A review on the use of operational research techniques in the medical records department

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Abstract

Introduction: Various operational research (OR) techniques have been used in different areas of healthcare. One of the areas in which OR techniques can be effective is the medical records department (MRD). The aim of this study is to review the applications of OR in the management of MRD and its related processes.

Methods: This is a review article. In order to collect data, English-language studies published between 2000 and 2018, related to the use of OR techniques in MRD, in the Medline, Science Direct, ProQuest and Web of science databases were investigated. From 1165 retrieved studies, 19 articles met the inclusion criteria and were included in the final review.

Results: The results showed that different OR techniques such as linear programming, integer programming, simulation, hierarchical analysis process, etc. have been used in various aspects of the MRD and its ongoing processes such as improving efficiency, workload management, resource allocation, optimal scheduling of staff work hours, patient scheduling, patient admission and discharge.

Conclusion: It can be concluded that if the managers and experts of MRD and health information management become familiar with the principles and techniques of OR and become aware of the importance of these techniques in improving efficiency of MRD, there is a hope that in the future these techniques will find their true place in MRD and ultimately enhance the quality of services provided to patients.

Keywords
Operational research, medical record department, health information management

Background

The medical records department (MRD) is one of the most important sources of information about patient diseases and their treatment, and performance assessment of healthcare staff. This department facilitates using medical records in addition to protecting medical records against unauthorized disclosure.¹²

The most important tasks of MRD include supporting and protecting current and future care of the patient, official activities, continuous training programs, healthcare research, auditing and financial measures of the patients, efficiency management and risk management, service quality assurance, legal and quasi-legal requirements and all patient-related services.³⁴

Other tasks include:

- Patient admission processes, including registration and identification of patients
- Retrieving patient information and delivering it to authorized individuals and entities
- Patient discharge processes and completion of medical records after discharge or death of the patient
- Coding of disease and surgical procedures
- Filling patient records

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• Evaluating MRD services
• Completing and reporting monthly and annual statistics
• Legal issues related to assigning patients’ information to other authorities.5,6

Because of the importance of the MRD in efficiency, quantitative and qualitative evaluation and improvement of healthcare activities, the activities of this department should use scientific and standard methods.7

MRD managers need to develop flexible strategies to enable their department to adapt to the changing needs of customers and their surrounding environment. This requires using standards, monitoring, and forecasting required activities, and exact planning and implementation of changes in MRD processes.6,8

These changes will be more effective when develop based on quantitative analytical models rather than the intuition and perception of the manager.9 The application of proper quantitative tools help the MRD manager to determine the optimal level of manpower required for the MRD, reduce operating costs of the department, and increase efficiency, quality and timeliness.10

There are many quantitative tools to assess the above items. The application of these methods help managers to understand various processes of the department completely, monitor productivity, manage staff, and control the operational costs of the MRD. They also provide solutions for solving problems. These tools include regression analysis, process statistical control, and various operational research (OR) techniques including discrete-event simulation, queue theory, linear programming, and so on.11-13

OR is one of the most popular management tools for decision making used in public and private organizations.14 The OR mission is to support decision making in solving real problems of various practical areas using mathematical and computer modeling.15

There are several applications of different OR techniques, such as integer linear programming, queue theory, discrete-event simulation, Markov model etc., in different areas of healthcare.16,17 Some of the applications of OR in healthcare include manpower listing and scheduling, management of hospital inventories, supply chain management, logistics planning, technology evaluation, quality management, decision support systems, optimal prices, vaccination modeling, resource allocation, pharmaceutical policies, and so on.18,19

According to the importance of using approaches, techniques and quantitative models for the optimal management of the MRD and health information management, this study aims to investigate the application cases of different OR techniques in the MRD and the related processes.

Methods
This study was conducted according to the PRISMA20 (Preferred Reporting Items for Systematic reviews and Meta-Analyses).

Search strategy
A comprehensive literature search was conducted in Web of Science, PubMed, Science Direct and ProQuest databases for English-language citations published from 1 January 2000 to 22 May 2018. A researcher with health information management expertise (HB) developed and carried out a Boolean search strategy using key words related to “operational research techniques” (e.g. Discrete Event Simulation, OR Queuing theory OR Linear integer programming OR Markov model) and keywords related to MRD or health information management (e.g. medical record management OR Admission OR discharge OR patient scheduling OR workflow OR health information management). We used MeSH terms in Medline, and truncation, wildcard and Proximity operators to strengthen the search.

Inclusion criteria
The inclusion criteria were studies in English that provide an application for OR in the MRD and other related processes such as admission, discharge, scheduling and patient flow, published from 1 January 2000 to 22 May 2018.

Exclusion criteria
Studies in a language other than English, and studies on applications of OR in other parts of health such as nursing, medicine, etc. that were not related to the MRD and other related processes, were excluded.

Study selection
After duplicates were removed, two researchers (HB and MJ) screened the titles and abstracts according to the inclusion/exclusion criteria. The same researchers then assessed the full texts of potentially relevant papers. Disagreements were resolved in consultation with a senior researcher (NT), who also examined and confirmed the relevance of all included papers.

Data extraction
Data elements extracted from selected articles included authors, date of publication, subject fields of MRD and related processes in which OR techniques were used, techniques used in MRD and related processes and short description about used techniques.

Results
We retrieved 1165 records by searching the previously mentioned databases. After removing duplicates, 1051 articles remained. Based on the review of titles and abstracts, 70 articles were found that met the initial selection criteria. After examination of the full texts, 19 articles met the inclusion criteria and were included in the final review (Figure 1). Most of the 19 articles were published in 2014 (36.8%).

The results showed that few different OR techniques have been used directly in the management of the MRD. These techniques have been more applicable to some MRD-related
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In the processes directly related to the MRD, manpower optimization, cost-benefit and cost effectiveness evaluation, data exchange etc., are among the areas in which these techniques have been used\textsuperscript{10-13} (Table 1). There were no cases of application of these techniques in other processes including diseases surgical procedures coding, healthcare measures, medical records filling, assessing MRD services, completing and reporting monthly and annual statistics and legal issues related to releasing patients’ information to other authorities. Among different OR techniques, discrete-event simulation, linear programming, integer programming, Markov model, queuing theory and data envelopment analysis (DEA) were the most widely used techniques in the studies\textsuperscript{10-13} (Table 1).

**Figure 1.** Flowchart of identifying, screening, and selecting related studies

**Table 1.** OR Techniques used in the MRD.

| Author (year) | Subject fields of MRD | Technique | Short description about used technique |
|---------------|-----------------------|-----------|----------------------------------------|
| Chan et al. (2002) | Workflow in a MRD | Programming, Linear Simulation | This paper portrays quantitative models incorporating accessible data to represent transcription activities of a MRD. Researchers forecasted the workload of the MRD, decided the ideal specialist plan and planned a simulation model to represent the work process of the transcription function of a MRD. |
| Kazley and Ozcan (2009) | Hospital electronic medical record (EMR) use and efficiency | Data envelopment analysis (DEA) | In this study researchers utilized DEA to analyze the connection between hospital EMR use and effectiveness in a national example of acute care hospitals. |
| Bhagat et al. (2009) | The operations in the health information management (HIM) department | Discrete-event simulation model | In this investigation specialists built up a discrete-event simulation model using Arena 10.0 simulation software for outlining the future state of the HIM department, showing the effect of Document Imaging on work process changes, and giving logical recommendations for the decision-making process in the HIM department. |
| Bhat et al. (2016) | Productivity and performance of MRD | Optimal Assignment Hungarian Method | This investigation has been done to improve the profitability and execution in the Health Information Department by allocating the correct individual to the correct activity. An assignment method has been utilized to decide the ideal individual for the correct activity. |
| Author (year)       | Subject fields processes related to the MRD | Technique                                      | Short description about used technique |
|--------------------|---------------------------------------------|-----------------------------------------------|---------------------------------------|
| Turhan and Bilgen  | Patient admission scheduling                | Mixed-integer programming                     | In this study, two Mixed Integer Programming (MIP)-based heuristics, namely Fix-and-Relax (F&R) and Fix-and-Optimize (F&O), were exhibited. Primary objective of this investigation was to give the best arrangements in shorter run times for patient admission scheduling. |
| Qin et al. (2017)  | Test different discharge strategies, reduce occupancy rates in the hospital, improving patient flow and minimizing frequency and duration of congestion episodes | Simulation approach                            | In this examination, “the point was to propose and test diverse release strategies, which, conceivably, could reduce occupancy rates in the hospital.” The authors utilized a simulation approach using HESMAD (Hospital Event Simulation Model: Arrivals to Discharge), an advanced simulation model catching patient flow through an expansive Australian hospital from arrival in Emergency Department to discharge. |
| Sowle et al. (2014) | Patient admission planning; Intermediate term allocation of resource capacities | Integrates a discrete-event simulation model and integer programming model | In this paper, a system that mixed discrete-event simulation model and integer programming model was produced for arranging patient admission and the allocation of resource capacities. |
| Range et al. (2014) | Patient admission scheduling problem        | Column generation approach/ integer programming | In this paper the patient admission scheduling problem was addressed. Researchers consider one such variant and propose an optimization-based heuristic building on branch-and-bound, column generation, and dynamic constraint aggregation to unravel it. |
| Prodel et al. (2014) | Patient admission policies in order to maximize the overall gain/ optimal patient admission policy | Markov Decision Process (MDP) Model           | In this paper the hospitalization admission control strategies of patients from an emergency was examined. Researchers initially proposed a MDP Model for assurance of the optimal patient admission. A simulation model was then implemented to evaluate MDP admission approaches. |
| Goldberg et al. (2014) | Patient admissions                          | Discrete-event simulation                     | In this investigation, a discrete-event simulation was made to study changes in patient flow and length of stay pre- and post-execution in the Neurovascular Unit. |
| Granja et al. (2014) | Patient admission scheduling problem        | Optimization based on simulation approach/ integer programming algorithm | In this paper, a simulation-based optimization approach to the patient admission scheduling problem was shown. Modeling instruments and simulation strategies were utilized in the improvement of a diagnostic imaging department. |
| Gartner and Kolisch (2014) | Patient flow in hospitals/ reduction of time between admission and surgery | Two mixed integer programs (MIPs)              | In this paper, planning the patient flow in hospitals subject to rare medical assets with the target of expanding the commitment edge was addressed. Two (MIPs) for this problem were created. |
| Khurma et al. (2013) | Discharge process                           | Simulation model                               | In this paper, the results of an investigation conducted jointly with a regional hospital and concerned with inpatient discharge process are shown. A simulation model of the discharge arranging path was made and approved. The model was utilized to investigate the impacts of standardizing parts of the discharge process. |
| Santibáñez et al. (2012) | Patient appointment scheduling              | Discrete-event simulation                     | In this investigation, a 17-month study was led to address booking, planning and workload issues and to create, execute, and assess solutions. Process improvement involved discrete-event simulation to evaluate alternative booking practice scenarios, creation of an optimization-based scheduling tool to improve booking effectiveness, and change the management for usage of process changes. |
| Ceschia and Schaerf (2012) | Patient admission scheduling problem       | Integer linear programming                     | The objective of this investigation was to propose and solve a new formulation of the patient admission scheduling issue. Specialists conceived a meta heuristic methodology that solves both the static and the dynamic forms of this new issue, which is based on simulated annealing and a complex neighborhood structure. |
existing manpower alternatives lists and the forecasting model to estimate the required workforce in the following weeks. The results showed that estimating the daily working volume of the MRD and duration of conducting processes can be done using prediction models. Data collection processes and formulating integer linear programming subsets provided the best scheduling solutions that were consistent with the listing in the real environment. The results also showed that the MRD is currently operating with the least-required manpower. This information was useful for management decision making in manpower replacement.11

Kazley and Ozcan12 used DEA to test the relation between using hospital electronic medical records and the efficiency of an acute care hospital at a national level. The results indicated that small hospitals might benefit from electronic medical records, but it does not usually make any special difference in medium and large hospitals.12

Bhagat et al.10 in their study focused on applying various industrial engineering tools to improving the operations of the health information management department. They used the simulation model for specific operational suggestions, such as determining the “optimum” batch size for patient chart arrival, workflow modifications and personnel scheduling. The results showed that the best possible way to allocate resources and manage processes was using simulation as a decision-making tool.10

Bhat et al.13 used the Hungarian model to determine the optimum mode for improving the efficiency and performance of the health information management department in a 100-bed hospital. They investigated the time needed to prepare medical records. Because of high work volume, this process was time-consuming: 30 minutes to prepare a medical record. Assignment problem and Hungarian method were used to solve the problem. Finally, preparation time was reduced to 18 minutes.13

Regarding other MRD-related processes, the results showed that different OR techniques were more used in the patient admission and discharge processes and patient scheduling. Linear programming, integer linear programming, discrete-event simulation, queue theory and Markov model were useful techniques in these studies.21–35

### Patient admission, discharge, and patient scheduling

Turhan and Bilgen21 identified the patient admission scheduling (PAS) problem as a combinatorial optimization problem and using two mixed integer programming (MIP)-based heuristics, namely fix-and-relax (F&R) and fix-and-optimize (F&O), to resolve it. They used patient length of stay (LoS), room inclination, admission date, specialization, and age and time deterioration in their model. Computational findings show that the proposed heuristics provide promising results toward the solution of the problem in faster CPU times than the previously reported values, where a less than 15% gap from the best known solutions is achieved for most of the test instances, and as low as a 5% gap for some sample data.21

Qin et al.22 in their study consider increased demand for services as the main reason for an increase in the length of time for patients to discharge from the emergency department. They used simulation to test different discharge strategies. The results showed that in the best proposed scenario, the simulation model reduced the gap between admission and discharge from 281.5 days to 22.8 days.22

| Author (year) | Subject fields processes related to the MRD | Technique | Short description about used technique |
|---------------|---------------------------------------------|-----------|---------------------------------------|
| Zhu (2011)    | Proper discharge pattern                    | Simulation approach | In this paper, different discharge patterns and their impacts on the bed occupancy rate and bed waiting time are contemplated. A discrete-event simulation model is built to assess the current discharge pattern in a Singapore regional hospital utilizing real hospital admission and discharge transaction data. |
| Utley et al. (2002) | Booked inpatient admissions | Queuing theory | In this investigation, a mathematical model of the operation of a speculative booking system demonstrates that such variability has a considerably effects on intensive care capacity prerequisites, showing that a high-level reserve capacity is required to avoid high rates of operation cancellation because of unavailability of suitable postoperative care. |
| Aslani and Zhang (2014) | Patient appointment scheduling | Simulation and data envelopment analysis (DEA) | This investigation mixed discrete-event simulation and DEA to decide the most effective patient appointment scheduling model. |
| Kozlowski and Worthington (2015) | Elective patient treatment | Queue modeling; Discrete-event simulation; Continuous-time Markov Chain | This paper shows the utilization of a queue modeling approach in the investigation of elective patient treatment represented by the maximum waiting time policy. Drawing upon the joined qualities of logical and reproduction approaches scientists create both Continuous-Time Markov Chain and Discrete-Event Simulation models, to give an insightful analysis of the public hospital performance under the policy rules. |
In their study, Sowle et al.\textsuperscript{23} used both discrete event simulation model and integer programming for patient admission planning. They used combination techniques to find the best balance between new and existing patients arriving to each appointment time during the day.\textsuperscript{23}

Range et al.\textsuperscript{24} proposed an optimization-based heuristic building on branch-and-bound, column generation, and dynamic constraint aggregation to solve assigning elective patients to beds.\textsuperscript{24}

Prodel et al.\textsuperscript{25} used the Markov Decision Model to determine the optimal patient admission policy, taking into account existing constraints and essential assumptions such as the patient’s LoS. They also used simulation models to evaluate these policies under real conditions. Their results showed that selective policy from the Markov model specifically improved patients’ admission.\textsuperscript{25}

Goldberg et al.\textsuperscript{26} used a discrete-event simulation to study changes in patient flow and LoS pre- and post-neurovascular unit implementation. The volume of referral patients and available resources was tested to determine the number of ideal beds in different conditions. Scenario testing showed that the current level of 20 beds is sufficient for accommodating the current demand and would continue to be sufficient with an increase in the demand of up to 20%.\textsuperscript{26}

Granja et al.\textsuperscript{27} in their study used a simulated annealing algorithm to optimize the patient admission sequence toward minimizing the completion and total waiting of patients in the imaging clinic. The obtained results showed average reductions of 5% on the total completion and 38% on the patients’ total waiting time.\textsuperscript{27}

Gartner and Kolisch\textsuperscript{28} in their study investigated patients’ mobility changes in the hospital. They used MIP. The results of their study showed that using this model reduced the waiting time between the patient’s admission and the time of surgery.\textsuperscript{28}

Khurma et al.\textsuperscript{29} in their research on the discharge process in a regional hospital, developed a simulation model for the patient’s discharge process to reduce the LoS for patients. This model examined the effect of standardizing the discharge process on reducing the LoS. The results showed a potential for 4.5 day reduction in the median of LoS. Obtained results of the model show that organizational changes (utilization of social services, improved information flow, close communication with foreign institutions, etc.) will lead to improved processes and economic benefits.\textsuperscript{29}

Santibáñez et al.\textsuperscript{30} in their study considered clinical complexity, scheduling restrictions, and long treatment waitlists at a chemotherapy clinic in a large cancer center in British Columbia, Canada. They used discrete-event simulation to evaluate alternative booking practice scenarios, development of an optimization-based scheduling tool to improve scheduling efficiency, and change management for implementation of process changes. The final appointment notification of 1-week lead-time target was reduced by 57% and median waitlist size decreased by 83%.\textsuperscript{30}

In their study, Ceschia and Schaefer\textsuperscript{31} presented a new formula for solving the PAS problem. They used a metaheuristic approach to solve this problem. They compared the quality of their approach with a more accurate method based on integer linear programming. The main output of this method was the ability to solve cases larger than 4000 patients, while the previous models only solved cases up to 250 patients. The results show that the metaheuristic approach is capable of solving dynamic problems.\textsuperscript{31}

Zhu\textsuperscript{32} studied different patterns of patient discharge and their impact on bed occupancy and waiting times, using the discrete-event simulation model to evaluate the existing pattern of patient discharge. The study then looked at different patterns. The simulation results showed that an appropriate pattern of discharge would promote the fluidization of bed occupancy rate and reduced bed waiting time.\textsuperscript{32}

Utley et al.\textsuperscript{33} used their mathematical model for a hypothetical appointment scheduling system in their study. The results showed that, despite the eagerness of using patient registration systems, queuing theory suggests that we should be cautious in using these systems for inpatients’ appointment scheduling.\textsuperscript{33}

Aslani and Zang\textsuperscript{34} combined discrete-event simulation approaches and DEA to determine the most efficient system for determining PAS. The researchers aimed to find out which of the available trilogy systems is more appropriate for a certain number of patients applying for registration.\textsuperscript{34}

In their study, Kozlowski and Worthington\textsuperscript{35} used a queuing modeling approach to analyze the waiting time for elective patients. They used Markov model and simulation to analyze the overall performance of the hospital. They conducted this study to strengthen the quality of services provided to elective patients.\textsuperscript{35}

**Discussion**

In this research, a systematic review was carried out on studies which used different OR techniques for management of the MRD and related processes such as admission of patients.

After reviewing these studies, we found a number of techniques such as linear programming, discrete event simulation, Markov model, queuing theory, optimal state determination and DEA, and a combination of simulation and linear programming techniques, simulation and DEA for cases such as listing, scheduling and registering patients, optimizing the discharge processes, improving the performance of the MRD, increasing the efficiency and effectiveness of the department, facilitating performing ongoing processes and optimizing the use of the patients’ electronic medical records.

Few studies have used OR techniques in managing the key processes in the MRD, such as patient information retrieval, circulating medical records, information provision to individuals, and the management of department manpower. However, further studies have been conducted on the application of OR in patient admission processes including the registration and identification of patients and the process of patient discharge.

One of the challenges managers face in different parts of the health care area is listing of employees. Various OR techniques have been used in this area, especially in listing nursing staff. Another issue is the PAS, which is one of the most important fields in the health sector. Various researchers have used different OR techniques for PAS and optimal patient listing in order to reduce waiting time.
Conclusion

In this study various applications of OR techniques were identified in the management of the MRD. In different studies the use of these techniques has led to an improvement in the activities under study. The limitation in the number of studies in the MRD indicates that experts in this field are still unaware of the importance of using quantitative tools in managing this department, or are less willing to use these tools.

Of course, in recent years health professionals in other areas, such as human resource management and resource management, have tended to use these approaches. The use of OR techniques in the management of the MRD will definitely enable the promotion of quality and development of this sector.

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Author contributions

HB, MJ, and NT contributed to the study conception and design. HB searched selected scientific sources. Screening the papers and full text assessment was carried out by HB and MJ. Drafting of the manuscript was carried out by all authors. NT critically revised the manuscript and provided insights on the review discussion. HB approved the version to be published.

Declaration of Conflicting Interest

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As a review based study, no verification of ethics committee approval was obtained.

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Availability of data

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