Using prediction to improve elective surgery scheduling

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RESEARCH

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Abstract

Background

An ageing population and higher rates of chronic disease increase the demand on health services. The Australian Institute of Health and Welfare reports a 3.6% per year increase in total elective surgery admissions over the past four years.[1] The newly introduced National Elective Surgery Target (NEST) stresses the need for efficiency and necessitates the development of improved planning and scheduling systems in hospitals.

Aims

To provide an overview of the challenges of elective surgery scheduling and develop a prediction based methodology to drive optimal management of scheduling processes.

Method

Our proposed two stage methodology initially employs historic utilisation data and current waiting list information to manage case mix distribution. A novel algorithm uses current and past perioperative information to accurately predict surgery duration. A NEST-compliance guided optimisation algorithm is then used to drive allocation of patients to the theatre schedule.

Results

It is expected that the resulting improvement in scheduling processes will lead to more efficient use of surgical suites, higher productivity, and lower labour costs, and ultimately improve patient outcomes.

Conclusion

Accurate prediction of workload and surgery duration, retrospective and current waitlist as well as perioperative information, and NEST-compliance driven allocation of patients are employed by our proposed methodology in order to deliver further improvement to hospital operating facilities.

Key Words

Surgery scheduling, Predictive optimisation, Waiting list.

What this study adds:

1. Managing stochastic activity durations, handling uncertainty in the arrival process of patients, and coordination of multiple activities are key challenges to effective surgery planning and scheduling.
2. We propose a two stage prediction based methodology for surgery scheduling to address the above limitations by employing predicted workload and surgery duration, waitlist and perioperative information, and NEST-compliance driven optimisation.
3. It is expected that by using this comprehensive methodology we can produce optimal surgery schedules which result in more efficient use of encumbered resources and increased patient satisfaction.

Background

Long waiting lists for elective surgery in Australian hospitals during recent years has driven a nationwide research agenda to improve the planning, management and delivery of health care services. Since operating rooms are the hospital's largest cost and revenue centre that has a major impact on the performance of the hospital, surgery scheduling has been studied by many researchers. The surgery scheduling problem deals with the allocation of operating rooms under uncertain demand in a complex and dynamic hospital environment to optimise the use of resources. Different techniques such as mathematical programming,[2-4] simulation,[5,6] meta-heuristics[5,7] and

distributed constraint optimisation[8] have been proposed to address this problem. However, most current efforts to solve this problem either make simplifying assumptions (e.g. considering only one department or type of surgery)[4] or employ simulated data,[3,5] which make them difficult to use in hospitals.

Elective surgery scheduling at the evaluation hospital

This work is to be evaluated at a major tertiary hospital in Queensland that has a total of 15 operating theatres generally performing 124 elective operating sessions and 23 emergency sessions per week. Currently, the allocation of available elective operating sessions at the hospital has been broken down into different specialties and teams of surgeons based on static case mix planning. This static allocation of available sessions between emergency and elective patients and among different departments often results in underutilisation or cancellation due to demand fluctuations. Also, the allocation of patients to theatres is carried out without considering the uncertainty and possible changes that might happen. Procedure times are estimated using generic data or recommended by surgeons and not based on individual patient or surgery characteristics. Patients are booked into schedules in a joint process between surgeons and the booking department. Due to the dynamic environment and rapid changes, these schedules need to be updated quickly. Typically, department managers have regular meetings to make any changes needed. Each department optimises their local schedules in accordance with departmental goals without considering hospital-wide optimisation functions.

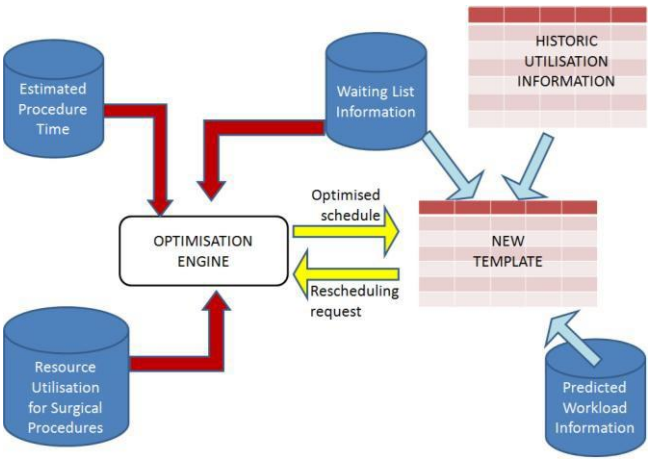
Current state of the art

Cardoen et al. present a comprehensive literature review on operating room scheduling that features performance measures, patient classes, solution technique and uncertainty.[9] One of the major issues associated with the development of accurate operating room schedules or capacity planning strategies is the uncertainty inherent to surgical services. Variability of frequency and distribution of patient arrivals, patient conditions, and procedure durations, as well as ‘‘add-on’’ cases are some instances of uncertainty in surgery scheduling.[10] Among these, stochastic arrival and procedure duration have been studied by many researchers. Procedure duration depends on several factors such as experience of the surgeon and supporting staff, type of anaesthesia, and pre-existing conditions of the patient. The study by Devi et al. estimates surgery times using adaptive neuro fuzzy inference systems, artificial neural networks and multiple linear regression analysis.[2] According to their results adaptive neuro fuzzy inference model estimates surgery time more accurately compare to the other two models, but they use a very limited sample from only one department to build and validate their models. Lamiri et al. develop a stochastic model for planning elective surgeries under uncertain demand for emergency surgery.[3] Lamiri et al. also address elective surgery planning under uncertainties related to surgery times and emergency surgery demands by combining Monte Carlo simulation and a column generation approach.[5] Although their method addresses uncertainties, it is based on simulated data and has not been tested on real data. What is needed is a comprehensive approach to provide more accurate prediction of surgery time, incorporation of predicted workload in planning the weekly surgery template, and target guided optimisation to ensure optimal allocation of resources.

Proposed Methodology

To improve the planning and optimisation tasks underlying the process, we propose a two-stage methodology for elective surgery scheduling.

Figure 1: Proposed methodology for improving surgery scheduling



In the first stage, predicted workload information (drawn from the Patient Admission Prediction Tool[11] currently used at the evaluation hospital), current waiting list information and historic utilisation information is used to manage theatre allocation and case mix distribution for each week (see Figure 1). This allows prediction based sharing of theatres between elective and emergency surgery and allocation of theatre time to surgery teams/departments. It is hypothesised that this results in a theatre schedule template which works better than a static allocation model (as demonstrated by Khanna et al.).[8]

In the second stage, the allocation of patients to the weekly theatre schedule is guided by an improved surgery duration prediction algorithm which is based on real data and

considers more variables than similar algorithms. The algorithm takes into account current patient, surgery and surgeon information, and related historic perioperative information to forecast the planned procedure time. It is assumed that regardless of the optimisation algorithm, incorporating National Elective Surgery Target (NEST) compliance in the optimisation function and accurate resource estimation will further improve the scheduling process and help deliver a more robust and optimal schedule (Figure 1).

Discussion

Although the surgery scheduling problem has been well addressed in the literature, it still remains an open problem in Operations Research and Artificial Intelligence. Despite the dynamic nature of the hospital environment, the majority of the current studies ignore the underlying uncertainty. This results in simplistic models that are not applicable in real world situations.

By using predicted workload information and retrospective analysis of waiting lists and theatre utilisation, we predict a theatre template representing an optimal case mix. The proposed methodology also employs accurate estimation of procedure time and predicted workload information to drive optimal elective surgery scheduling, and helps hospitals fulfil NEST targets.[1]

We are currently working towards collecting over five years of surgery scheduling, waiting list and perioperative information for the evaluation hospital from the corporate information systems. This data will be used for modelling and independent validation of the prediction algorithms as well as building historic resource utilisation knowledge banks to guide other stages of the scheduling process.

Conclusion

In this paper we propose a novel methodology which could improve current elective surgery scheduling. This improvement is achieved by providing more accurate workload and procedure time estimation, as well as incorporating NEST-compliant in scheduling process.

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PEER REVIEW

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

ETHICS COMMITTEE APPROVAL

This research has received ethics approval from the Gold Coast Health Service District Ethics Committee.