ANALYSIS OF IMPACT OF NOSOCOMIAL INFECTIONS ON COST OF PATIENT HOSPITALISATION

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SUMMARY

Objectives: The scale of the economic problem of the occurrence of nosocomial infections and the resulting high additional costs of treatment can only be assessed using economic analyses. The aim of the study was to analyse the impact of a nosocomial infection in a patient in the treatment process and the direct costs of patient hospitalisation. The article contributes to a cost analysis, which is a relevant basis for adopting effective solutions and decisions on the introduction of new programmes and measures to reduce nosocomial infections and associated costs.

Methods: In the first phase of the micro-economic analysis, we analysed the course of hospitalisation of a non-colonised patient treated in an ordinary hospital room. In the second phase, we analysed the process of hospitalisation of a patient who developed a nosocomial infection and was transferred to an isolation room. The difference in cost of both types of treatment allowed us to carry out an economic analysis to estimate the direct costs of nosocomial infection, which are not related to the initial diagnosis of the patient but only to the patient hospitalisation. To calculate the individual types of direct costs of both alternative treatments, we first used the process flow diagram method, which then enabled us to analyse the impact of the occurrence of nosocomial infection on the efficiency and costs of the hospital.

Results: The results showed that the total direct cost of hospitalisation of a non-colonised patient was 1,317.58 euro per day, and the direct cost of hospitalisation of a patient with a nosocomial infection was 2,268.14 euro per day of hospitalisation.

Conclusions: We found that reducing nosocomial infections would have a significant impact on the savings or reduction in healthcare costs associated with a different work process for patients in isolation. It would save 950.56 euro per patient for each day of hospitalisation for individual treatment of a patient hospitalised in an isolation room as consequence of a nosocomial infection.

Key words: economic evaluation, costs, nosocomial infections, isolation, general hospitals

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INTRODUCTION

Nosocomial infections are a major concern for the global health safety of both patients and healthcare workers (1–3). Nosocomial infections are defined as infections that were not in a state of transmission or incubation at the time of admission and that manifest in a patient within 48 hours of admission to hospital (4). These infections are not related to the main cause of hospital admission and may occur even after the patient has been discharged from the hospital (5).

The previous research has indicated that nosocomial infections lead to excess morbidity, increased mortality, and substantial additional costs within healthcare facilities, mainly due to different treatment modalities, higher antibiotic consumption and longer hospitalisations (6–8). Nosocomial infections have been found to double the risk of mortality and excess morbidity in patients and cause approximately 90,000 deaths annually in the United States (9). In Europe, nosocomial infections are estimated to occur in 4.1 million patients and cause approximately 37,000 nosocomial infection-related deaths (10).

In developed countries, nosocomial infections are reported to occur in 5% to 15% of hospitalised patients within main hospital wards and as many as 50% or more of patients in intensive care units (ICU). In developing countries, the number of nosocomial infections is significantly higher. Here, the percentage of nosocomial infections within main wards is as high as 30%, and the scale of the problem within these countries also remains largely underestimated (11). Nosocomial infections are responsible for 11% to 25% of all neonatal deaths in the United States, and for 4% to 56% of all neonatal deaths in developing countries (12, 13).

In Slovenia, we record about 18,000 of nosocomial infections per year (14), i.e., a non-negligible number. The prevalence of nosocomial infections in Slovenia (6.6%) is similar to the overall prevalence of nosocomial infections in the EU (5.9%), country range from 2.9% in Lithuania to 10.0% in Greece (15). Of concern is the prevalence of nosocomial infections among ICU patients (30.6%), which is quite high compared to the overall European estimate of 19.2% for patients classified as specialized ICU patients (15).

Nosocomial infections significantly increase the financial expenses related to the patient's medical treatment. According

to a report by the World Health Organization, hospital-acquired infections in the United States increase financial expenses by approximately 4.5 billion USD, or by considering inflation rates by 6.5 billion USD, and in Europe by approximately 7 billion EUR (16). More recent estimates have considered changes in the epidemiology of hospital-acquired infections and, at the same time, an increase in financial expenditure. Health economists have calculated that the cost of treating hospital-acquired infections in the United States is estimated to be between $28.4 and $33.8 billion, with this estimate rising to $45 billion using a different methodology (17).

If only 20% of all hospital-acquired infections could be prevented, medical costs in the United States could be reduced by $5.7 billion. However, if healthcare facilities could reduce hospital-acquired infections by 70%, the financial savings would be USD 31.5 billion. If we compare these data with the costs of treating individual diseases, we see that the value of reducing hospital-acquired infections by 20% is the same as the costs of treating stroke, diabetes or chronic obstructive pulmonary disease (17).

The five most common hospital-acquired infections in the United States, which include urinary tract infection, pneumonia, catheter sepsis, surgical wound infection, and infection caused by the bacterium *Clostridium difficile*, are estimated to cost the healthcare system in the United States $10 billion annually. The cost of a single medical treatment of a patient with catheter sepsis is approximately $45,000, and the cost of medical treatment of pneumonia in a patient on mechanical ventilation is approximately $40,000. *Clostridium difficile* infection is estimated to be the second most common nosocomial infection in the United States, and the cost of treating a patient with this type of infection is approximately $11,000 (18).

All this suggests that healthcare providers will have face a challenge on how to reduce nosocomial infections. The scale of the problem of nosocomial infections and the resulting high additional costs of treatment can only be assessed using economic analyses, which are still in their infancy in the field of nosocomial infections (19). The additional costs incurred as a result of nosocomial infections that are difficult to be estimated accurately, which is why estimates vary considerably between studies analysing the costs of treating patients for nosocomial infections (20). Most studies generally divide the costs of nosocomial infections into several groups. Some are directly related to the patient's original diagnosis, while others are direct costs that arise as a result of treating the patient differently, regardless of the patient's original diagnosis. In addition to direct costs, nosocomial infections also result in indirect costs, which cause additional costs for the entire healthcare system and society.

The key contribution of the article is an elaborated economic assessment of the potential savings that occur if a patient is prevented from developing a nosocomial infection. This is one of the first studies of its kind to accurately distinguish between direct costs, which are related to the hospitalisation of the patient itself, and indirect costs, which also depend on the initial diagnosis for which the patient was admitted to hospital. In addition, the paper contributes to a cost analysis which can help to make decision-makers and health policy-makers more aware of the problem of nosocomial infections, and that provides an appropriate basis for adopting effective solutions and decisions on the introduction of new programmes and measures to reduce nosocomial infections. Finally, the results and findings can be of managerial and practical relevance for cost monitoring in hospitals.

MATERIALS AND METHODS

A nosocomial infection in a patient can cause both changes in the volume of outputs produced and the volume of inputs consumed, but since efficiency is shown in the relationship between the volume of outputs and the volume of inputs, we must observe either changes in the volume of inputs for a given amount of outputs or changes in the volume of outputs for given amount of inputs. In our analysis, we have taken into account that the volume of outputs produced does not change, as we analyse the impact of the occurrence of nosocomial infection on the efficiency and costs of the hospital through a single business process, which means that our output was defined as the treatment of a hospitalised patient on a single hospital day. However, the volume of inputs consumed changes, depending on whether the patient is a colonised patient or a patient without nosocomial infection.

To analyse the economic impact of a nosocomial infection on the efficiency and costs of the hospital, we first needed data on the quantity of inputs and outputs, and data on the prices of inputs. According to the classic economic definition, inputs are expressed in the form of labour and capital (21). Thus, we first defined the labour input data, which was estimated separately for different groups of employees, and then the capital input data, which was expressed in terms of the value of medical and other consumables. Mathematically, costs of patient hospitalisation are defined as the sum of the products of the costs and prices of business process elements, which can be written in the equation:

$$C_{i=1}^{n} = \sum Q_i \times p_i$$

wherein C = costs, Q_i = quantity of the business element i, p_i = price per unit of the business element i, indices i = 1, and n belong to the sum.

In this study we analyse those types of costs that are directly related only to the hospitalization of the patient and not to the original diagnosis for which the patient was admitted and treated in the hospital, namely the two main groups of costs, labour costs and material costs.

To estimate the economic impact of nosocomial infections on treatment costs, we first calculated the labour costs. In the first step, we quantified the work inputs by expressing work in terms of the number of staff hours involved in each activity within the treatment of a non-colonised patient and in the treatment of a patient with a nosocomial infection. Since labour costs are defined as the product of the volume of labour inputs and their prices, we have also defined the price data for labour inputs in the second step.

In the following, we also defined the quantity and price of the capital input, which we defined in the form of the value of medical and other consumables, while we defined only those values of the mentioned category that do not depend on the original diagnosis of the patient and occur in all hospitalized patients. When determining the impact of the occurrence of nosocomial infection on the efficiency of the hospital, we did not determine the distribution of other elements of the capital among individual activities. We

used only those elements of capital that are directly affected by the occurrence of a hospital-acquired infection in a patient.

Some of the direct costs of treating a patient as a result of nosocomial infection can be estimated with relative accuracy (22). Among the direct costs of nosocomial infections of this type are increased costs due to longer patient hospitalisation; more expensive treatment due to the use of additional medicine, repeated examinations and additional surgeries; higher costs due to additional laboratory and diagnostic tests; higher costs due to the use of additional medical devices, as well as their decontamination, cleaning, disinfection and sterilisation of surgical instruments; higher costs due to the use of additional personal protective equipment; additional costs due to more complex implementation of nursing care; and higher costs due to extended working hours of medical and non-medical staff in the hospital.

To calculate the individual types of direct costs of both alternative treatments, we first used the process flow diagram method (23). This way, we have defined very precisely the new activities and business tasks that change when a patient develops a nosocomial infection. For ease of understanding, a "treatment of a patient in an ordinary patient room" business process flow diagram and a "treatment of a patient in an isolation room" process flow diagram have also been made to show the number and sequence of activities for both types of treatment. Next, the direct costs of implementing individual activities were precisely calculated, which lead us to the final calculation of the direct costs of medical treatment for the first and second alternative treatments.

The study took into account the newly incurred costs of treating a colonised patient, related to the additional use of personal protective equipment, cleaning costs, hospital linen costs, waste costs, and sterilisation costs. The treatment of patients in isolation rooms involves a number of additional activities, some of which have to be carried out repeatedly due to the colonised environment, which increases the working time of medical and non-medical staff, and some additional staff are also involved. Due to the precise delineation of direct costs unrelated to the patient's initial diagnosis, their economic evaluation did not include the costs of prolonged hospitalisation, additional consumption of medicines, repeated examinations and additional surgeries, additional laboratory and diagnostic tests, the cost of using additional medical devices in the operating theatre, and consequently their decontamination, cleaning, disinfection and sterilisation, nor the higher staff costs resulting from the additional complications of the patient's treatment and the prolonged hospitalisation. The economic analysis thus excludes all costs related to activities within the operating theatre and activities taking place in the outpatient department.

All cost data for each alternative treatment is based on our own calculations and interviews with staff at one of Slovenia general hospitals. These were carried out between August 2021 and October 2021. The information systems of general hospitals do not track costs per patient, which means that there is no direct correlation between the data. Thus, the data monitored by the observed hospital at aggregate level was used, and then the individual types of direct costs for a given alternative treatment were calculated using the keys for their division to direct costs to obtain total costs.

In the observed hospital, 1,099 isolations were ordered in 2019, with the largest number of isolated patients in the paediatrics department, which is also in line with other studies. Among them, there were the most extended-spectrum beta-lactamases (ESBL) isolations (219 cases), while the most common infections were *E. coli* (182 cases), Methicillin-resistant *Staphylococcus aureus* (MRSA) infections were also common (125 cases). Accordingly, when calculating the costs of hospital infections, we took into account that the hospital has approximately 1,000 isolates per year.

RESULTS

For non-colonised patient hospitalisation, labour input was observed separately for 13 different staff profiles: specialist doctors, registered nurses, nosocomial infection control nurses, licensed practical nurses, radiological engineers, social care workers, health administrators in the health administration service, health administrators in the procurement service, paramedics, technicians, transport workers, housekeepers, and security guards. In the case of a patient with a nosocomial infection, we observed the labour input for an additional staff profile; the nosocomial infection control physician, who is not involved in the traditional management of the patient.

The labour cost for the first and second alternative treatments in Table 1 shows the number of activities and the labour cost by individual departments for both treatment alternatives.

In contrast to the "treatment of a patient in an ordinary hospital room" business process, we can see that the number of activities increases significantly in the "treatment of a patient in an isolation

Table 1. *Labour cost of the first and second alternative treatments*

Hospital departments	First alternative		Second alternative	
	Number of activities	Labour cost (EUR)	Number of activities	Labour cost (EUR)
Procurement department	4	1.33	4	1.33
Reception	5	1.88	5	2.04
Reception office	6	6.40	15	20.80
Inpatient department	46	164.22	54	240.36
Diagnostic and therapeutic interventions department	2	14.7	6	31.60
Unclean area of a hospital ward	4	1.16	3	1.12
Central sterile services department	8	285.9	16	580.80
Total	75	475.59	103	878.05

room" business process. The "treatment of a patient in an isolation room" business process thus comprises 103 activities, while the "treatment of a patient in an ordinary hospital room" business process involves 75 activities. Among the different staff profiles, the highest increase in labour costs is observed for registered and licensed practical nurses, who have the most direct contact with colonised patients. However, when comparing departments, we found that labour costs increase the most in the central sterile services department, where the number of activities also doubles.

In the case of a non-colonised patient treated in an ordinary hospital room, the labour cost per hospitalisation is 475.59 euro per day. In the case of hospitalisation of a patient with a nosocomial infection, the aforementioned cost amounts to 878.05 euro per day. The labour cost therefore increases by 402.46 euro (84.62%) per day of hospitalisation in the event of a nosocomial infection.

In addition to evidence on the volume and price of labour input, which is expressed in the form of labour costs, according to classic economic theory, economic evaluation also requires data on the value of capital input. In our case, we have expressed the input capital in a way that identifies the costs of medical and other consumables incurred in treating a patient who is hospitalised in an ordinary patient room and in treating a patient who is hospitalised in an isolation room. When determining the impact of the occurrence of nosocomial infection, we did not determine the distribution of other elements of the hospital's assets among individual activities. We considered only those capital elements that are directly affected by a nosocomial infection in a patient. We used data on the purchase value of medical and other consumables.

The value of material costs for the first and second alternative treatments shows the number of activities and the value of material costs by individual departments for both alternative treatments (Table 2).

Among all hospital departments, the cost of medical and other consumables increases the most in the central sterile services department and in the hospital reception office. Notwithstanding the fact that the number of activities within the inpatient department increases significantly, the calculations show that there are no higher costs in this department when dealing with a colonised patient. The biggest difference in material costs can be seen in the central sterile services department, where costs increase by 373.59 euro.

The material costs for treating a patient in a regular hospital room are 841.99 euro, and the costs for treating a patient in an isolation room are 1,390.09 euro. When a patient who developed a nosocomial infection is treated in a hospital, the material costs increase by 548.10 euro (65.10%). In absolute terms, the biggest savings would be in the cost of medical and other consumables (Table 1 and 2).

The economic analysis shows that the total direct cost of hospitalisation of a non-colonised patient was 1,317.58 euro per day, while the direct cost of hospitalisation of a patient with a nosocomial infection was 2,268.14 euro per day of hospitalisation. By preventing the occurrence of nosocomial infection, the total costs of treating the patient, which are not related to the original diagnosis but only to the patient's hospitalisation, are reduced by 950.56 euro (72.14%). This clearly shows that the occurrence of a nosocomial infection in a patient has a significant impact on the level of costs or savings for a given healthcare provider.

The economic assessment of the first and second alternative treatments can thus be illustrated by the following equation:

$$\frac{1}{1{,}317.58} > \frac{1}{2{,}268.14} \text{ or } 1{,}317.58 < 2{,}268.14$$

The equation shows that the additional cost saving of preventing a nosocomial infection in a patient is 950.56 euro per day of hospitalisation. If a hospital has 1,000 isolations ordered per year, the additional cost of ineffective containment of infection transmission is approximately 950,560 euro per year, not including the additional days of hospitalisation incurred due to the occurrence of a nosocomial infection in a patient, which adds significantly to the cost of treating such a patient.

DISCUSSION

The aim of the study was to analyse the impact of nosocomial infection in a patient in the treatment process and to quantify in detail the direct costs of nosocomial infection using economic analysis. In doing so, we focused on one of the key processes within the medical treatment of the patient, i.e., the process of patient hospitalisation. In the first phase, our aim was to analyse the process of hospitalisation of a non-colonised patient treated in an ordinary hospital room. In the second phase, our aim was to analyse the process of hospitalisation of a patient who developed a nosocomial infection, as a result of which the patient was transferred to an isolation room. This allowed us to carry out an

Table 2. *Value of material costs using the first and second alternative treatments*

Hospital departments	First alternative		Second alternative	
	Number of activities	Material costs (EUR)	Number of activities	Material costs (EUR)
Procurement department	4	0.70	4	0.70
Reception	5	0.46	5	0.46
Reception office	6	1.82	15	210.23
Inpatient department	46	512.13	54	468.80
Diagnostic and therapeutic interventions department	2	0.00	6	12.69
Unclean area of a hospital ward	4	17.03	3	13.77
Central sterile services department	8	309.85	16	683.44
Total	75	841.99	103	1,390.09

economic analysis in the next phase to estimate the direct costs of nosocomial infection, which are not related to the initial diagnosis of the patient but only to the patient hospitalisation.

The economic analysis of the costs that can be attributed to the occurrence of nosocomial infections has already been evaluated in some other studies around the world. It is reported that the additional costs resulting from treating a patient with a nosocomial infection range between 1,018 US dollars and 2,280 US dollars per infected patient (24–26). Our economic analysis findings also confirm the results of other researches around the world. We found that the direct costs resulting from the treatment of a patient with a nosocomial infection amount to 950,560 euro per day of hospitalisation. Similar findings were reached by Jarvis, who reported an average cost of nosocomial infections in a range of 558–593 US dollars for each urinary tract infection, 2,734 US dollars for each surgical site infection, 3,061 US dollars for each bloodstream infection, and 4,947 US dollars for each case of pneumonia occurring in a patient (27). Even one of the latest studies from Scotland, which deals with the mentioned issue, states that the total costs for a single day of patient hospitalisation amount to 799.17 pounds (28).

Some of the direct costs of treating a patient as a result of a nosocomial infection are much more difficult to estimate, so financial estimates of such costs are much less precise and are usually based largely on lump-sum calculations (18). In our analysis, we include the costs associated with occupied beds and closed wards and also operating theatres, which are reflected in the opportunity costs of the hospital or the cost of lost benefits. Patients with nosocomial infections usually experience treatment complications, increased morbidity and increased mortality. In hospitals, there is a loss of reputation, which can be institution-wide or department-specific. This has a significant impact on the hospital's contracts with healthcare payers and patient referrals. Nosocomial infections also often lead to legal disputes that have to be settled in the courts, resulting in additional costs for the hospital in terms of legal fees, lawyers' fees and court proceedings. While all these costs are also directly linked to increased costs for the healthcare facility where nosocomial infections occur, they are much more difficult to be measured and therefore the financial implications are usually based mainly on estimates.

Nosocomial infections can also have indirect costs, which are not directly linked to higher costs for the healthcare facility. They can be linked to higher costs for the healthcare system and society as a whole (29). This includes the lengthening of queues caused by nosocomial infections that prolong hospitalisations and often lead to the closure of wards and operating theatres. Increased patient morbidity and mortality resulting from nosocomial infections do not only cause higher costs for healthcare facilities, but also additional costs to communities and society. These costs are difficult to quantify, but they can have a very large impact. Often, patients are discharged from the hospital while the infection is still present, resulting in additional costs for home care staff or for patients staying in a rehabilitation centre. While the patient is still infected, the likelihood of infecting others with whom he or she comes into contact increases, which means that new costs are subsequently incurred for the treatment of those infected. Patients with nosocomial infections incur additional costs in terms of time away from work, as well as additional costs for the patient's relatives and friends, who incur travel and opportunity costs in terms of time spent between visits. Nosocomial infections, as a common cause of the core of the dispute, not only increase the costs of the medical institution where the nosocomial infection occurred, but also cause additional costs for society as a whole.

Economic analyses are essential to support the development of programmes for the control and prevention of nosocomial infections. Nevertheless, economic analyses are a relatively new field in infection prevention programmes. Nosocomial infections are known to be preventable causes of morbidity, leading to the development of many programmes to control them. It is estimated that about 70% of catheter-related bloodstream and urinary tract infections, about 55% of pneumonia requiring ventilator-assisted treatment and surgical site infections can be prevented (30). If we compare this with our economic estimates, with a reduction in nosocomial infections by just 20%, the hospital would save at least 189,888 euro annually, just from the reduction in the cost of personal protective equipment, sterilisation costs, cleaning costs, the cost of hospital waste, and the labour costs associated with treating a patient in a patient room, without taking into account the increase in the number of days a patient is treated. If they could manage to reduce infections by 70%, they could save at least 665,392 euro annually at the observed hospital, where they have approximately 1,000 cases of infection every year.

Nosocomial infections are known to be preventable causes of morbidity, leading to the development of many health programmes to control them. Some economic analyses thus already analyse the effectiveness of infection control programmes. Studies have shown that the savings in treating patients are significantly higher compared to the resources needed to reduce or prevent nosocomial infections (31–33). This is also confirmed by economic analyses, in which the costs are estimated very liberally, while on the other hand, the benefits of the treatment are presented relatively conservatively (34). This is consistent with our economic assessment and analysis of the savings that would occur if only a proportion of nosocomial infections could be prevented. It is therefore crucial for healthcare providers to strengthen control of nosocomial infections in these circumstances. This is also explicitly confirmed by other studies evaluating health programmes (35).

Cleaning and disinfecting the hospital environment are important components of a comprehensive hospital infection control process, especially in departments treating immunocompromised patients. This has been the message of health policy-makers for many years, and it is also the message of many reports and studies in this field (36, 37). Studies assessing the effectiveness of cleaning and disinfection in hospital premises show that approximately 5–30% of surfaces remain potentially contaminated due to the ineffectiveness of ingredients in detergent and disinfectant formulas to disrupt biofilms (38, 39).

One of the key measures that healthcare providers should follow is the contamination of patient rooms. This measure is also suggested in some other studies, which similarly point out that contamination plays a very important role in reducing the transmission of antibiotic-resistant organisms (40, 41). The factors that most increase the likelihood of hospital infections are suboptimal or ineffective manual cleaning and disinfection of hospital premises. We can see the potential in reducing nosocomial infections in a case of automated systems for cleaning the hospital environment, such as ultraviolet light machines in particular, used

as an additional tool in cleaning and disinfection. Some other authors who evaluated programmes for the prevention of hospital infections also found their positive effects (42–44).

It is necessary to point out two limitations of the study. The first limitation is substantive in nature. As implied in the above text, our cost analysis relates to one of the selected Slovenian general hospitals. The second limitation is related to available data. The selected hospital indeed has introduced a comprehensive information system for monitoring certain information; however, such data is not monitored by patient but at the level of a hospital as a whole. This means that we accessed certain information only with the use of keys and conducting interviews with employees at the hospital.

Implications of the study are for science, policymakers, and managerial practice in hospitals. The scientific contribution is in cost analysis to optimize expenditures related to the hospitalisation of nosocomial infection. The developed information base can be important for decision making process and health policy development. The developed tools can be important for managerial practice in hospitals for cost monitoring and optimizing costs in providing health services.

CONCLUSION

In line with the economic analysis, we can conclude that reducing nosocomial infections would have a significant impact on the savings or reduction of healthcare costs associated with a different work process for patients in isolation. It would save 950.56 euro per patient for each day of hospitalisation per individual treatment of a patient who is hospitalised in an isolation room as consequence of a nosocomial infection.

All of these calculated costs represent only a small fraction of all hospital costs associated with nosocomial infections. Therefore, it would make sense to extend the study to an economic cost analysis, where the individual patient's original diagnoses for which they were admitted to hospital are also monitored in parallel. In this way, it is possible to estimate by how much the length of stay increases, how much the consumption of medicines and other medical devices increases, how many additional examinations and interventions are needed, how many complications occur in the primary disease, how many additional staff profiles are needed, and how much the staff time and consequently the staff costs increase, including activities related to outpatient examinations and the operating theatre.

The calculated costs in the Slovenian general hospital represent only one tenth of all costs incurred as a result of the occurrence of a nosocomial infection in a patient. If we consider all the direct costs that are related to the diagnosis of patients and also all the indirect costs that are related to the occurrence of nosocomial infections, the savings would be significantly higher. The projected lump sum estimate of savings is about ten times higher, which means that between 2 and 7 million euros would be saved on an annual basis.

The results are based on the investigation of a single general hospital. Therefore, the future research should be extended to more hospitals and use more sophisticated methods of analysis when developing better information base that can be used in empirical analysis.

Conflicts of Interest
None declared

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