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Optimising the complete care pathway for cerebrovascular accident patients

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ABSTRACT

Cerebrovascular accidents or stroke is an important healthcare concern. For this reason, the need to optimise waiting times along the patient's diagnostic-therapy care pathway has gained considerable attention in operations management. In this context, the bed-blocking problem is perceived as an important healthcare logistical bottleneck where, although medically ready, the patient cannot transit upstream their care pathway due to unavailable bed resources. In addition, the care pathway is characterised by shifting bottle-necks whereby, optimising resources at downstream departments often yields considerable waiting time delays for patients transiting further upstream for rehabilitation and nursing home care. This paper addresses these concerns by simulating the stroke patient's complete pathway, right from arrival at the emergency department and ending at the nursing homes for terminal care. A case study of a large university hospital is presented where intervention strategies aimed at minimizing patient waiting time delays for available bed resources at upstream departments, such rehabilitation wards, and nursing homes are evaluated. The simulation outcomes show that implementing intervention strategies that maximise the bed resource utility, and moreover, implementing buffer management yields considerable improvements in the patients' waiting time delays.

1. Introduction

1.1. Background

Cerebrovascular accident or stroke occurs when blood flow to a part of the brain is prevented due to blockage, or rupture of blood vessels (Sacco et al., 2013). Recent statistics on European cardiovascular diseases indicate that stroke is responsible for 4 million deaths, with over 1.9 million deaths recorded in the European Union (Nichols et al., 2012). In 75% of the cases, the stroke attack is attributed to blood clot, i.e. ischemic stroke. The remaining cases are attributed to ruptured blood vessel in the brain, i.e. hemorrhagic stroke.

Stroke survivors often remain disabled, both mentally and/or physically. In particular, the elderly are more prone to stroke attacks. Since the ageing population in the European Union is increasing rapidly, stroke care is becoming an important health care problem (Nichols et al., 2012). In recent years, considerable research has focused on improving the stroke patient's clinical pathway. One important concern relates to bottlenecks in the patient's diagnostic-therapy care pathway, and often attributed to sub-optimal resource allocation or use. De Bleser et al. (2006), defines the term 'care pathway' as; "a method for the patient-care management, for a well-defined group of patients during a well-defined period of time, with the objective of improving the quality of care, reduce risks, increase patient satisfaction and enhance the efficient use of resources". Such resources may include diagnostic equipment, healthcare personnel, or hospital beds.

In many hospitals, the average bed occupancy rate is widely used as a decision variable for allocating and analysing bed resource supply and often, these occupancy rates are derived from historical usage data (Halpern & Pastores, 2015). Although costs are also included in bed allocation decisions, determining bed

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supply sorely on occupancy and costs is considered as sub-optimal approach, because balance with other resources, for instance, diagnostic capacity is hardly achieved (Green, 2012). The resulting inefficiencies often affects the quality of the healthcare delivery system, as often characterised by extended length of stay for stroke patients, and here, the bed-blocking problem is an important contributor (Lewis & Purdie, 1988; Manzano-Santaella, 2010).

From a logistical and healthcare perspective, the bed-blocking problem is viewed as an important problem, and has drawn considerable attention, especially from the logistical perspective (Bhattacharjee & Ray, 2014). For the stroke patient, the typical care pathway integrates several departments, starting with arrival at the emergency department, diagnosis and treatment at the stroke unit, rehabilitation at specialized centres, and for patients whom rehabilitation is not possible, transit to the nursing homes for terminal care. From the healthcare perspective, the bed-blocking problem, apart from extending the patient length of stay, places considerable strain on hospital resources (Halpern & Pastores, 2015).

However, how can hospital managers minimize the patient length of stay without necessarily compromising resource utilisation in the patient care pathway? To answer this question, Green (2012) argues that there is the need for implementing operations management concepts and models for evaluating care pathways. Such models, she argues, would yield the much needed managerial insights and decision support on better resource utility. Nonetheless, modelling such care pathway is not straightforward because often, optimising resources in one department in the care pathway causes a shift of the bottleneck either downstream, or upstream the pathway. For instance, optimising the diagnostic test capacity at the stroke unit may minimise medical length of stay at the unit, but may shift the bottleneck to the upstream department, especially in instances where the upstream department, e.g. the rehabilitation centre is under-capacitated. In addition, modelling such pathway where multiple institutions are involved is often challenging for several reasons. For instance, mapping the care pathway for patients across department in the pathway requires identifiable logistical attributes such as the unique patient identifier (Chemweno, Thijs, Pintelon, & Van Horenbeek, 2014; Jeremic et al., 2012). In addition, modelling the care pathway requires a careful identification of model parameters and relevancy for the specific modelling task, and the identification process can be daunting since patient attribute data often consists of a large number of feasible modelling attributes (Green, 2012).

1.2. Study aim and motivation for the research

Thus, to address the need for decision support with respect to optimising resource use in the stroke patient's care pathway, a simulation modelling approach is proposed. Specifically, this paper is motivated by the need to provide a tool for decision support for bed resource allocation in the uncertain environment that characterises the stroke patient's care pathway. The uncertainties include; varying diagnostic capacity, bed resource utilisation, stochastic patient arrival patterns, shifting bed-blocking problem, either downstream or upstream the care pathway, and competition for bed-resources at the post-acute facilities by both the stroke and non-stroke patients. In this study, the post-acute facilities include the designated rehabilitation centres and nursing homes. As is often the case, optimising resources in one department, for instance, the diagnostic test capacity in the stroke unit, would likely lead to a bottle-neck shift upstream in under-capacitated departments, for instance, the rehabilitation centres. Thus, the resource optimisation problem should focus on the entire pathway rather than specific departments. Modelling the complete pathway is, however, challenging especially in a multi-institutional set-up as is the case in this research. Thus, modelling the aforementioned aspects in a way that integrates the complete stroke patient care pathway is considered an important contribution of this research. It should be mentioned that such modelling approaches in which the complete stroke patient care pathway is integrated is underreported the literature.

The proposed simulation modelling approach evaluates the feasibility of implementing operational strategies that minimize average waiting time delays for stroke patient in their respective pathway. This is achieved through implementing simulation experiments that mimic alternative and more realistic improvement strategies in the care pathway such implementing buffer management at the rehabilitation centre or adding bed resources at upstream departments. In simulation modelling, evaluating the impact of the alternative improvement strategies is achieved without implementing physical changes in the care pathway. As a consequence, the decision makers are in a better position of evaluating the alternative strategies more cost-effectively, and in a less disruptive manner. Thus, the intuitive applicability of the simulation model as the basis for evaluating alternative improvement actions in a practical set-up is also viewed as an important contribution.

Apart from the integrated care pathway modelling outlook, the simulation model validity is demonstrated using the case study of stroke patient flow in a multi-institutional set-up that consists of a large university hospital, rehabilitation centre and a nursing home.

The remaining sections of this paper are organised as follows: Section 2 presents a comprehensive review of previous related studies evaluating the bed-blocking problem. The review highlights gaps in existing work, and provides a further justification for the proposed simulation modelling approach. Section 3 evaluates the integrated stroke care pathway and discusses modelling aspects as included in the simulation model. Section 4 discusses the model design and verification where sensitivity analysis is performed. Section 5 evaluates alternative improvement strategies aimed at optimising bed resources with a view of minimizing stroke patient waiting delay times attributed to the bed-blocking problem. The results of the case study are further presented in this section. Section 6 discusses the results where operational insights on the bed-blocking problem are drawn from the simulation modelling approach. Moreover, the applicability of the modelling approach for decision support is also discussed. A general outlook is also presented where applicability of the simulation methodology approach for care pathway resource optimisation is discussed in-depth. Section 7 draws important conclusions, study limitations and possible directions for future work.

2. Literature review

In recent years, the applications of operations management models for evaluating the bed-blocking problem in the patient pathway are discussed in the literature. The models are largely analytical, for instance, queuing models or based on simulation approaches. Analytical models have been applied, for instance in Green (2002), where queuing models are applied for estimating the optimal bed resource allocation for intensive care and obstetrics units for New York state hospitals. Osorio and Bierlaine (2009) models patient flow as a finite capacity queuing network where patient congestion attributable to bed-blocking is evaluated based on impact on the queue waiting times. Asaduzzaman, Chaussalet, and Robertson (2010) propose a queuing model for evaluating optimal bed resource capacities in a hospital's neonatal facility. More recently, Wiler, Bolandifar, Griffey, Poirier, and Olsen (2013) models the patient flows to the emergency department of a hospital, but also notes the following deficiencies generally