Coronary Artery Bypass Graft Surgery Clinical Quality: A Network-DEA approach

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Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

Clinical quality, as a technical result quality of health services, is a concept that outlines how health system inputs are transformed into health outcomes. The aim of the study is to develop a model in which the relative clinical quality levels of the patients are evaluated with the Network Data Envelopment Analysis (NDEA) method by using the structure, process, and outcome measures of the Coronary Artery Bypass Graft (CABG) surgery. The research was conducted in a tertiary training and research hospital as a prospective, cross-sectional and registry research. Clinical quality levels of patients who underwent CABG surgery were evaluated with NDEA (two-stage) method in managerial and clinical efficiency stages. NDEA showed that 3 patients had the best clinical quality level. The patient profile with a low clinical quality level was created in managerial and clinical stages and quality improvement points were determined. The NDEA model enabled the analysis of all the structure, process and outcome measures simultaneously and was used to evaluate clinical quality with multiple measures. Using this data, the CABG surgical process profile was created. Intensive care unit (ICU) and postoperative inpatient day, cardiopulmonary bypass (CPB) and cross-clamp (CC) duration, and the use of fresh frozen plasma (FFP) were determined as the CABG surgery points requiring quality improvement.

Highlights

- We applied Network Data Envelopment Analysis (NDEA) (two-stage) to evaluate the clinical quality of CABG at the patient scale. We identified each patient as a Decision Making Unit (DMU) and use the health care structure, process, and outcome measures simultaneously during the analysis.
- NDEA determined the patients with the best clinical quality level who underwent CABG surgery. Clinical quality evaluation was made in the managerial and clinical efficiency stages.
- We created a clinical quality profile for patients undergoing CABG surgery. According to this profile, patients with lower clinical quality levels need more intensive care treatment, and the postoperative recovery durations take longer. EuroSCORE and the number of bypassed vessels are statistically different in these patients and preoperative quality of life is lower.

- In the managerial efficiency stage, the preoperative radiology-laboratory, and ICU medicine costs are statistically significant for DMUs with low clinical quality. Also, for the DMUs with low clinical quality in the clinical efficiency stage, preoperative other transaction and postoperative consumables' costs are higher compared to patients with high clinical quality.
- CABG surgery points requiring quality improvement are intensive care unit and postoperative inpatient day, cardiopulmonary bypass and cross-clamp duration, and the use of fresh frozen plasma.

Keywords: Clinical Quality, Coronary Artery Bypass Graft, Network Data Envelopment Analysis.

1. Introduction

Every year, millions of patients all over the world suffer from unsafe and poor-quality healthcare.[1] Poor-quality care, which threatens patient safety, causes some negative health consequences that can lead to mortality. 134 million adverse events occur each year due to unsafe care, resulting in 2.6 million deaths. 4-17% of patients experience poor results whereby 44 –50 percent of these events are preventable. Up to 15% of hospital activity and expenditures are spent for the treatment of direct sequelae of patient harm, resulting in an annual economic burden of €21 million in European Union countries and $ 1 trillion in the USA. [1][2][3][4] Patient safety is built on "quality" in health care. The quality framework consists of the components of a safe, effective, patient-centered, timely, efficient and fair delivery of service. [5]

Clinical quality, as a technical outcome quality of health services, is a concept that outlines how health system inputs are transformed into health outcomes, includes the concrete outcomes and outputs of healthcare, and shows the interaction between patients and service providers. With clinical quality measurements, the status of the clinician to provide the most appropriate, most effective, and safest clinical care for the patient in the most appropriate time frame is evaluated. [4][6] Measurements are needed to drive evidence-based decision processes, identify best practices, and guide quality improvement efforts for all stakeholders of the health system from patients to health system funders and policymakers. [7][8]

The topics emphasized in the assessment of clinical quality are the scope of the measures to be used, the use of multiple measures and the measurement method. In assessing the level of clinical quality, it is essential to understand the structure and process characteristics of healthcare and the relationship between them as well as the healthcare outcome. The difficulty of establishing a causal link between the structure, process and outcome characteristics of healthcare makes it difficult to conduct research on this issue. The impact of patient perception and individual differences on health outcomes and subjective measures (such as the pain, satisfaction or morbidity felt by the patient) are difficult to measure and require additional measurement. This situation reduces the frequency of measurements in which multiple measures determined for structure, process and outcome characteristics are used simultaneously. However, studies conducted with multiple measures are more valuable for managers, funders and patients to assess whether high-quality care is provided. [9][10]

To evaluate clinical quality with multiple measures, structure, process and outcome of care should be considered together because of their effects on each other. Donabedians defend that a good outcome can be achieved with the right processes and the right processes can only be achieved with a good structure that has been accepted all over the world. [11] In the first studies, to evaluate the structure of health care the structural measures focused on the environment in which the care was provided. With the initiation of clinical quality assessments, patient-related variables began to be used as structure measures. In clinical quality assessment, disease severity level can use as a structure measure. [12] Process measures cover the care cycle and focus on the diagnosis and management of disease, so they are used as feedback points for quality improvement efforts. Evidence-based process measures include accepted and scientifically valid clinical service principles. [12][13][14] The patient's recovery is evaluated with the outcome measure. Outcome measures are used to measure whether the health care has achieved the expected effects/changes. Measures with precise definitions that can be reported by clinicians are classically the most commonly used outcome measures. [9] These measures have been defined as tools that assist in the assessment and monitoring of quality.[11]

Evidence-based medical guidelines, clinical pathways and standards, which are the main components of clinical quality, are used in determining the structure, process and outcome measures to be used. Indicators are used as a method of monitoring and assessing clinical quality. By using indicators, compliance with evidence-based guidelines and standards in different aspects of the service is evaluated, and information is obtained at an institutional scale. By using indicators, the clinical quality level of the institution is determined in the area where the measurement is made, and the obtained measurement result allows institutional comparisons. Indicators can focus on disease-specific or general characteristics of the service structure, process or outcome measures. Measures such as financing, personnel qualifications, facility infrastructure, the type of insurance the patient has, and the severity of the disease are used in the indicators for structure quality of the health care. Process quality indicators measure diagnosis-specific aspects of the care (such as the number of patients with diabetes mellitus who have retinal examination once a year), treatment, care activities (the number of patients receiving beta-blockers at discharge in the treatment of myocardial infarction etc.), and acute, chronic or preventive care activities (penicillin prophylaxis until 5 years of age in children suspected of being positive for sickle cell disease). In order to measure the outcome quality, indicators (mortality, morbidity, functional health status, length of stay, reoperation/readmission after surgery, quality of life, patient satisfaction, etc.) that measure whether the health service has reached the expected effects/changes in the short, medium and long term are used. However, when indicators are used, the entire cycle of health service cannot be analyzed simultaneously. Each indicator developed for a specific area is evaluated individually. Indicators are rarely specific enough to show a particular healthcare professional's performance or an individual patient's condition. [15][16][17]

Clinical quality measurement is expected to include data for the entire service cycle and explain the relationships between the service's structures, process and outcome. [9] Multiple measure evaluation is required to meet this expectation. Data Envelopment Analysis (DEA), which allows for the analysis of multiple measures at the same time, is a method frequently used in efficiency evaluations. DEA is preferred in cases where the relationships between multiple inputs and multiple outputs are unknown, and a measurement cannot be made with other approaches due to the case's complex nature. DEA, which is used in healthcare services, is a non-parametric method based on linear programming principles and is specifically designed to estimate relative efficiency in research groups. [18] DEA has often been used to evaluate hospital technical efficiency, service quality, and physician performance in healthcare. The inclusion of quality measures in DEA research is considered promising for ensuring efficiency in hospitals. [19] The results of DEA studies, which included the quality of outcomes in the evaluation of technical efficiency in hospitals, showed that low efficiency is associated with low-quality outcomes and that resources should be used more efficiently in order to reduce undesirable outcomes. [19][20][21] It has been shown that quality improvement points can be determined by using quality measures for the process and outcome as input and output variables in DEA and that efficiency increase can be achieved without sacrificing quality. In addition, a correlation was found between the technical efficiency scores and quality. [19][22][23][24] The fact that the use of resources in terms of technical efficiency is affected by the clinical differences of the patients showed the necessity of including clinical measures in DEA studies. [25]

However, the number of studies using patient clinical data and assessing clinical outcomes has been limited.[26] In DEA studies, in which clinical measures are used and patients are identified as DMUs, aimed to determine the relative efficiency of the treatment method. In these studies, using process and structure measures related to the treatment process in DEA, specific features for which potential improvements can be made for each patient were determined. [27][28] Today, DEA researchers do not treat the care process as a black box consisting only of inputs and outputs. NDEA which considers the network with distinct stages and interactions and can examine sub-processes and sub-inputs and outputs of each process has been developed and also started to be used in healthcare research. [29][30] Since multiple measures can be managed simultaneously by using NDEA, it enables the analysis of the structure, process, and outcome of clinical quality together. Also, it is a precision method for demonstrating improvement points, determining resource waste, and performance evaluation. [31][32] Therefore, NDEA is a method that provides results with the precision needed in clinical quality assessment in terms of performance, costs, reference-DMUs, and quality improvement points.

Clinical quality assessments are made starting from the most common health phenomena in terms of their impact on the individual and society, disease burden and measurability [33]. A 2017 WHO report states that 17.9 million people died from cardiovascular diseases in 2019 [34] cardiovascular diseases and cardiovascular disease-related death rates, which tend to increase all over the world. In this study, CABG surgery, which is the preferred method of treatment for coronary heart disease, was selected as the research application area.

The study aims to develop a model in which the relative clinical quality levels of the patients are evaluated with the NDEA method by using the structure, process, and outcome measures of the CABG surgery. The goal of the developed model is to constitute a tool for performance evaluation and quality improvement studies, and a resource for clinical quality and healthcare NDEA research.

2. Methodology

2.1. Design, data sources and sample

The research is a prospective, cross-sectional, registry research. The research was conducted in a tertiary training and research hospital in Ankara. Inpatients with a pre-diagnosis of CABG between December 15, 2018, and March 15, 2019, constituted the research population. Data from 139 patients who agreed to participate in the study with informed consent were collected. Patients discharged with medical treatment (n=38) and patients who died in the hospital (n=3) were excluded from the study. Clinical quality levels of 98 patients over the age of 18 who underwent CABG surgery were evaluated with NDEA.

Measures determined to affect the clinical quality of CABG surgery:**structure** measure: EuroSCORE, **process measure**: coronary angiography result, ejection fraction (EF) examined by ECHO cardiography, level of evidence supporting the efficiency and effectiveness of the procedure, comorbidities affecting CABG surgery, CPB and CC time, carotid endarterectomy, CABG application in a beating heart, amount of blood and blood products used in CABG surgery, the use of inotropic agents after CABG surgery, the use of intra-aortic balloons, extracorporeal membrane oxygenation (ECMO), number of bypassed vessels, reoperation, inpatient day **outcome measure**: postoperative serum creatinine, urea, AST, ALT, CRP value, development of EQ5D5L, health care costs (Operation and preoperative, intensive care unit, postoperative period costs).

During the data collection process, data on all variables were collected, but all the operations were performed in the beating heart. The level of evidence supporting the efficacy and effectiveness of the procedure class was the same in all patients and Carotid Endarterectomy, Intra Aortic Balloon, and Extracorporeal Membrane Oxygenation (ECMO) were not applied to any patient; therefore, these variables were not included in the data envelopment analysis.

The data regarding the structure, process and outcome measures of the CABG surgical process, which will be used in the evaluation of the clinical quality level, were obtained from the written and electronic records of the hospital. The invoice created by the hospital was subclassified by the researcher as radiology laboratory, blood and blood products, consumables, medicine and other transaction costs subclasses. In order to evaluate the quality of life of the patients, the EQ-5D5L questionnaire was used by face-to-face preoperative and by telephone conversation three months after surgery. The difference between the two questionnaires was calculated and the quality of life improvement value was determined. "Harmonized functional health value" was calculated by scoring the results of ECHO cardiography, serum urea, creatine, AST, ALT, and CRP as positive-negative according to the cutoff points determined by the researchers.

2.2. Analysis

The data including the CABG surgery structure, process and outcome measures were analyzed by using the two-stage NDEA method. In the study, each patient who underwent CABG surgery was defined as DMU in accordance with NDEA.

2.3. Network DEA (two-stage)

Under some conditions, the production/service process of DMUs has a two-stage structure. The structure in which the first stage outputs constitute the inputs of the second stage and where there are common measurements called "intermediate products" is called "two-stage systems". Just as the first stage does not have its own output in this structure, the second stage does not have its own input. [35] In the literature, there are examples in which the analysis is performed as the administrative services under the control of the manager and the medical services stage where the manager cannot be involved in by applying two-stage NDEA. [36]

Kao and Hwang (2008) describe the overall efficiency of a DMU in a two-stage NDEA as the product of the efficiency of two stages. Chen et al. (2009) developed a methodology to represent the overall radial efficiency of a DMU as a weighted average of the radial activities of each stage or components.

The two-stage network structure is given in Figure 1. In this model, each KVB j's (j ¼ 1, 2, ..., n) to the first stage xij, (i ¼ 1, 2, ..., m), it is assumed that the input m and the output D of this stage is zdj, (d ¼ 1, 2, ..., D). These D outputs are then added to the second stage as input and called intermediate products. The outputs in the second stage are shown as yrj, (r ¼ 1, 2,…, S).

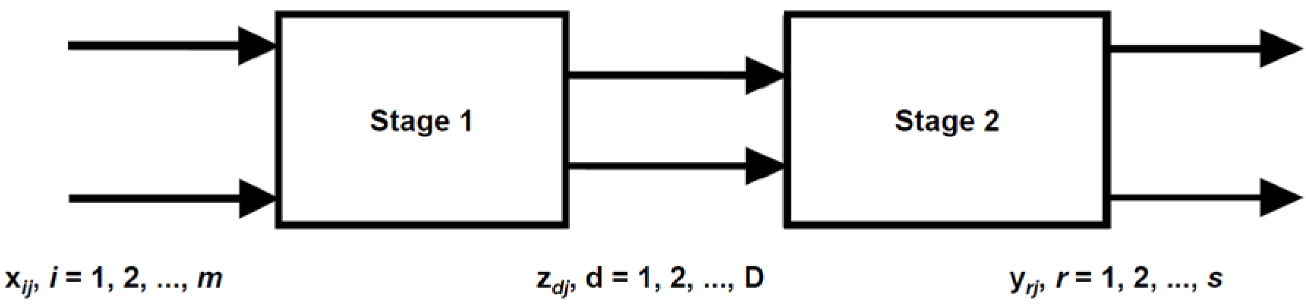

Figure 1. Two-Stage Network Process

In the case where the first stage is represented by e_j^1 and the second stage by e_j^2, it is formulated as follows.

$$e_j^1 = \frac{\sum_{d=1}^{D} w_d z_{dj}}{\sum_{i=1}^{m} v_i x_{ij}} \quad ve \quad e_j^2 = \frac{\frac{\sum_{r=1}^{s} u_r y_{rj}}{w}}{\sum_{d=1}^{D} w_d z_{dj}}$$

According to the definition above; an approach emerges where the overall productivity is calculated as $e_j = (e_j^1 \cdot e_j^2)$. This model is converted to the linear program as follows.

$$Max \sum_{r=1}^{s} u_r y_{ro}$$

$$s.t. \sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} w_d z_{dj} \leq 0 \quad j = 1, 2, \ldots, n$$

$$\sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad j = 1, 2, \ldots, n$$

$$\sum_{i=1}^{m} v_i x_{io}$$

$$w_d \geq 0, \quad d = 1, 2, \ldots, D; \quad v_i \geq , \; i = 1, 2, \ldots, m; \quad u_r \geq , \quad r = 1, 2, \ldots, s$$

This model gives the overall efficiency. When the overall efficiency is achieved, the divisional efficiency is achieved through efficiency decomposition. NDEA (two-stage) model has been constructed as follows to evaluate the clinical quality of CABG surgery.

First Stage Inputs

- Operation and preoperative period costs
- Post-operative period costs
- Intensive care unit period costs
- Preoperative period inpatient day

Intermediate products

- Intensive care unit inpatient day
- Post-operative period inpatient day
- CPB time
- CC time
- The number of bypass vessels made
- The number of blood and blood products used

Outputs of second stage

- • EuroSCORE
- • Quality of life improvement value
- • Harmonized functional health value (echocardiography, serum AST, ALT, CRP, urea, creatine levels)

The data including the structure, process, and outcome measures of CABG surgery was analysed by using NDEA (two-stage) method. **Mann-Whitney U test** was used in order to compare the means of the efficient and inefficient patients in both managerial and clinical stages.

Scores obtained after NDEA are examined as efficiency and inefficiency. In the analyzes in which this type of distinction is made, although it is close to the efficiency limit, there may be DMUs whose characteristics are overlooked due to their classification as inefficiency. In advanced statistics made after DEA, subjective different cut-off points can be determined for different models according to the analysis type. For example, to test the sensitivity of the logistic regression analysis based on DEA scores, the cut-off point can be set as 0.90. Another way can be by dividing DEA scores into several quartiles to be determined according to the research group or assigning a value close to "1". [37] Hu and Shieh's (2014) study, evaluating the service efficiency of Traditional Chinese Medicine Hospitals, DMUs with a DEA-score between 0.9-1 were defined as the marginally inefficient group. It has been reported that those in this group can reach the efficiency limit with small modifications, and they have been analyzed together with their efficient DMUs that get 1 point. In the study of service and financial efficiency in health organisations by Kaçak and Bağcı (2020), inefficient health organizations were grouped as marginally inefficient, above-median, below-median and most inefficient.

In this study, in order to see the difference between efficient and inefficient patients more clearly, NDEA scores were divided into quartiles and classified as marginal inefficient most inefficient, above the median and below the median. Marginally inefficient patients were identified as those in the 4th card with efficiency scores between 0.775 - 1 in the clinical efficiency stage and 0.849-1 in the managerial efficiency stage.

Patients with marginal inefficiency can increase the level of efficient-DMUs by making minor improvements in the input levels. The most inefficient patients are those in the first card with efficiency scores between 0-0.513 in the clinical efficiency stage and 0-0.535 in the managerial efficiency stage. Patients in the Most Inefficient, Above Median, and Below Median classes determined as being low clinical quality in analyzes were named "inefficient DMUs". In the findings of the study, inefficient and marginally inefficient patients were evaluated in the same class, as patients with high clinical quality. The Mann-Whitney U test was used to compare the averages of the efficient-marginally inefficient and inefficient patients at the managerial and clinical stages.

3. Results

98 patients who underwent CABG surgery were included in the study. Eighty (81.63%) of the patients in the study group were male. The number of patients with EuroSCORE 1 was found to be 49 (50%), EuroSCORE 2 patients 37 (37.75%), and EuroSCORE 1 patients (14.28%). The most common comorbid disease was diabetes with 42 (41.58%) patients, while 50 patients had no comorbid disease. Mean inpatient days preoperative, ICU, and postoperative period were 6.24 ± 4.48, 1.8 ± 1.55, and 5.5 ± 3.02 days, respectively. The mean and standard deviation of CPB and CC duration were 106.46± 37.25 and 67.24 ± 25.58, respectively. As a result of the quality-of-life evaluation, the EQ5D5L score was 0.706 ± 0.227 in the first application and 0.880 ± 0.181 in the second application. While the use of erythrocyte suspension (ES) was 3 ±

2.89, the use of FFP was 2.27 ± 2.24 units. The harmonized functional health level calculated by the researchers was determined as 11.56 ± 2.01.

The central efficiency score obtained through NDEA showed that 3 patients had the best clinical quality level. The average efficiency score of the 98 patients included in this study's analysis was found to be 0.43. It was found that 15 patients (mean score of 0.68) were in the managerial efficiency stage and 11 patients (mean score of 0.68) were efficient in the clinical efficiency stage.

The distribution of efficiency in the managerial and clinical stages of the patients is shown in Figure 2.

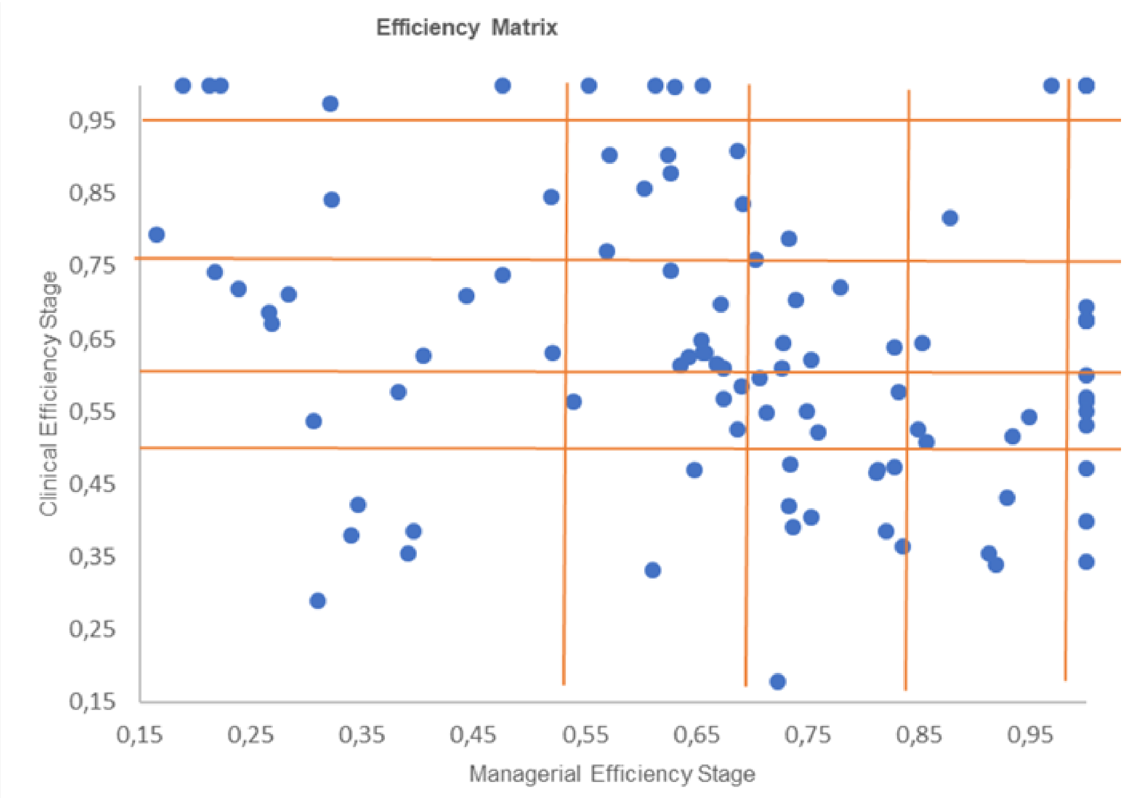

Figure 2. Distribution of NDEA Result Managerial and Clinical Efficiency Scores

It was determined that DMUs who were efficient in the clinical efficiency stage were not efficient in the managerial efficiency stage, except for five patients (Figure 2). This data suggests that although clinical efficiency was ensured, resources were not efficiently used and that efficient service of clinical quality was not met. It was found that 20 of the 25 DMUs that were evaluated as managerially inefficient were not efficient in the clinical efficiency stage, and the desired clinical quality level was not achieved in these DMUs.

The patients referenced by NDEA and the frequency of referrals are shown in Table 1. As a result of the analysis, 22 patients were accepted as reference patients. The most efficient patient, H6, has been referenced 85 times. H59, referenced 46 times, and H41, referenced 34 times, are the other most efficient patients.

Table 1. DMUs Referenced by NDEA and Reference Frequency

No	Name of DMU	Referencing Frequency	No	Name of DMU	Referencing Frequency
1	H6	85	12	H32	6
2	H59	46	13	H56	6
3	H41	34	14	H19	4
4	H54	33	15	H37	4
5	H57	26	16	H45	4
6	H1	21	17	H67	4
7	H94	16	18	H30	3
8	H31	13	19	H3	1
9	H14	12	20	H24	1
10	H16	10	21	H63	1
11	H53	8	22	H83	1
				Total*	339

* It is the cumulative total value.

The mean cost values and statistical test results of the DMUs who are efficient -marginal inefficient and inefficient in the managerial and clinical efficiency stages regarding the structure, process and outcome criteria are given in Table 2.

Table 2. Average Cost Values of Efficient and Inefficient DMUs (Patients) According to the NDEA Results by Stages

Measures	Managerial Efficiency Stage		Clinical Efficiency Stage	
	Efficient-marginal inefficient DMU (≥0,84) (n=25)	**Inefficient DMU (<0,84) (n=73)**	**Efficient -marginal inefficient DMU (≥0,77) (n=25)**	**Inefficient DMU (n=73)**
Operation and preoperative period costs ($)	**956,73±623,9***	**1327,23±998,43***	1137,55 ± 734,56	1265,31± 988,96
Radiology Laboratory ($)	**348,98±657,57***	**635,87±907,28***	559,24 ±730,25	563,50±900,46
Blood and Blood Products ($)	16,25±23,92	24,09±31,77	18,21±28,00	23,42±30,78
Other Transaction ($)	329,25±87,69	373,82±157,54	**308,91±72,09***	**380,79±157,56***
Consumables ($)	167,35±114,5	190,42± 1330,23	160,46±124,37	195,71±156,86
Medicine ($)	94,9±46,28	103,03±45,07	99,28±41,15	101,53 ±46,87
ICU period costs ($)	356,82±269,74	455,83±374,04	354,25±206,34	456,71±387,03
Radiology Laboratory ($)	32,26±70,98	95,17±166,90	55,90±88,43	87,07±166,44
Blood and Blood Products ($)	31,72±41,40	36,12±51,98	26,83±34,43	37,79±53,48
Other Transaction ($)	234,78±207,77	231,59±236,87	200,25±166,06	243,42±246,63
Consumables ($)	23,60±48,28	17,67±20,97	12,10±14,14	21,61±33,70
Medicine ($)	**34,46±50,48***	**75,28±92,29***	59,18±63,68	66,81±91,82
Post-operative period costs ($)	**137,86±126,69***	**173,24±126,96***	147,56±101,10	169,92±135,12
Radiology Laboratory ($)	38,36±55,48	55,71±71,40	42,95±51,58	54,14±72,69
Blood and Blood Products ($)	26,57±28,71	25,82±27,86	20,62±21,35	27,86±29,76
Other Transaction ($)	29,99±22,93	33,89±24,10	229,24±19,54	34,15±25,03
Consumables ($)	9,03±18,97	8,86±13,32	**4,26±6,81***	**10,61±16,44***
Medicine ($)	33,90±51,72	44,48±47,14	37,75±50,45	43,16±47,81

*Note: * Statistically significant p <0,05*

In the managerial efficiency stage, although there was no statistically significant difference, the costs were found to be relatively higher in the inefficient DMU group except for preoperative and operative post-operative period costs. The average preoperative and operative period cost is 1327.23±998,43 $, while radiology laboratory costs are 635.87±907,28 $ and post-operative period costs are 173,24±126,96 $ for inefficient DMUs. It was found that there was a statistically significant difference not only in preoperative costs but also in post-operative costs. There is a statistically significant difference between efficient and inefficient DMUs especially the radiology and laboratory costs during the preoperative and operative period and ICU medicine costs (Table 2).

In the clinical efficiency stage, although there was no statistically significant difference the costs were found to be relatively higher in the inefficient DMU group except for preoperative other transaction and operative post-operative consumable costs. The average preoperative other transaction cost is 380,79±157,56 $, while post-operative consumable costs are 10,61±16,44 $ for inefficient DMUs (Table 2).

Table 3. Average Resource Use and Clinical Outcome Values of Efficient and Inefficient DMUs (Patients) According to the NDEA Results by Stages

	Managerial Efficiency Stage		Clinical Efficiency Stage	
Measures	**Efficient-marginal inefficient (≥0,84) (n=25)**	**Inefficient (<0,84) (n=73)**	**Efficient -marginal inefficient (≥0,77) (n=25)**	**Inefficient (n=73)**
Preoperative period inpatient day*	**3,20±2,31***	**7,30 ± 4,57***	5,96 ± 3,49	6,36 ± 4,78
ICU inpatient day	**2,04 ± 1,02***	**1,71 ± 1,42***	1,44 ± 0,77	1,92 ± 1,46
Post-operative period inpatient day	5,68 ± 4,03	5,73 ± 2,52	5,44 ± 1,64	5,81 ± 3,29
CPB time **(m)**	111,64 ± 28,92	101,14 ± 27,95	**87,72 ±25,98***	**109,33 ± 27,25***
CC time (m)	68,88 ± 23,33	64,93 ± 22,75	**54,56 ±17,98***	**69,84± 23,13***
Amount of Blood and Blood products used **ES**	2,48 ± 1,58	2,85 ± 2,20	2,08 ± 1,32	2,99 ± 2,21
FFP	2,16 ± 1,60	2,03 ± 1,50	**1,44 1,04***	**2,27 ± 1,60***
Harmonized functional health value	11,36 ± 1,35	11,63 ± 2,19	11,68 ± 2,43	11,52 ± 1,86

*Note: * Statistically significant p <0,05*

In the managerial efficiency stage Preoperative period, inpatient days are 3,20±2,31 in efficient-marginal inefficient DMUs while 7,30 ± 4,57 days in inefficient DMUs, and there is a statistically significant difference between them. Also, ICU inpatient days have statistically significant differences between efficient-marginal inefficient DMUs (2,04± 1,02 days) and inefficient DMUs (1,71 ± 1,42 days). There are no significant differences between efficient-marginal inefficient DMUs and inefficient DMUs in both managerial and clinical efficiency stages about other inpatient day values. (Table 3)

It is determined that in the clinical efficiency stage variable affecting clinical outcomes such as CPB time have statistically significant differences between efficient-marginal inefficient DMUs (87,72 ±25,98 m) and inefficient DMUs (109,33 ± 27,25 m), and inefficient DMUs' duration of CPB time is longer. In terms of CC time, it was determined that this time lasted 69,84± 23,13 minutes in inefficient DMUs and was statistically significant. While no significant difference was found in both managerial and clinical stages in terms of the use of ES, it was found that the use of FFP was statistically significantly overused in DMUs that were inefficient at the clinical efficiency stage. (Table 3)

Table 4. Average EQ5D5L Scores of Efficient and Inefficient DMUs (Patients) According to the NDEA Results by Stages

	Managerial Efficiency Stage		Clinical Efficiency Stage	
Measures	**Efficient-marginal inefficient (≥0,84) (n=25)**	**Inefficient (<0,84) (n=73)**	**Efficient -marginal inefficient (≥0,77) (n=25)**	**Inefficient (n=73)**
EQ5D5L quality of life improvement value	0,410 ±0,220	0,386 ± 0,225	0,354 0,219	0,406 ± 0,224
Preoperative EQ5D5L	**0,643 ± 0,217***	**0,738 ± 0,215***	**0,543 ± 0,254***	**0,773 ± 0,170***
EQ5D5L Postoperative 3. month	0,898± 0,124	0,910 ± 0,085	0,914 ± 0,080	0,905± 0,101

*Note: * Statistically significant p <0,05*

While the preoperative EQ5D5L quality of life score had statistically significant differences between efficient and inefficient patients, no significant difference was found in the post-operative 3rd month EQ5D5L quality of life score and the improvement value in the quality of life. (Table 4)

Table 5. Distribution of EuroSCORE, Comorbidity Situations, Number of Bypassed Vessels in Managerial and Clinical Efficiency Stages and Test Results

		EuroSCORE		Comorbidity Situations		Number of bypassed vessels	
		Efficient -marginal inefficient (≥0,84)	**Inefficient**	**Efficient -marginal inefficient (≥0,84)**	**Inefficient**	**Efficient -marginal inefficient (≥0,84)**	**Inefficient**
Managerial Efficiency Stage	Mean and SD	1,44 ± 0,651	1,67 ± 0,708	0,24 ± 0,436	0,53 ± 0,502	3,32 ± 0,988	2,96 ± 1,006
	Rank average	42,90	51,76	38,76	53,18	56,24	47,19
	U	747,500		644,000		744,000	
	z	-1,489		-2,535		-1,437	
	p	0,137		**0,011***		0,151	
Clinical Efficiency Stages	Mean and SD	1,96 ± 0,790	1,49± 0,626	0,60 ± 0,500	0,41 ± 0,495	2,48 ± 0,872	3,25 ± 0,983
	Rank average	61,46	45,40	56,40	47,14	34,48	56,64
	U	613,500		740,000		537,000	
	z	-2,698		-1,629		-3,203	
	p	**0,007***		0,103		**0,001***	

At the clinical efficiency stage, it was found that there was a statistically significant difference (p <0.05) between the efficient -marginally inefficient DMUs and the inefficient DMUs in the number of bypassed vessels and EuroSCORE (Table 5). It was determined that the number of bypassed vessels was high in inefficient DMUs. In the managerial efficiency stage, there was a significant difference between the two groups in terms of the patient's comorbidity status. More comorbid diseases were found in patients who were found to be inefficient. (Table 5)

Table 6. Recommended Optimal Intermediate Product Values for Patients Determined to be Inefficient as a Result of NDEA

	Average of Proposed Values		Proposed Percentage of Change	
	Managerial Efficiency Stage	Clinical Efficiency Stages	Managerial Efficiency Stage	Clinical Efficiency Stages
ICU Inpatient Day	1	1	20%	27%
Postoperative Inpatient Day	3	3	50%	52%
CPB Time (M)	70	67	32%	37%
CC Time (M)	41	40	37%	42%
Amount of Blood and Blood Products (unit)	3	3	45%	49%

The optimal values suggested by NDEA in intermediate products in the managerial and clinical efficiency stage are provided in Table 6 to increase clinical quality in patients determined to have a low clinical quality level. In the study, it was found that CPB and CC duration, ICU, and postoperative inpatient days were longer in patients with a low clinical quality level in the managerial and clinical efficiency stages in comparison to efficient patients.

According to the profile created by the NDEA for patients who are not managerially efficient and have a low clinical quality level, the preoperative and postoperative period costs are higher than efficient patients. In managerially inefficient DMUs, the increase in preoperative radiology-laboratory and ICU medicine costs are statistically significant. The preoperative quality of life in these patients is lower, and the preoperative and ICU care durations are longer. To increase efficiency, there is a need of optimizing the length of postoperative hospitalization. Moreover, comorbid diseases are more common and the duration of CPB and CC is longer.

According to the profile created by the NDEA for patients who are not clinically efficient and have low clinical quality levels, preoperative other transaction costs and postoperative consumable costs are higher in these patients compared to efficient DMUs. The preoperative quality of life in these patients was lower. Patients determined to be inefficient require more intensive care treatment, and the postoperative recovery time takes longer. EuroSCOREs and the number of bypassed vessels are statistically different in clinically inefficient DMUs. CPB and CC duration is longer than clinically inefficient DMus. These patients need to use significant quantities of blood products; a statistically significant amount of FFP is used.

4. Discussion

In this paper, we demonstrated the use of a novel approach to examining clinical quality on a patient scale using NDEA efficiency measurement. As a result of the research, we developed a model in which the clinical quality assessment of CABG surgery is performed using NDEA on a patient scale, considering the entire service cycle. In the developed model, NDEA (two-stage) enabled the analysis of all the structure, process, and outcome measures that could be used in the evaluation of clinical quality. Patients were accepted as DMUs; the CABG surgical process profile was constructed; and the patients with the best clinical quality level in the managerial and clinical stages were determined. The patient profile created for patients with relatively low clinical quality and inefficiency is consistent with the CABG surgery literature. In addition, with the developed model, the frontiers of best practice and quality improvement points were determined. Since there are not exactly similar studies with the methods and tools used in this study, the research results have been discussed with studies investigating similar variables.

As a result of the NDEA, we determined the improvement points of the CABG surgery healthcare cycle on a patient basis. To increase clinical quality and ensure managerial and clinical efficiency NDEA identified improvement points such as ICU and postoperative inpatient day, CPB and CC duration, and use of blood products. Obtaining results consistent with the CABG surgery literature showed that NDEA [38][39], which is used to evaluate technical efficiency and productivity in healthcare, can also be used in clinical quality assessment.

The NDEA results suggest that the use of resources was higher in patients with low clinical quality levels in terms of managerial and clinical stages. It was determined that although the patients had similar clinical quality levels in the clinical efficiency stage, efficient resource use could not be achieved in the managerial efficiency stage. Most of the managerial efficient patients (84%) provided efficient resource use in the managerial efficiency stage; it was determined that clinical efficiency could not be achieved at the clinical efficiency stage. Also, it was concluded that the amount and number of resources used for the treatment of patients with similar clinical conditions were not similar and could be optimized. Studies evaluating clinical outcomes in CABG patients show that poor clinical quality leads to increased resource use. In addition, when clinical efficiency is ensured by the use of clinical quality tools, efficiency is also achieved in resource use in terms of costs, inpatient day ect. [40][41][42][43] In cases where resource use, inpatient day and costs are good, studies concluded that there is a simultaneous improvement in clinical outcomes. While clinical quality and resource use in health services are inversely related [41][42][43], it was determined that, unlike the literature, resource use and clinical quality could not be achieved simultaneously in this research group. It has been interpreted that this may be due to the differences in the examination, treatment, and follow-up practices of the physicians who performed the surgery and followed the patient. The results of efficiency analysis using DEA show that physicians' resource use differs and their level of expertise is associated with costly resource use efficiency and can be achieved without sacrificing quality. [19][25] Similar efficiency levels can be achieved in patients with the same clinical condition, with studies to be conducted in the quality improvement points determined by NDEA and this will also support increasing clinical quality.

The effect of disease severity and risk level on clinical outcomes have been demonstrated in disease-based studies using disease severity as a structural measure. [9][44] Our findings concluded that EuroSCORE, which shows the severity of the disease, causes a significant difference between the efficient-marginally inefficient and inefficient patients in the clinical efficiency stage and it is one of the variables that affect clinical quality level.

There is a statistically significant difference between efficient and inefficient DMUs in terms of "EQ5D5L quality of life", managerial and clinical efficiency in the preoperative period, and inefficient patients have a higher preoperative quality of life score. Although there was an increase in EQ5D5L scores postoperatively, there was no significant difference in this development. Studies evaluating the quality of life in CABG surgery have shown that CABG surgery improves the patient's quality of life. [45][46][47][48][49][50] Our result of an increase in the quality of life supports these studies. The clinical quality level reached at the end of the surgery process is relatively low in patients who had a better quality of life level before the CABG surgery. It was determined that patients with the lower preoperative EQ5D5L score and higher EuroSCORE were efficient and marginally inefficient patients. This result was attributed to the more pronounced effect of surgical treatment in patients with relatively low quality of life and higher disease severity.

The clinical quality assessment results derived from the NDEA model revealed that the presence of comorbidity negatively affects clinical quality results. Comorbidity is found to be significantly more common in patients who are found to be inefficient. Many studies in CABG surgery literature indicate that comorbidities such as diabetes and chronic renal failure increase poor health outcomes, complications, and inpatient days after CABG surgery. [51][52][53][54][55][44][56]

The findings showed that there was a significant difference between efficient and inefficient patients in the use of FFP. It was determined that more FFP was used in clinically inefficient patients. Several other studies indicate that not applying intraoperative FFP in CABG surgery is safer and cost-effective and the perioperative use of FFP is the major determinant of mortality. Also, the use of blood products has an increasing effect on the risk of developing adverse clinical outcomes after CABG surgery, especially mortality. [57][58] Our finding using FFP affects clinical quality negatively corresponds to these studies.

The longer duration of CPB and CC in patients with relatively low clinical quality levels is consistent with the CABG surgery literature. Studies have reported that the long duration of these two periods of CABG surgery is associated with adverse clinical outcomes and significantly increases mortality and morbidity. [59][60][61] This particular study identified a significant difference in the number of bypassed vessels between efficient and inefficient patients in both the managerial and clinical stages. As in this study, CABG surgery studies have shown the effect of differences in the number of vessels bypassed on patients' clinical prognosis. [62] However, the effects of vessel numbers on clinical quality need to be examined in more detail to determine clinical quality improvement points on this issue.

5. Conclusion

This paper examined the clinical quality with NDEA (two-stage) on a patient basis using structure, process, and outcome quality measures of CABG's entire cycle of healthcare. We determined clinical quality improvement points through NDEA in order to increase managerial and clinical efficiency.

The NDEA (two-stage) method enabled the analysis of all structure, process, and outcome measures simultaneously and was used to evaluate clinical quality with multiple measures. During the research, the patients with the best clinical quality level were determined, and patient profiles with lower clinical quality were created. Intensive care unit and postoperative inpatient day, cardiopulmonary bypass and cross-clamp duration, and use of fresh frozen plasma were determined as the CABG surgery points requiring quality improvement.

This study recommends the creation of disease-specific standard data packages that include disease-specific structure, process, and outcome measures, and to use multiple measures simultaneously in the evaluation of clinical quality. The study also recommends the use of NDEA as a method for evaluation, and conducting studies on quality improvement points determined from the results of the analysis.

Limitations and suggestions for future research:

The results of this study are valid only for patients who underwent CABG surgery in the research hospital during the study period.

In order to measure efficiency with DEA, the variables to be used in the research should represent the service and be affected by direct actions. [63] *However, the availability and reliability of the data and the ability to capture application variations limit the selection of metrics. It was planned to include the effect of the surgeon, physicians and other staff who performed the operation and its impact on the operation process, as an output variable. However, the variables related to the characteristics of the physician and other staff were accepted as a constant and were not included in the study because of the inability to measure direct effects on the health level of the patient and the lack of sufficient data. These data are unavailable, and each patient is operated on by different physicians and teams. Models to be developed by using the measurement results on the effect of the physician performing the surgery and other team members can be used in the performance evaluation of physicians and health professionals.*

Informed Consent

Informed consent was obtained from the patients included in the study.

Conflict of interest

The authors declare that they have no conflict of interest in connection with this paper.

Acknowledgments

We would like to thank Dr. Hakan KAÇAK for their comments.

Other References

- Kao C, Hwang NS (2008) Efficiency decomposition in two-stage data envelopment analysis: An application to non-life

insurance companies in Taiwan. European Journal of Operational Research 185(1):418–429, https://doi.org/10.1016/j.ejor.2006.11.041

- Chen, Y, Cook, WD, Li N, Zhu J (2009) Additive efficiency decomposition in two-stage DEA. European Journal of Operational Research 196:1170–1176. doi:10.1016/j.ejor.2008.05.011
- Hu R, Shieh C (2014) Evaluating the Performance of Service Quality in the Hospitals of Traditional Chinese Medicine with Data Envelopment Analysis, Studies on Ethno-Medicine 8(1): 69-75. doi:10.1080/09735070.2014.11886474
- Kaçak H, Bağcı H (2020) Assessment of service and financial efficiency in health care organizations - an application with data envelopment analysis and BCG matrix. KOCATEPEİİBF Dergisi, 22(2), 188-203. (in Turkish)

References

1. a, b *WHO (2019) Patient Safety, https://www.who.int/news-room/fact-sheets/detail/patient-safety, 2019, Accessed 23 December 2021.*
2. ^ *European Commission (2016) Costs of unsafe care and costeffectiveness of patient safety programmes,https://ec.europa.eu/health/sites/health/files/systems_performance_assessment/docs/2016_costs_psp_en.pdf,Accessed 03 July 2021.*
3. ^ *OECD (2017) The Economics of Patient Safety, Strengthening a value-based approach to reducing patient harm at national level, Website https://www.oecd.org/els/health-systems/The-economics-of-patient-safety-March-2017.pdf, Accessed 9 December 2020.*
4. a, b *Offıce Of The National Coordinator For Health Information Technology (2021) What are clinical quality measures? Website https://www.healthit.gov/faq/what-are-clinical-quality-measures, Accessed 23 July2021*
5. ^ *Committee on the Quality of Health Care in America (2001) Crossing the quality chasm: A new health system for the 21st century. Washington, DC: National Academy Press*
6. ^ *Hanefeld J, Powell-Jackson T, Balabanova D (2017) Understanding and measuring quality of care: dealing with complexity, Bull World Health Organ, 95:368–374 doi: http://dx.doi.org/10.2471/BLT.16.179309*
7. ^ *Dlugacz YD, (2017), Introduction to Health Care Quality: Theory, Methods, and Tools, San Francisco, USA, Jossey-Bass, ISBN-13: 978-0-7879-8383-3*
8. ^ *Instıtute of Medicine, (2006), Performance Measurement, National Academies Press, Washington, USA*
9. a, b, c, d *Lane-Fall MB, Neuman MD (2013) Outcomes measures and risk adjustment. Int Anesthesiol Clin. 51(4):10-21. doi:10.1097/AIA.0b013e3182a70a52*
10. ^ *The American Health Information Management Association (2020) Quality Check: An Overview of Quality Measures and Their Uses, Website http://library.ahima.org/doc?oid=101998#.XW7bEigzbIV. Accessed 23 June 2021.*
11. a, b *Donabedian A (2005) Evaluating the quality of medical care. 1966. Milbank Q. 83(4):691-729. doi:10.1111/j.1468-0009.2005.00397.x*
12. a, b *Eve AK., Asch SM, Hamilton EG, Mcglynn EA (2000), Introduction- Selecting Quality Indicator, in Quality of Care for General Medical Conditions: A Review of the Literature and Quality Indicators, RAND Corporation, Santa Monica, CA, USA, doi: https://doi.org/10.7249/MR1280MR-1280-AHRQ, 2000,*

https://www.rand.org/pubs/monograph_reports/MR1280.html

13. ^*Rubin HR, Pronovost P, Diette GB (2001) The advantages and disadvantages of process-based measures of health care quality. Int J Qual Health Care. 13(6):469-74. doi: 10.1093/intqhc/13.6.469. PMID: 11769749.*
14. ^*Lilford RJ, Brown CA, Nicholl J (2007) Use of process measures to monitor the quality of clinical practice. BMJ. 335(7621):648-50. doi: 10.1136/bmj.39317.641296.AD..*
15. ^*Agency Of Healthcare Research And Quality (2011) Quality Indicator Measure Development, Implementation, Maintenance, and Retirement, Website https://www.qualityindicators.ahrq.gov/Downloads/Resources/Publications/2011/QI_Measure_Development_Implementation_Maintenance_Retirement_Full_5-3-11.pdf, Accessed 23 July 2021*
16. ^*Campbell SM, Braspenning J, Hutchinson A, Marshall MN (2003) Research methods used in developing and applying quality indicators in primary care. BMJ. 326(7393):816-9. doi: 10.1136/bmj.326.7393.816.*
17. ^*Mainz J (2003) Defining and classifying clinical indicators for quality improvement. Int J Qual Health Care. 15(6):523-30. doi: 10.1093/intqhc/mzg081.*
18. ^*Cooper WW, Seiford LM, Zhu J (2011) Handbook on Data Envelopment Analysis, New York USA, DOI 10.1007/978-1-4419-6151-8, Springer*
19. [a, b, c, d]*Nayar P, Ozcan YA (2008) Data envelopment analysis comparison of hospital efficiency and quality. Journal of Medical Systems. 32(3):193–199. doi: 10.1007/s10916-007-9122-8*
20. ^*Clement JP, Valdmanis VG, Bazzoli GJ, Zhao M, Chukmaitov A. (2007) Is more better? An analysis of hospital outcomes and efficiency with a DEA model of output congestion. Health Care Management Science. 11(1):67–77*
21. ^*Valdmanis VG, Rosko MD, Mutter RL (2008) Hospital quality, efficiency, and input slack differentials. Health Services Research. 43(5,Part2):1830–1848. doi: 10.1111/j.1475-6773.2008.00893.x.*
22. ^*Kang H, Bastian ND, Riordan JP. (2017) Evaluating the Relationship between Productivity and Quality in Emergency Departments. J Healthc Eng. 9626918. doi:10.1155/2017/9626918*
23. ^*Nayar P, Ozcan YA, Yu F, Nguyen AT. (2013) Benchmarking urban acute care hospitals: efficiency and quality perspectives. Health Care Management Review. 38(2):137–145. doi: 10.1097/HMR.0b013e3182527a4c.*
24. ^*Kaçak H, Ozcan YA, Kavuncubaşı Ş (2014), A new examination of hospital performance after healthcare reform in Turkey: sensitivity and quality comparisons, Int. J. Public Policy, l(10),4/5,201:178-194*
25. [a, b]*Ozcan YA, Jiang HJ, Pai CW. (2000) Do primary care physicians or specialists provide more efficient care?. Health Serv Manage Res.13(2):90-96. doi:10.1177/095148480001300203*
26. ^*Chilingerian J (1995) Evaluating physician efficiency in hospitals: A multivariate analysis of best practices, EJOR, 80 (3): 548-574 https://doi.org/10.1016/0377-2217(94)00137-2.*
27. ^*Law M, Haghiri M, Nolan JF. (2010) Evaluating the relative efficiency of cancer treatments in nova scotia using the patient as the unit of analysis, CJRS, 33 (3): 163-176*
28. ^*Santos Arteaga, FJ, Di Caprio D, Cucchiari D. et al (2021) Modeling patients as decision making units: evaluating the efficiency of kidney transplantation through data envelopment analysis. Health Care Manag Sci 24, 55–71 https://doi.org/10.1007/s10729-020-09516-2*
29. ^*Kao C (2007) Efficiency decomposition in network data envelopment analysis: A relation model, European Journal of*

Operational Research, 192:949-962 https://doi.org/10.1016/j.ejor.2007.10.008.

30. ^*Tavassoli M, Saen Fr, Faramarzi GR (2015) Developing network data envelopment analysis model for supply chain performance measurement in the presence of zero data, Expert Sys: J Knowl Eng 32(3): 381-391, DOI: 10.1111/exsy.12097*
31. ^*Cooper WW, Seiford LM, Tone K (2002) Data Envelopment Analysis A Comprehensive Text with Models, Applications, References and DEA-Solver Software, Kluwer Academic Publishers, New York, Boston, Dordrecht, London, Moscow, USA, eBook ISBN: 0-306-47541-3*
32. ^*Chilingerian J (2010) Evaluating clinical performance in health care services with data envelopment analysis (DEA), in Jones R, Jenkins F, Humphris P, Middleton K (editors). Managing Money, Measurement and Marketing, 1st Edition, London, CRC Press https://doi.org/10.1201/9781315375885*
33. ^*MoH (2017) Klinik Kalite Ölçme ve Değerlendirme Rehberi, Koroner Kalp Hastalığı, Sağlık Bakanlığı Yayınları, Ankara, (in Turkish)*
34. ^*WHO (2021) Cardiovascular diseases (CVDs), WHO Fact sheets, Website https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) Accessed 23 July 2021*
35. ^*Cook WD, Zhu J (2014) DEA for Two-Stage Networks: Efficiency Decompositions and Modeling Techniques, (ed) Wade D Cook, Joe Zhu, Data Envelopment Analysis A Handbook on the Modeling of Internal Structures and Networks Book, Chapter 1, Springer, London, ISBN 978-1-4899-8068-7*
36. ^*Chilingerian J, Sherman D (2011) Health-Care Applications: From Hospitals to Physicians, from Productive Efficiency to Quality Frontiers, (ed) William W. Cooper, Lawrence M. Seiford, Joe Zhu, Handbook on Data Envelopment Analysis, Springer New York Dordrecht Heidelberg London doi:10.1007/978-1-4419-6151-8*
37. ^*Ozcan YA (2008) Health care benchmarking and performance evaluation, an assessment using data envelopment analysis (DEA), Springer Science, New York, USA e-ISBN 978-0-387-75448-2*
38. ^*Chilingerian J, Sherman D (1997) DEA and primary care physician report cards: Deriving preferred practice cones from managed care service concepts and operating strategies, Annals of Operations Research, 73:35–66 https://doi.org/10.1023/A:1018993515090*
39. ^*Mogha SK, Yadav SP, Singh SP (2014) SBM-DEA Model Based Efficiency Assessment of Public Sector Hospitals in Uttarakhand, in Proceedings of the Third International Conference on Soft Computing for Problem Solving, SpringerLink, India, ISBN:978-81-322-1770-1*
40. ^*Osnabrugge RL, Speir AM, Head SJ, Jones PG, Ailawadi G, et al (2014) Cost, quality, and value in coronary artery bypass grafting. J Thorac Cardiovasc Surg 148(6):2729-35.e1. doi:10.1016/j.jtcvs.2014.07.089.*
41. [a, b]*El Baz N, Middel B, van Dijk JP, Boonstra PW, Reijneveld SA (2009) Coronary artery bypass graft (CABG) surgery patients in a clinical pathway gained less in health-related quality of life as compared with patients who undergo CABG in a conventional-care plan. J Eval Clin Pract. 15(3):498-505. doi: 10.1111/j.1365-2753.2008.01051.x.*
42. [a, b]*Aniza I, Saperi S, Zafar A, Aljunid SM, Wan Norlida I, et al (2016) Implementation of Clinical Pathways in Malaysia: Can Clinical Pathways Improve the Quality of Care? Int Med J. 23(1): 47 – 50*
43. [a, b]*Homagk L, Jarmuzek T, Homagk N, Hofmann GO (2019) Advantages of clinical pathways in severity-based treatment of spondylodiscitis, Neurosurgical Review, 43(1) https://doi.org/10.1007/s10143-019-01166-5*

44. [a, b]*Mavili İ, Şahutoğlu C, Pestilci Z, Kocabaş S, Aşkar FZ (2016) Etiological factors concerning the early complications that occur following coronary artery bypass graft surgery, GKDA Derg, 2016; 22(1): 16-23, doi:10.5222/GKDAD.2016.016 (In Turkish)*
45. ^*Peric V, Jovanovic-Markovic S, Peric D, Rasic D, Novakovic T, et al (2015) Quality of Life in Patients of Different Age Groups before and after Coronary Artery By-Pass Surgery. Ann Thorac Cardiovasc Surg. 21(5):474- 80. 10.5761/atcs.oa.15-00041*
46. ^*Lavdaniti M, Tsiligiri M, Palitzika D, Chrysomallis M, Marigo M D, Drosos G (2015) Assessment of health status using SF-36 six months after coronary artery bypass grafting: A questionnaire survey. Health Science Journal, 9(1):1-6.*
47. ^*Vincelj J, Bitar L, Jendričko T, Udovičić M, Petrovečki M (2015) Health-related quality of life five years after coronary artery bypass graft surgery. Int J Cardiol. 182:68-9. doi: 10.1016/j.ijcard.2014.12.106.*
48. ^*Razmjoee N, Ebadi A, Asadi-Lari M, Hosseini M (2017) Does a "continuous care model" affect the quality of life of patients undergoing coronary artery bypass grafting? J Vasc Nurs. 35(1):21-26. doi: 10.1016/j.jvn.2016.12.002.*
49. ^*Bond MMK, de Oliveira JLR, Farsky PS, Amato VL, Jara AA, et al (2019) Use of Quality of Life in Cardiovascular Surgery in Coronary Artery Bypass Grafting: Validation, Reproducibility, and Quality of Life in One Year of Follow-Up. Ann Thorac Surg 108(3):764-769. doi: 10.1016/j.athoracsur.2019.03.012.*
50. ^*Järvinen O, Hokkanen M, Huhtala H (2019) Diabetics have Inferior Long-Term Survival and Quality of Life after CABG. Int J Angiol 28(1):50-56. doi: 10.1055/s-0038-1676791.*
51. ^*Anderson RJ, O'Brien M, Mawhinney S, Villanueva CB, Moritzte SEThi GK, Henderson WG, Hammermeister KE, Grover FL, Shroyer AL (1999) Renal failure predisposes patients to adverse outcome after coronary artery bypass surgery, Kidney International 55(3):1057-1062, ISSN 0085-2538, https://doi.org/10.1046/j.1523-1755.1999.0550031057.x*
52. ^*Li X, Zhang, S, Xiao F (2020) Influence of chronic kidney disease on early clinical outcomes after off-pump coronary artery bypass grafting. J Cardiothorac Surg 15:199 https://doi.org/10.1186/s13019-020-01245-5*
53. ^*Safaie N, Chaichi P, Habibzadeh A, Nasiri B (2011) Postoperative outcomes in patients with chronic renal failure undergoing coronary artery bypass grafting in madani heart center: 2000-2010. J Cardiovasc Thorac Res. 3(2):53-56. doi:10.5681/jcvtr.2011.011*
54. ^*Ziabakhsh Tabary SH, Fazli M (2013) Clinical outcome of coronary artery bypass grafting (CABG) in hemodialysis-dependent patients and comparison with non-renal failure patients. Eur Rev Med Pharmacol Sci. 17(19):2628-31. PMID: 24142610.*
55. ^*Dinçer M (2014) An application on the impacts of cardiac risk factors on the length of hospital stay and treatment expenses, Phd, Ankara Gazi University*
56. ^*Sungur SN (2019) The role of nurse in hospitalization duration of the diabetic patients who underwent coroner artery by-pass surgery, Mba, İstanbul Haliç University*
57. ^*Wilhelmi M, Franke U, Cohnert T, Weber P, Kaukemüller J, Fischer S, Wahlers T (2001) Haverich A. Coronary artery bypass grafting surgery without the routine application of blood products: Is it feasible? Eur J Cardiothorac Surg 19(5):657-61. doi: 10.1016/s1010-7940(01)00648-0.*
58. ^*Mikkola R, Heikkinen J, Lahtinen J, Paone R, Juvonen T, Biancari F (2013) Does blood transfusion affect*

intermediate survival after coronary artery bypass surgery? Scand J Surg 102(2):110-6. doi: 10.1177/1457496913482246.

59. ^*Aydın OÖ (2006) Kardiyopulmoner baypas sonrası gelişen böbrek hasarının risk faktörleri, hemoliz ve serum ferritin seviyesi ile ilişkisi, Phd, İstanbul Dr. Siyami Ersek Thoracic And Cardiovascular Surgery Education Research Hospital, (In Turkish)*
60. ^*Hamulu A, Özbaran M, Alay Y, Posacıoğlu H, Aras I, et al (1995) Evaluation of Risk Factors Related to Morbidity and Mortality in Patients Undergoing Coronary Artery Bypass Grafting, GKD Cer Derg,3:245-252 (In Turkish)*
61. ^*Ekim H, Kutay V, Başel H, Turan E, Hazar A, Karadağ M (2004) Revision Operations For Hemorrhage After Open Heart Surgery, Van Tıp Dergisi, 11(4):119-123 (In Turkish)*
62. ^*Lopes NH, Paulitsch Fda S, Gois AF, Pereira AC, Stolf NA, Dallan LO, Ramires JA, Hueb WA (2008) Impact of number of vessels disease on outcome of patients with stable coronary artery disease: 5-year follow-up of the Medical, Angioplasty, and bypass Surgery study (MASS). Eur J Cardiothorac Surg 33(3):349-54. doi: 10.1016/j.ejcts.2007.11.025.*
63. ^*Heimeshoff M, Schreyögg J, Kwietniewski L (2014) Cost and technical efficiency of physician practices: a stochastic frontier approach using panel data, Health Care Manag Sci, 17:150–161 doi:10.1007/s10729-013-9260-0*