A lean six sigma approach combined with Discrete Event Simulation (DES) has been adopted to achieve this objective. Discrete Event Simulation is a simulation wherein the model of the system is represented as a sequence of stochastic events which occur in a chronological time based order. The changes in the state of the system only occur at discrete points in time as a result of the occurrences of events [18]. Parameters such as patient wait time at the CACU, patient transfer time, and inter-procedure delays were studied in this research.

Most of the healthcare studies from operational management perspective have been related to reducing wait times or increasing the throughput at hospitals. This study deals with reducing patient turnaround time, as well as reducing the procedure end time for each day by eliminating considerable amount of Non-Value Added (NVA) time spent by the patients in the system. Moreover, studies conducted so far are predominantly based on emergency department, where only one type of entity (emergency patients) is handled. For other systems with different types of entities the scope of the system is very limited, in the sense, the performance of that system is not interrelated to the other systems. For a catheterization lab setup like the one in the current study, the processes are interrelated to CACU and inpatient units, and also include dynamicity involved by the emergency patient arrivals.

As opposed to operational management studies where the operational improvement decisions are typically made by the top level management, in the healthcare setting, the voice of the personnel working in the respective departments is very essential before making any changes to the existing process for operational improvement. In this perspective, the research team carefully designed a tailor-made survey to capture the views of each type of personnel on some of the operational improvement activities. The survey results helped in developing and analyzing alternative scenarios which were feasible to implement. Simulation helped in evaluating the scenarios which were best suited for improving a particular aspect of the overall process.

Section 2 of this paper reviews the related literature while Section 3 presents the methodology followed for the process improvement study. Section 4 elaborates on the system description and identifies the causes of delays within the system. Section 5 discusses the data collection and analysis for this study. Section 6 describes in detail the baseline simulation model, model assumptions, and the alternative scenarios for improving the existing system. Section 7 discusses the results of these alternative scenarios when incorporated into the baseline simulation model. Finally, Section 8 concludes the research with recommendations for future work.

2. Related literature on healthcare and simulation

Health care costs continue to rise due to increased demand for services [36]. At the same time, there is tremendous scope for reducing the costs and improving the service in the healthcare industry. Simulation is an excellent tool to model uncertainties and as uncertainty is a major characteristic of illness, it would be more appropriate to use simulation models in healthcare systems [10,23]. The complex systems can be modeled more easily and its performance over long period of time can be analyzed in compressed simulated time.

Kuljis et al. [20] defined seven axes of differentiation in healthcare like patient fear of death, medical practitioners, healthcare support staff, healthcare managers, political influence and control, society's view, and utopia. The primary challenge of healthcare simulations is bridging the socio-technical aspects and other metrics like performance, efficiency and effectiveness [20]. Some of the other challenges faced by the simulation experts in duplicating an existing healthcare system involve good understanding of the business needs, creating a valid model, and verifying the same against the existing system [32]. Healthcare system simulation involves the modeling of people in a dynamic and volatile environment. It is not uncommon that data cannot be collected on all important factors. Therefore, assumptions have to be made to make the simulation model work as close as possible to the existing system. Substantial simulation studies have been conducted in the areas of modeling an outpatient surgery unit, two large emergency departments, a cancer treatment center, a cardiology department, a blood bank, a spinal cord injury center, and a hospital engineering department [32].

Operations research has been used in the healthcare industry for over 40 years that encompasses resource allocation, facility planning, and evaluation of system and organizational redesign [6]. Simulation is a commonly used operations research approach and is the choice of the majority in the healthcare domain [6]. Kolker [18] discussed in detail the applications and limitations of queueing theory and DES in healthcare. When modeling a complex system, analytical formulas used in queueing models become less tractable. DES models are preferred to queueing models due to its flexible and versatile nature [18]. Brailsford [6] provides an overview of simulation approaches in the healthcare industry and discusses the advantages of using DES for the procedure rooms. The primary objective of these studies has been to reduce the patient wait times and increase the throughput in different units of the hospitals [33].

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