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Identification and Prioritization of Key Factors in the Liver Transplantation System using DEMATEL-modified ANP Method

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Abstract

Background: Organ transplantation is one of the great advances in modern medicine and the treatment process in many diseases begins with the provision of transplanted organs. Unfortunately, the need for organ donors is much greater than the number of people who donate.

Objectives: With a significant gap between waitlisted patients and those who undergo liver transplantation (LT), it is crucial to have efficient allocation of this scarce resource and improve the performance of LT centers.

Methods: In the present research, using the DEMATEL-modified ANP method, an attempt was made to identify, weigh, and prioritize the key factors influencing the transplantation process in the LT system. For this purpose, the liver transplant center at Mashhad University of Medical Sciences, Mashhad, Iran, was piloted to study the transplant process and interview the medical staff as specialists to draw a relationship map.

Results: The obtained results indicated that the accuracy of patient selection for transplantation, surgical equipment, and the level of expertise of personnel were important factors in LT success. Then, by analyzing the results, management suggestions regarding the improvement of the quality of the services and systems were presented.

Conclusion: The findings of this research can help health policy-makers and decision-makers to better understand the determinants of the performance of a transplantation center and suggest improvement plans. This means saving more lives and, at the same time, minimizing the cost of service.

Keywords: Causal relations, DEMATEL-modified ANP, Liver transplantation, Performance factors

1. Background

Organ donation is the process of surgically removing an organ or tissue from one person (the organ donor) and placing it into another person (the recipient). Transplantation is necessary because the recipient's organ has failed or has been damaged by disease or injury. Organ transplantation is one of the great advances in modern medicine. Unfortunately, the need for organ donors is much greater than the number of people who donate. The treatment process in many diseases begins with the provision of transplanted organs, continues with preparing the patients that require organ transplantation for surgery, performing surgery, and finally, ends with training and postoperative care. In addition, the demand for medical services in the world has increased dramatically with the growth of the elderly population in societies, the advancement of science, the increase of health insurance programs, and the creation of new diagnostic technologies.

Health economics is the science of the correct use of limited resources to meet the needs of society in the field of health (Mosadeghrad, 2004). Today, economic and political crises have caused a significant reduction in the resources and budgets of countries. In this situation, the lack of adequate access to up-to-date medical facilities has significantly reduced the efficiency of healthcare organizations. Therefore, in the long run, this will increase the number of illnesses and disabilities, which in the macro dimension will lead to many social, economic, and political issues for a country. In such situations, identifying key success factors of the organization, such as performance indicators and budgeting based on them, can tremendously help to implement the processes correctly. If quantitative indicators are well- identified, the organizations will focus on activities that will positively impact their performance and will not spend their time and resources on low-value activities. On the other hand, by planning to improve the organizations' indicators, we can expect quality improvement in the system's performance. Various models and methods can be used to measure the efficiency of organizations, such as data envelopment analysis, stochastic boundary analysis, and performance indicators (Gannon, 2005).

To calculate the efficiency of a liver transplantation (LT) center, the relationships among sub-processes and how they affect each other should be identified. The transplantation process is a complicated system, and paying attention to these kind of systems can play an essential role in timely identification, improving maintenance conditions,

performing successful operations, and ultimately saving many lives. Therefore, drawing the causal relationships between different parts of the transplantation process and determining the most influential factors of the process and sub-processes can help decision-makers to design more appropriate evaluation frameworks. Health administrators can use this framework to find the strengths and weaknesses of the relevant organizations and make better decisions to improve their performance.

Considering the issue of LT as a network of related processes and using a systematic framework to evaluate its performance is the main contribution of this study. In addition, the critical factors of any process in this area are another contribution that has been identified and prioritized.

2. Objectives

The remainder of the research is as follows: Part two included the conceptual framework and the method of the study. In part three, the results were examined, and research findings were discussed in part four. Finally, the conclusions of the study were presented in part five.

3. Methods

In this research, the vital factors of the LT process and its sub-factors have been obtained by reviewing the related literature, interviewing specialists, and studying the process. Then, using decision making trial and evaluation laboratory (DEMATEL), dependencies and their interrelationships were extracted and finally, using analytic network process (ANP), the priority of factors and sub-factors was calculated.

Key factors of the liver transplantation process

Several studies have been conducted to identify the critical success factors of the LT process. Youn and Greer (2014) realized that factors like the proper maintenance of potential donors in the special care unit, effectively communicating with the family of brain dead patients, gaining their trust, and educating them are profoundly affecting factors for providing high-quality transplantable organs. Findlater and Thomson (2015) examined how potential donors can be managed to increase the quality and quantity of transplantable organs. They concluded that factors such as advertising campaigns to raise awareness of people, increasing professional medical training, improving donor management practices, and technological advances could be critical success factors in the donation rate. Several researchers suggested that the diversity in opinions submitted for identifying suitable transplant cases was the leading cause of LT reduction in America (Goldberg et al., 2016; Zamora-Valdes, Leal-Leyte, Kim, & Testa, 2017). Lausevic et al. (2015) and Modra and Hilton (2018) suggested that factors such as lack of patient's family consent or improper care of transplantable organs were the main reasons for the low rate of organ transplantation before 2010. Furthermore, other factors such as the role of health systems (Laidouni, Gil-González, & Latorre-Arteaga, 2016; Niazkhani, Pirnejad, & Khazaee, 2017), access to primary health care (Fos & Zúniga, 1999; Wong & Pagalilauan, 2015), and the existence of home health care provider agencies (Gaber, Schwartz, Bernard, & Zylicz, 2013; Valdmanis, Rosko, Leleu, & Mukamel, 2017) are useful for improving the proper identification of organ donors and organ transplant systems.

In this section, the factors related to the LT unit are introduced.

a) Caring for the patients with end-stage liver disease (ESLD) on the waiting list: Since the only way to save patients with severe liver failure is LT; therefore, the waiting list for these classes of patients is formed based on the councils' opinions and severity of the disease. Five sub-factors affect it.
b) Doing the surgery: The effectiveness of transplant surgery depends on its three sub-factors.
c) Postoperative care: After transplantation, what makes it successful is proper postoperative care that depends on its three sub-factors.

A summary of factors affecting the performance of a LT center is shown in Table 1.

The cluster of factors and sub-factors of the LT center are also shown in Figure. 1. At first, the relationships between the main factors and even the relationships between sub-factors were determined. Finally, the weight of each group was calculated.

Table 1. Main factors and sub-factors in the liver transplantation center

Main factors		Sub-factors	
Caring for a patient with liver failure (ESLD) who is on the waiting list	LT1	Patient's candidacy approval by the Liver Council	LT11
		Training the patient on the waiting list	LT12
		Post-operative training for the patient	LT13
		Physician's proficiency	LT14
		Quality of the specialized pre-transplant consultation	LT15
Performing the surgery	LT2	Quality of the operating room equipment	LT21
		Surgeon's proficiency	LT22
		Mastery of the operating room staff	LT23
Post-operative care	LT3	Quality of liver transplant equipment	LT31
		Physician's proficiency	LT32
		Mastery of the liver transplant personnel	LT33

*LT: Liver Transplantation; ESLD: End-stage liver disease

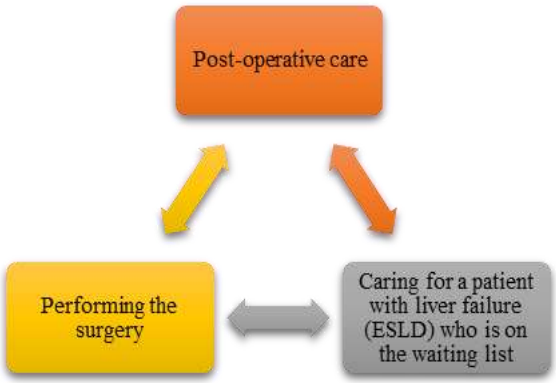

Fig 1. Factors and sub-factors cluster in the liver transplantation center (Arrows show the inner and outer dependencies)

Multi-criteria decision making in the liver transplantation

Cook et al. (1990), in their study, used the analytical hierarchical process (AHP) method to develop a liver allocation rating system for orthotropic transplantation. This study was intended to demonstrate the usefulness of the AHP process in complex medical decisions. Labib and Perris (2004) tried to improve previous preliminary research on prioritizing patients' waiting lists for LTs. They aimed to investigate the effectiveness of fuzzy logic in the field of complex decisions to prioritize patients on the kidney and liver transplant waiting list (TWL) and compare it with actual results. Veerachandran (2006) explored the shortcomings of the current LT policies to ultimately provide a more balanced allocation system based on productivity and fairness. In this regard, the tradeoff between the two main goals, namely efficiency and equity, has been considered. In this study, the AHP method was used to construct a framework to investigate this issue. Lin and Harris (2013) studied the issue of equitable allocation of organs donated for LT to eligible patients, and proposed a multi-criteria decision-making model based on the AHP. Rahimi and Jamshidi (2014) in their study discussed the need to prioritize TWLs. For this purpose, a model inspired by a multi-criteria decision-making method was designed in which the ANP method was used to prioritize patients in the TWL. Piegat and Sałabun (2015) used the characteristic object's method as a potential multi-criteria decision-making method for medical use. The proposed method was compared with technique for order preference by similarity to ideal solution (TOPSIS) and ANP.

According to the literature review, it is observed that multi-criteria decision-making methods are used in different areas of the treatment system. These were followed by different goals.

Many of the multi-criteria decision-making methods do not consider the relations between criteria. Therefore, the criteria are assumed hierarchical and linear structure. In real-world, relationships between decision problem criteria can be network structure, and in this case, the problem cannot be analyzed by linear methods like AHP, TOPSIS, and *Visekriterijumska Optimizacija i Kompromisno Resenje* (VIKOR). Saaty (1996) developed the ANP method to release this restriction of the linear methods. In the original ANP method, the network relation map is demonstrated presumptively, and the unweighted supermatrix is generated by pairwise comparisons to calculate the importance weightiness of the dimensions/criteria (Özveri, Güçlü, & Aycin, 2015). In the traditional network analysis process, it is implied that each cluster has the same weight, although it is clear that the effect of one cluster on other clusters may be different. Therefore, it is not reasonable to assume that the traditional network analysis process is the same as the weight of the clusters in creating a super-balanced matrix; in this method, the results are obtained based on the basic concept of the network analysis process from the total relationship matrix calculated by DEMATEL. Consequently, the DEMATEL technique is used to build a network structure model for each criterion and improve the process of normalizing the conventional network analysis process. This technique is suitable for real-world problems compared to traditional methods and considers the interdependence between the criteria. Finally, DEMATEL is combined with the network analysis process method to form the DEMATEL-modified ANP method (DANP) to determine the effective weights of each dimension and criterion (Huang, Hung, & Tzeng, 2011).

After identifying the factors and sub-factors affecting the success of the LT system, based on the experts' statements, it was concluded that the above factors have interdependencies, and there exist complex causal relationships between them. Therefore, in the following sections, the interrelations between the factors and sub-factors in the LT center were extracted using DEMATEL. Finally, the weight of each factor and sub-factor was calculated by ANP.

4. Results

The proposed method has been applied in a public health system in Iran. In this study, after interviewing the experts, an attempt was made to complete the designed questionnaires. These questionnaires were pair comparison matrix that examined the effect of the indicators on each other. These matrices were considered as the beginning of the DANP method.

Table 2 shows the total relations matrix T for the LT center.

Table 3 shows the total group influence matrix as well as (r + c) and (r - c) for the factors of the LT center.

By performing calculations and determining the total group influence matrix as well as (r + c) and (r-c) for the factors of the LT center, the network relationship map can be plotted. Figure. 2 shows the network relationship map for the main factors of the liver center.

After calculating the weighted super-matrix and limit super-matrix of factors, the relative weights of factors and sub-factors were calculated, and the results are displayed in Table 4.

Table 2. Total relations matrix T for the liver transplant center

Liver Transplant Center		LT1				LT2				LT3		
		LT11	LT12	LT13	LT14	LT15	LT21	LT22	LT23	LT31	LT32	LT33
LT1	LT11	0.0460	0.1325	0.1484	0.069	0.1236	0.0613	0.1028	0.1010	0.0725	0.1259	0.1109
	LT12	0.0559	0.0634	0.1853	0.1405	0.0596	0.0869	0.1995	0.1968	0.1123	0.2566	0.2271
	LT13	0.0482	0.0546	0.0613	0.0568	0.0513	0.074	0.1673	0.1650	0.0968	0.2214	0.1966
	LT14	0.0469	0.0531	0.0841	0.0552	0.0499	0.0774	0.1958	0.1934	0.0793	0.1566	0.1286
	LT15	0.0627	0.1457	0.1659	0.1919	0.0668	0.1017	0.2489	0.2458	0.1287	0.3004	0.2636
LT2	LT21	0.0464	0.0526	0.0590	0.0547	0.0494	0.0854	0.2474	0.2103	0.0732	0.1349	0.1021
	LT22	0.0521	0.0591	0.0663	0.0614	0.0555	0.2224	0.1273	0.2198	0.1038	0.2635	0.1698
	LT23	0.0473	0.0536	0.0601	0.0557	0.0503	0.0884	0.1970	0.0943	0.0957	0.2479	0.1583
LT3	LT31	0.0441	0.0500	0.0560	0.0519	0.047	0.0544	0.0735	0.0719	0.0955	0.2419	0.1952
	LT32	0.0441	0.0500	0.0560	0.0519	0.047	0.0544	0.0735	0.0719	0.2161	0.1214	0.1952
	LT33	0.0429	0.0485	0.0544	0.0504	0.0456	0.0528	0.0713	0.0698	0.1781	0.2032	0.0986

Table 3. Total group influence matrix for the liver transplantation center

	LT1	LT2	LT3	r+c	r-c
LT1	2.4772	2.2176	2.2185	10.6952	3.1314
LT2	1.3492	1.4923	0.8234	7.9683	-0.6385
LT3	1.5453	0.5936	0.7399	8.2504	-2.4929

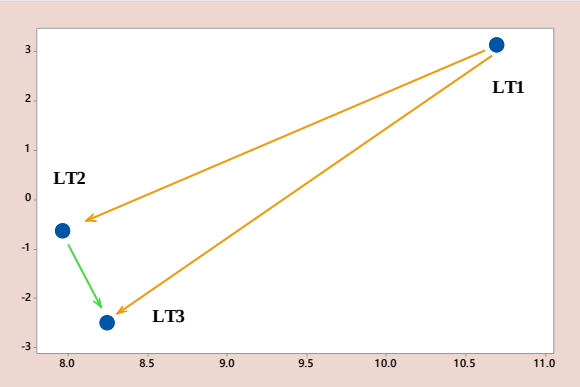

Fig 2. The network relationship map among the main factors of the liver transplantation center

Table 4. Relative weight of factors and sub-factors in the liver transplantation center

Factors		Relative weight	Sub-factors		Relative weight	The degree of importance
Caring for a patient with liver failure (ESLD) who is on the waiting list	LT1	0.1852	Patient's candidacy approval by the Liver Council	LT11	0.0265	8
			Training the patient on the waiting list	LT12	0.0436	2
			Post-operative training for the Patient	LT13	0.0326	4
			Physician's proficiency	LT14	0.0304	7
			Quality of the specialized pre-transplant consultation	LT15	0.0520	1
Performing the surgery	LT2	0.1016	Quality of the operating room equipment	LT21	0.0307	6
			Surgeon's proficiency	LT22	0.0384	3
			Mastery of the operating room staff	LT23	0.0325	5
Post-operative care	LT3	0.0755	Quality of liver transplant equipment	LT31	0.0263	9
			Physician's proficiency	LT32	0.0253	10
			Mastery of the liver transplant personnel	LT33	0.0238	11

ESLD: End-stage liver disease

5. Discussion

The present research was conducted to determine the relationships between factors and sub-factors and, finally, prioritize them to find the most critical factors that affect the performance of the LT centers and propose practical solutions that can help to improve their performance. In the following, the findings are analyzed.

Liver transplantation is critical since the slightest mistake can lead to the patient's death. Therefore, it seems necessary to attempt to improve the LT system. Examining Table 4 shows that the LT1 factor is the most important in the system. On the other hand, based on Fig 2, this factor can be obtained entirely independent of other factors. This suggests that to improve it, one must be content with one's factors. By examining the relationships between the sub-factors and the impact of factors and sub-factors in the unit, more details can be observed. Accordingly, the two factors, LT11 and LT15, can improve the system. In this regard, treatment managers are advised to pay special attention to the quality of specialized sessions of the liver transplant team to identify individuals in the priority of transplantation because the condition of the selected person will have a high impact on the outcome of the transplant. This can be done by calculating the index of the number of successful liver transplants and by a specialized committee examining the causes of failure. On the other hand, the quality of pre-transplant specialized counseling can be beneficial in identifying the right person for the transplant. In this unit, the quality of equipment, especially surgical equipment, and the level of expertise of the personnel can be essential and play a significant role in improving the LT2 and LT3 factors. In this regard, managers can update the experience of the Liver Transplant Committee by forming research teams to review the latest equipment, surgical methods, and care methods. In addition, providing suitable training programs and recruiting a skilled workforce can be another step toward improving the system's efficiency.

6. Conclusion

Health organizations continuously seek to find ways to improve their service quality and, at the same time, decrease service costs. One of the significant determinants of the quality of service in health issues is the appropriate performance of medical procedures. In the field of LT, in particular, the focus of further studies is better to be on prioritizing the queues. The present research was conducted to identify the key factors and sub-factors affecting the performance of an LT center. After that, the causal relations between these factors and sub-factors and their weights were extracted using the DEMATEL-modified ANP method. The LT center of a public health system in Iran was selected as a case study.

The results indicated that the accuracy of patient selection for transplantation, surgical equipment, and the level of expertise of personnel are important factors in LT success. Based on the findings, system managers can nominate the most suitable patient for LT by forming specialized committees and conducting pre-transplant consultations. In addition, by forming research and development teams, they can review the latest technologies, surgical methods, and care methods in the world and take action to obtain them by allocating the optimal budget. Finally, providing suitable training programs and recruiting a skilled workforce can be another step toward improving the system's efficiency.

Future studies can focus on identifying the critical success factors of other types of organ transplants, such as kidney, heart, lung, etc. Moreover, the framework can be used to explore different areas of treatment. On the other hand, using other methods of weighting and ranking can provide results for comparison with this research.

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Conflicts of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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