Capacity planning for robotic surgeries: A simulation based approach

Maria Saabye Jørgensen
Aalborg University, Copenhagen

Atanu Chaudhuri
atanu@business.aau.dk
Department of Materials and Production, Aalborg University, Copenhagen
2450 Denmark

Abstract

The purpose of this research is to assess the implications of transition from open to robotic surgery at the surgical gastroenterology clinic of a public hospital in Denmark. A Discrete Event Simulation model was developed with multiple scenarios in order to assess the implication of robotic surgeries utilization of operating rooms, wards and overtime. The simulation models identified overtime as a critical performance measure. The results showed that to successfully adopt robotic surgeries for the next 3 years, the clinic needed to standardize processes. After the initial years, the clinic could either plan for less robotic surgeries and thus avoid any further investment or invest in more robotic surgery capacity.

Keywords: capacity planning, robotic surgeries, simulation

Introduction

Robotic surgery has developed rapidly since the 1980s in relation to the major advancement in microelectronics and computer technology. Till the 1990s the US Army noticed the development of robotic surgeries and identified the potential of decreasing the wartime mortality rate by bringing the surgeon to the wounded soldier through robotic surgery. The idea was to operate on remote by placing the wounded soldier in a Mobile Advanced Surgical Hospital and extend the life of the soldiers. The system has been successfully demonstrated on animals but has never been tested in actual battlefields (AVRA Medical Robotics, Inc., 2017).

The development of robotic surgeries has continued in the civilian surgical community and today the technology is used in many procedure types, especially operations deep inside the body, where extreme accuracy is needed. The abdominal centre in the surgical gastroenterology clinic of a large hospital in Denmark is currently conducting most of its surgeries as open procedures. However, the abdominal centre has realized that if they want to be a leading University Hospital, it needs to improve the technical ability and the process technology. Before the implementation of a new process technology, it is important to assess the feasibility and to assess its impact on the operating performance measures. Thus, the objective of this research is to assess how will the transition to robotic surgeries affect the abdominal centre of the hospital in terms of utilization of operating rooms, overtime, and postponed patients.

Literature Review

The literature review was conducted using the Science Direct database, using scholarly journal articles published between 2010 and 2016. The search stings were developed using keywords-healthcare, patient pathways, robotic surgeries, models and simulations. 28 articles were finally selected for review.

The healthcare sector aims to deliver the highest quality of care at the lowest cost by providing the right resources at the right time to the right patient (Van Riet and Demeulemeester, 2015). Conflicting objectives complicate capacity planning in the healthcare system where many stakeholders are involved. Some of the conflicting objectives are maximization of utilization of resources, improving quality of care, improving efficiency of diagnosis systems, managing increasing patient flows within the time constraints, while minimizing costs of healthcare (Bhattacharjee, and Ray, 2014). Discrete event simulation (DES) models have been used in healthcare to study the effect and performance of a range of health interventions such as implementation of alternative improvement strategies, such as varying bed resources and rehabilitation treatment time that minimizes waiting time in the pathway (Shukla et. al.,2015). Modelling a care pathway is complex as optimizing resources in one department in the care pathway causes a shift of the bottleneck either downstream or upstream in the pathway. DES can help in understanding the impact of various factors on multiple performance objectives. Chemweno et al., 2014 simulated the diagnostic pathway for patients suffering from strokes at a large university hospital. By using DES, based on patient arrival, resource capacity variation and patient waiting time, the patient flow could be improved and reduction in waiting time and LOS could be achieved by investing in the right test scans. Healthcare robotics has experienced substantial growth with the increasing use of robotic systems in surgeries. The development of surgical robots is motivated by the desire to enhance the effectiveness of a procedure by coupling information to action in the operating room and transcend human physical limitations in performing surgery, while still keeping the human control over the procedure (Okamura. et. al., 2010). But, there is limited research on capacity planning of robotic surgeries.

We also reviewed the literature on impact of robotic surgeries on surgery time, length of stay (LOS) etc. Sorensen et al. (2011) argued that pediatric pyeloplasty surgery times increased by 38% in the beginning. Several studies compared open, laparoscopy and robotic surgeries in order to identify differences. Barakat et al. (2011) studies the surgical outcomes and differences in Myomectomy. The results show that laparoscopy and robotic surgeries resulted in significantly lower LOS for the patient after the procedure and significantly lower blood loss, however the procedure time is significantly higher than open surgery. Al-Mazrou et al. (2016) elaborated the differences between laparoscopy and robotic assisted surgeries of complex colorectal procedures. Their results showed insignificant medical postoperative complications between the two, however robotic surgery was associated with shorter postoperative hospital stay i.e 4 days vs. 5 days. In contrast, Maeso, et al. (2010) did not find any difference in LOS between laparoscopy and robotic surgeries.

The learning curve is also based on many parameters related to the expertise of the individual surgeon, and the procedure type. Sorensen et al. (2011) defined the learning curve as “the way to achieving mastery, the curve represents the initial challenges in competences, and the change in technical proficiency and efficiency with increasing experience". In the case of robotic assisted pediatric pyeloplasty surgeries they found evidence of a learning curve effect was observed after 15-20 robotic cases (Sorensen et al., 2011). Gala et al. (2014) stated that as surgical efficiency develops over time as the surgeon and operation room team gain additional experience, the initial plateau point of 20 procedures with the use of robotic surgery could be considered reasonable.

Methodology

The purpose is to simulate the transition phase from open to robotic surgeries over the next five years in order to identify changes in utilization of OR's, overtime and potential bottlenecks. Before the simulation model was built, a detailed understanding of processes, procedures and resources was needed. Hence, semi-structured interviews with the management and involved clinical staff were conducted to understand the processes at the clinic. Interviews were conducted with head of the clinic, two outpatient head nurses, the head nurse of surgery, three head physicians, two project nurses and the financial planning coordinator.

Quantitative data was obtained from different databases within the hospital. These were supplemented by observations and field visits to the clinic, its ORs and wards to have a thorough understanding of processes at the clinic. Finally, a Discrete Event Simulation model was developed in order to assess utilization of ORs and wards, overtime. The simulation model was developed based on an in-depth understanding of procedure types, patient flows and real life data, allowing a realistic variation of the process steps into the simulation model. Different scenarios were simulated to identify how the clinic can succeed with the transition year by year.

Analysis and Findings

Assumptions and static calculations

Assumptions were made about duration of stay, learning curve effect and length of stay based on literature review and analysis of the procedures conducted in 2015 and 2016. The duration of surgery is expected to increase when the procedures are transferred to robotic surgery, though it is not clear how much the duration time will increase. The physician performing one of the observed procedures expected the duration time to increase very little over time. Overall, there was a consensus in the clinic that surgery duration will increase more in the beginning whereas experience with the robot will result in reduced durations over time. However, the overall duration time is expected to increase compared to open surgery. Analysis of the robotic surgeries conducted in 2015 and 2016 at the clinic showed that compared to open procedures, the median duration of the robotic surgeries increased between 5 and 11%. Thus, it was assumed that surgery duration would increase by 10% due to shift from open to robotic procedures. Length of Stay (LOS) for the patient after the procedure is an important factor when discussing robotic surgeries. The data from 2015 and 2016 showed that the LOS for the patient was decreased significantly by 13% after procedures. The clinic expected a higher decrease in the LOS than what was seen from the historic data. The management have been clear in their expectations towards the reduction in LOS, and they have explicit stated that if awareness is increased at ward the LOS will most likely decrease even more. Therefore, for the purpose of baseline calculations, it is assumed that LOS will be decreased by 2 full days i.e. around 14%. Such assumptions were used for conducting static calculations and for developing baseline scenarios before building the simulation model.

Simulation Results
The simulations were performed using FlexSim Healthcare; which is a powerful DES software program, especially developed for simulating new process designs and operations in healthcare settings.

Verification and validation of the model was carried out continuously throughout the development of the model. The validation of the model was achieved through three steps. The model was first presented in two meetings. The purpose of the first meeting was to present the principles of DES and how a simulation model would be able to support decisions within the clinic. The second meeting was a presentation of the model in order to verify patient flows, the logic of the model, staff allocation and the assumption taken based on the future robotic setup, based on interviews. The outcomes of the model were explained and discussed, ending with a common understanding and an agreement to continue with the model. Secondly, all distributions determined from the data, going into the simulation model were validated by using the statistical program ExpertFit. Both graphical comparison and goodness-of-fit tests were applied in order to ensure the correct use of distribution, before applying these in the model. If the evaluation of a selected model were doubtful, an empirical distribution of the data was applied instead, in order to make sure the data was handled appropriate and only valid data were allowed into the simulation model. Thirdly, a comparison of the static calculations and the simulation results was conducted. The results are reckoned as comparable between the two, showing the same trends and pattern, however significant differences occurs in overtime and postponed patients due to the variation included in the simulations.
The static and simulated results for the baseline scenario are compared in

Figure , based on the 5 years.

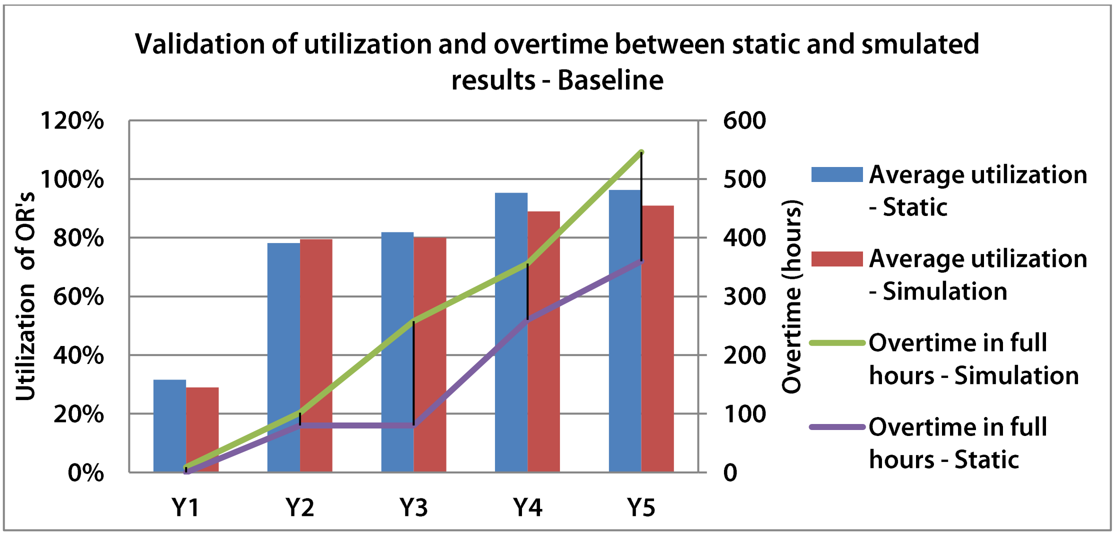

Figure 1: Static and simulation results

The utilization rates for the static and simulated results are very similar, only varying by a few percent-points. The overtime is in contrast significantly different from each other. The overtime from the simulation increases rapidly over the five years and represents in year 3 69% more overtime than the static result, this decreases to 24% and 35% for year 4 and 5. The overtime was identified to be the largest challenge for the clinic in the

transition period toward robotic surgeries. If the decision had been based on the static calculations, the clinic might have already faced capacity problems in year 2 and 3.
Scenarios were developed for multiple scenarios considering reduction in pre and post processing time by 20%, no whipples prodecures, less number of liver procedures etc, introduction of additional robots in years 4 and 5.
The results showed that to successfully adopt robotic surgeries for the next 3 years, the clinic needs to standardize processes. After those first three years, the clinic can either plan for less robotic surgeries and thus avoid any further investment or invest in more robotic surgery capacity. Overtime will play an important role in such a decision. Thus, in year 4 and 5, the clinic can either:

1) Minimize overtime by reducing the amount of procedures transferred to robotics and thereby limit the development of robotic surgery. This solution does not require any investment.
2) Invest in more capacity and thereby reduce the overtime and postponement of surgeries, thereby creating the optimal patient experience and the foundation to become the leading Robotic Center in the Nordics.

The financial assessment favours the reduction of robotic surgeries in the short term, however the investment of more capacity turns out to be more favourable in the long term, assuming that the clinic become a leading robotic centre.

Conclusion, research implications and limitations

Simulations results showed that to minimize the impact of additional overtime, there is a need to standardize processes and to improve process efficiencies. In the current processes, waiting times occur due to delays from physicians, nurses, materials and transport assistants not being on time or in place at the right time. In order to change this, a cultural change might be needed. Creating a lean culture takes time and consistent training of all staff members; it requires full attention from the management as well as all other employees. Bringing awareness to the timeliness and punctuality and standardizing changeover procedures can minimize waiting time. The routines of, how and when the physicians are called, just before the nurses have prepared for surgery needs to be investigated in details. Currently, the process of contacting physicians is unstructured and individualized. Developing a standard of when to contact the physicians and other functions can bring stability and predictability into the processes and thereby minimize waiting time. Also implementing 5S and ensuring that the right tools are available for each surgery at the right time can further minimize the pre/surgery waiting times. Such process improvements can ensure that overtime of doctors and support medical staff will be minimized. In the future years, if the clinic managers want to pursue excellence in robotic surgeries, they need to invest in additional capacity.

This research has certain limitations. It is restricted to simulating processes only in one clinic without taking into account other related processes eg. diagnostics etc. Future research can be directed at building more comprehensive simulation models considering the entire care processes. To our knowledge, this is one of the earliest research to make a long term planning for transition to robotic surgeries using DES.

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