Clinical quality assessment of coronary artery bypass graft surgery

Koroner arter bypass greft cerrahisi klinik kalitesinin değerlendirmesi

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ABSTRACT

Objective: Clinical quality (CQ) describes the technical quality of healthcare services and explains how healthcare system affect patient outcomes. This study aims to assess CQ on the patient scale by using structure, process, and outcome measures in the context of coronary artery bypass graft (CABG) surgery.

Methods: Network Data Envelopment Analysis NDEA) was used to assess the CQ levels of patients undergoing CABG. The structure, process, and outcome quality measures of CABG surgery which include clinical factors of the patient as well as the medical procedures, costs, inpatient days, and quality of life, are examined simultaneously. These variables are used to assess CQ and to determine the quality improvement points.

Results: According to the results of NDEA three patients had the highest level of CQ. Detailed profiles were generated for CABG surgery and for patients with low-clinical quality levels. This research highlighted areas for quality improvement to maximize resource utilization and clinical efficiency.

ÖZET

Amaç: Sağlık hizmetlerinin teknik kalitesini tanımlayan "klinik kalite (KK)" sağlık sisteminin hasta sonuçlarını nasıl etkilediğini açıklayan bir kavramdır. Bu çalışmada, koroner arter bypass greft (KABG) ameliyatının yapı, süreç ve sonuç ölçütlerini kullanarak hasta bazında KK'nin değerlendirilmesi amaçlandı.

Yöntem: KABG uygulanan hastaların KK düzeylerini değerlendirmek için Network Veri Zarflama Analizi (NVZA) kullanıldı. Hastanın klinik bulgularının yanı sıra tıbbi prosedürler, maliyetler, hasta yatış günleri ve yaşam kalitesini içeren KABG ameliyatının yapı, süreç ve sonuç ölçütleri eş zamanlı analiz edildi. Bu değişkenler KK'yi değerlendirmek ve kalite iyileştirme noktalarını belirlemek için kullanıldı.

Bulgular: NVZA sonuçlarına göre en yüksek KK düzeyinin üç hastada sağlandığı tespit edildi. KABG ameliyatı ve KK düzeyi düşük olan hastalara yönelik ayrıntılı profiller oluşturuldu. Çalışma bulguları ile kaynak kullanımını ve klinik verimliliği en üst düzeye çıkarmak için kalitenin iyileştirilme noktaları belirlendi.

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Conclusion: As a result of this study, CQ with the NDEA on a patient scale, encompassing the structure, process, and outcome quality measures across the entire healthcare cycle of CABG surgery and the analysis model demonstrated its potential as a useful tool for assessing and improving CQ. The intensive care unit and postoperative length of stay, the duration of cardiopulmonary-bypass and cross-clamp, and the use of fresh frozen plasma were identified as the areas requiring quality improvement. The study recommends creating disease-specific standard data packages including multiple quality measures for CQ assessment, and employing the NDEA method for further quality improvement studies.

Key Words: Coronary artery bypass graft, clinical quality, network data envelopment analysis

Sonuç: Çalışma sonucunda KABG ameliyatı sonrası elde edilen KK hasta bazında değerlendirildi. Yoğun bakım ve ameliyat sonrası hasta yatış günü, kardiyopulmoner bypass ve kros klemp süresi, taze donmuş plazma kullanımı, kalitenin iyileştirilmesi yapılabilecek alanlar olarak belirlendi. NVZA ile oluşturulan modelinin KK'nin değerlendirilmesi ve iyileştirilmesinde yararlı bir araç olduğu sonucuna ulaşıldı. Bu çalışma ile KK değerlendirmesinde, hastalığa özgü kalite ölçütlerinin içerildiği standart veri paketlerinin oluşturulması, daha ileri kalite iyileştirme çalışmaları için NVZA yönteminin kullanılması önerilmektedir.

Anahtar Kelimeler: Koroner arter bypass greft, klinik kalite, network veri zarflama analizi

INTRODUCTION

Each year, unsafe care imposes a significant economic burden on European Union countries, totaling €21 million, and in the United States, this burden escalates to $1 trillion annually (1). The prominence of healthcare quality has increased due to unsafe healthcare delivery and financial stress. CQ, representing the technical outcome quality of healthcare, encompasses the tangible outcomes derived from healthcare interventions (2). CQ indicators focus on specific aspects of quality rather than assessing the entire service cycle. Unfortunately, these indicators are rarely specific enough to evaluate the performance of healthcare professionals or a patient's condition. (3) Nonetheless, CQ measurement is anticipated to elucidate the intricate connections between the structure, process, and outcome characteristics of a healthcare service. (4) CQ assessments initiate by prioritizing prevalent health phenomena, considering both their impact and measurability. (5) Consequently, this study selected CABG surgery, a treatment option for cardiovascular disease—a leading global cause of death affecting 17.9 million individuals in 2019—as the focal point for CQ measurement. (6)

The CABG outcome for each patient is influenced by various factors of the whole healthcare cycle including the severity of the disease, medical interventions, treatment protocols, and duration of postoperative care both in the intensive care unit and in the clinic. (7) This study aims to assess patients' relative CQ levels by employing structure, process, and outcome quality measures in the context of CABG surgery.

MATERIAL and METHOD

This prospective, cross-sectional research was conducted at a tertiary training and research hospital in Ankara. The study included inpatients with a pre-diagnosis of CABG between December 15, 2018, and

March 15, 2019, making up the research population. Data were collected from 139 patients who provided informed consent to participate. Excluded from the study were patients who were discharged without surgery (n=38), and passed away during their hospital stay (n=3). The CQ levels of 98 patients aged 18 and above were assessed using a two-stage NDEA. The measures affecting CABG surgery CQ were identified as follows:

Structure: EuroSCORE risk score (1=Low; 2=Intermediate; 3=High).

Process: Coronary angiography, ECHO cardiography ejection fraction, level of evidence supporting the efficiency and effectiveness of the procedure (LESEEP), comorbidities, cardiopulmonary-bypass (CPB) and aortic cross-clamp (CC) duration, carotid endarterectomy, CABG application on a beating heart, blood product transfusion (erythrocyte suspension, fresh frozen plasma), the use of inotropic agents, intra-aortic balloons, Extracorporeal Membrane Oxygenation(ECMO), number of bypassed vessels, reoperation, length of stay (LOS).

Outcome Measures: Postoperative serum creatinine, urea, AST, ALT, CRP values, quality of life (QoL), and healthcare costs (operation and preoperative, ICU, postoperative period).

Data Collection Process: Data on all variables was gathered. The Carotid Endarterectomy, Intra-aortic Balloon, and ECMO, LESEEP class remained uniform across all patients; hence, these variables were omitted from consideration in the NDEA.

Data were sourced from both written and electronic health records. The hospital invoices were meticulously categorized by the research team into distinct subcategories, including radiology-laboratory, blood products, consumables, medications, and other transaction costs. The QoL evaluated by EQ-5D5L questionnaire. The initial assessments conducted face-to-face before surgery and follow-up assessments conducted via telephone three months post-surgery. The difference between the two EQ-5D5L scores was defined as the " QoL improvement value." Furthermore, an Adjusted Functional Health Value was calculated by scoring the results of ECHOcardiography, serum urea, creatinine, AST, ALT, and CRP as positive or negative based on the determined cutoff points established by the researcher (cardiovascular surgeon).

We conducted statistical analyses to examine the relationships among demographic characteristics, structure, process, and outcome measures. In addition to descriptive statistics, we employed the Mann-Whitney U test and two-stage NDEA. p-value of <0.05 was considered statistically significant. In the two-stage Network DEA, each patient was defined as a Decision-Making Unit (DMU). This method was chosen because it accounts for networks with distinct stages and interactions, allowing for the examination of sub-processes as well as sub-inputs and outputs of each process (8). In addition, it can also manage multiple measures simultaneously, highlights improvement points, and is a sensitive method in identifying waste of resources and evaluating performance (8,9).

The scores obtained through NDEA analysis were assessed in terms of efficient and inefficient. The literature revealed that, even when close to the efficiency frontier, subjective cutoff points or quartiles can be employed to identify DMUs whose characteristics might have been overlooked due to their classification as inefficient (10,11). In our analysis, to provide a clearer distinction between efficient and inefficient patients, the NDEA scores were divided into quartiles and categorized as follows: marginally inefficient, most inefficient, above the median, and below the median. Marginally inefficient patients fell within the fourth quartile with efficiency scores ranging from 0.775 to 1 in the Clinical Efficiency Stage (CES) and 0.849 to 1 in the Resource Efficiency Stage (RES). In this research "efficient and marginally inefficient patients were termed "**high-CQ patients(efficient)**". Conversely, the most inefficient patients were situated in the first quartile, characterized by efficiency scores ranging from 0 to 0.513 in the CES and 0 to 0.535 in the RES. Patients identified as being in the "Most Inefficient," "Above Median," and "Below Median" categories, indicative of low CQ in the analyses, were collectively termed " **low-CQ patients(inefficient)**".

The study was approved by the Ankara University Health Sciences Sub-Ethics Committee (Date: 06.12.2018 and Number: 218).

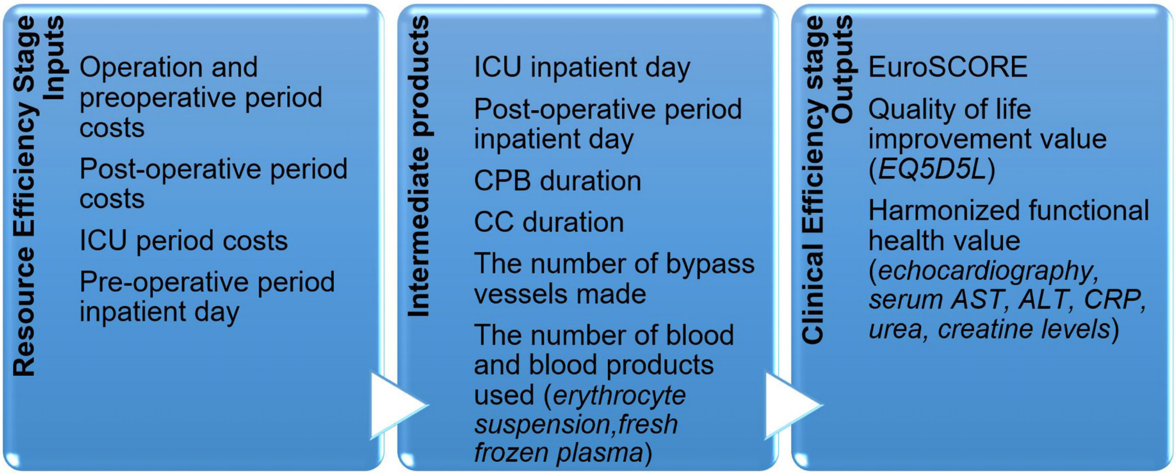

Figure 1. Swo-Stage NDEA Model -CQ Assessment of CABG Surgery

RESULTS

Ninety-eight patients who underwent CABG surgery were enrolled in the study. Descriptive findings for the patients are presented in Table 1. Among the study participants, eighty (81.63%) were male. The distribution of patients based on the EuroSCORE revealed 49 (50%) in the low-risk category, 37 (37.75%) in the moderate-risk category, and 14 (14.28%) in the high-risk category. The most prevalent comorbid condition was diabetes, affecting 42 (41.58%) patients, while 50 patients had no comorbidities. The mean LOS prior to surgery, in the ICU, and during the postoperative period were 6.24 ± 4.48, 1.8 ± 1.55, and 5.5 ± 3.02 days, respectively. The average duration of CPB and CC were 106.46± 37.25 and 67.24 ± 25.58 minutes, respectively. In terms of QoL assessment, the EQ5D5L score was 0.706 ± 0.227 upon initial evaluation and increased to 0.880 ± 0.181 in the subsequent assessment. The utilization of erythrocyte suspension (ES) amounted to an average of 3 ± 2.89 units, while fresh frozen plasma (FFP) use averaged 2.27 ± 2.24 units. Researchers determined the adjusted functional health level to be 11.56 ± 2.01.

The central efficiency score derived from the NDEA analysis indicated that three patients achieved the highest CQ level. The average efficiency score among the 98 patients included in this study's analysis was determined to be 0.43. It was observed that 15 patients had an efficiency score of 0.68 in the RES, and 11 patients also had an efficiency score of 0.68 in the CES. The distribution of patient efficiency scores in both the RES and CES is visually depicted in Figure 2.

It was determined that the patients who were efficient in the CES were not efficient in the RES, except for five patients (Figure 2). It was determined that 20 of 25 patients, which were considered inefficient in RES, were not efficient at the CES and a relatively high-CQ level could not be achieved in these patients. Table 2 provides the mean values and statistical test results for patients categorized as high-CQ and low-CQ in both the RES and CES, with respect to the structure, process, and outcome measures.

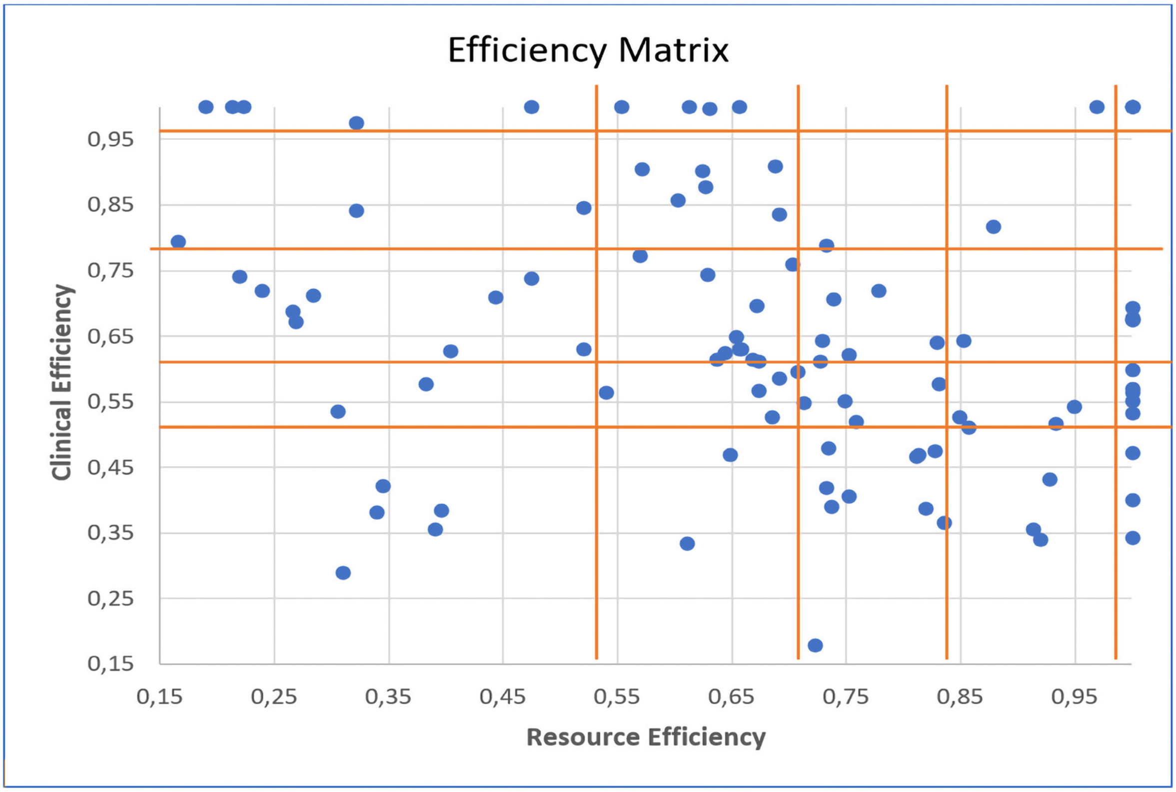

Figure 2. Distribution of the NDEA Result RES and CES Scores

In the RES, although there was no statistically significant difference, the costs were found to be relatively higher in the low-CQ patient group except for preoperative operative and post-operative period costs. The average preoperative and operative period cost was \$1327.23±998,43, whereas radiology laboratory costs amounted to \$635.87±\$907.28, and post-operative period costs were \$173.24±\$126.96 for low-CQ patients. 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 high-CQ and low-CQ patientsespecially regarding the radiology and laboratory costs during the preoperative and operative period and ICU medicine costs (Table 2).

In the CES, although there was no statistically significant difference the costs were found to be relatively higher in the low-CQ patient 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 low-CQ patients (Table 2).

In the RES preoperative period, inpatient days are 3,20±2,31 in high-CQ patients while 7,30±4,57 days in low-CQ patients, and there is a statistically significant difference between them. Also, ICU inpatient days have statistically significant differences between high-CQ patients (2,04± 1,02 days) and low-CQ patients (1,71±1,42 days). There are no significant differences between high-CQ and low-CQ patients in both RES and CES about other inpatient day values (Table 3).

Table 1. The descriptive statistics of patients

Patient characteristics	N=98
	n (%)
Male	80 (81.63)
Female	18 (18.36)
EuroSCORE	
"1" n (%)	49 (50)
"2" n (%)	37 (37.76)
"3" n (%)	12 (12.24)
Comorbidity Situations	
Diabetes	42 (42.85)
Chronic renal failure	2 (2.04)
Other and combined comorbidities	4 (4.08)
Number of patients without comorbid disease	50 (51.02)
LOS	**mean. std**
preoperative period	6.24 ±4.48
ICU period	1.8±1.55
postoperative period	5.5±3.02
EQ5D5L Quality of Life Survey	
First application	0.706±0.227
Postop 3rd month	0.880±0.181
CPB duration (min)	106.46±37.25
CC time (min)	67.24±25.58
Use of blood and blood products	
Erythrocyte suspension (ES) (unit)	3±2.89
Fresh frozen plasma (FFP) (unit)	2.27±2.24
Harmonized functional health value	11.56 ±2.01

Table 2. Average values of efficient and inefficient DMUs (Patients) according to the NDEA results by stages

	Resource Efficiency Stage		Clinical Efficiency Stage	
Measures	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

Table 2 (cont). Average values of efficient and inefficient DMUs (Patients) according to the NDEA results by stages

	Resource Efficiency Stage		Clinical Efficiency Stage	
Measures	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)
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
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 duration (m)	111.64± 28.92	101.14± 27.95	**87.72 ±25.98***	**109.33 ± 27.25***
CC duration (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
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

Table 3. Distribution of EuroSCORE, comorbidity situations, number of bypassed vessels in resource and clinical efficiency stages and test results

		EuroSCORE		Comorbidity Situations		Number of bypassed vessels	
		Efficient -marginal inefficient	Inefficient	Efficient -marginal inefficient	Inefficient	Efficient -marginal inefficient	Inefficient
Resource 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***	

It is determined that in the CES variable affecting clinical outcomes such as CPB duration have statistically significant differences between high-CQ patients (87,72±25,98m) and low-CQ patients(109,33±27,25m), and low-CQ patients' duration of CPB is longer. In terms of CC duration, it was determined that this time lasted 69,84±23,13 minutes in low-CQ patientsand was statistically significant. While no significant difference was found in both RES and CES in terms of the use of ES, it was found that the use of FFP was statistically significantly overused in patients that were low-CQ at the CES (Table 2).

While the preoperative QoL score had statistically significant differences between high-CQ and low-CQ patients, no significant difference was found in the post-operative QoL 3rd month score and the improvement value in QoL (Table 2).

At the CES, it was found that there was a statistically significant difference ($p < 0.05$) between the high-CQ and low-CQ patients in the number of bypassed vessels and the EuroSCORE (Table 3). It was determined that the number of bypassed vessels was high in low-CQ patients. In the RES, 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 low-CQ (Table 3).

A reference group is formed based on the results of the NDEA. The patients in this group are compared with other patients, and improvement points to be intervened are recommended so that the clinical results are close to the best. In this study as a result of the NDEA, 22 patients were accepted as the reference group. The most efficient patient, P6, has been referenced 85 times. P59, referenced 46 times, and P41, referenced 34 times, are the other most efficient patients. The optimal values suggested by the NDEA in intermediate products in the RES and CES stage are provided in Table 4 to increase the CQ of patients determined as low-CQ.

In this study, it has been found that low-CQ patients, tend to have longer durations of CPB and CC, extended stays in the ICU, and prolonged inpatient postoperative days compared to high-CQ patients both in the RES and CES.Additionally, according to the profile created by the NDEA, the patients classified as low-CQ in RES have higher preoperative and postoperative costs compared to high-CQ patients. Notably, the increase in preoperative radiology-laboratory and ICU drug costs is statistically significant for patients considered low-CQ in RES. Patients in this group also exhibit lower preoperative QoL and experience longer durations of preoperative and ICU care. To enhance efficiency, optimizing the length of postoperative hospitalization is crucial. Furthermore, comorbid diseases are more prevalent in this category of patients, and the duration of CPB and CC is longer.

Similarly, the profile created by the NDEA for low-CQ in CES reveals higher pre-operative other transaction costs, and post-operative consumable costs in these patients in comparison to high-CQ patients. Preoperative QoL in these patients is lower as well. Low-CQ patients require more ICU care, and their postoperative recovery time is prolonged. Statistically significant differences are noted in EuroSCOREs and the number of bypassed vessels in clinically low-CQ patients. Moreover, CPB and CC durations are longer among clinically low-CQ patients, and these patients require a significant quantity of blood products, with a statistically significant amount of FFP being used.

Table 4. Recommended optimal intermediate product values for low-CQ patients

	Average of Proposed Values		Proposed Percentage of Change	
	Resource Efficiency Stage	Clinical Efficiency Stages	Resource 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%

DISCUSSION

As a result of the research, we assessed the CQ of CABG surgery for each patient by using the NDEA and considering the entire healthcare service cycle.

The NDEA (two-stage) enabled us to analyze simultaneously all the structure, process, and outcome measures of CABG to assess CQ. Furthermore, the research has delineated, the frontiers of best practices and quality improvement points within the context of CABG surgery. To increase CQ and ensure resource and clinical efficiency, improvement points were identified such as ICU and postoperative inpatient days, the duration of CPB and CC, as well as the utilization of blood products as key areas for potential enhancement. Obtaining the fact that these results align with findings in the existing CABG surgery literature obtained that NDEA, which is used to assess technical efficiency and productivity in healthcare (12, 13), could also be used in the CQ assessment.

Several previous studies assess CQ with indicators for specific aspects of quality at the institutional scale (14,15). Our results provide a new model by which CQ can be assessed at the patient scale, considering the entire healthcare cycle, and improvement points can be identified.

Literature has consistently demonstrated a notable directly proportionate connection between lower CQ levels and increased resource consumption (like cost and inpatient days etc.) and emphasized CQ can be achieved through the utilization of quality improvement tools (16-19). Our results indicate that the resource use of patients with similar CQ levels is not uniform and could be optimized. Contrary to prevailing literature our study highlights the challenge of simultaneously achieving optimal resource utilization and maintaining high CQ in cardiovascular surgery. These results have been interpreted as potentially stemming from variances in the examination, treatment, and follow-up practices among physicians. The challenge of simultaneously achieving optimal resource utilization and maintaining high-CQ underscores the complex interplay between clinical efficiency and resource allocation, which demands further investigation and strategic considerations for healthcare providers and policymakers.

The impact of disease severity and risk level on clinical outcomes has been well-documented in disease-specific studies. EuroSCORE has been proven as a determinant to be associated with increased mortality after CABG surgery (4,20,21). Our research findings concluded that the EuroSCORE is one of the variables influencing the level of CQ and significantly differs between high and low CQ. And also, there is a statistically significant difference between the high and low CQ in terms of QoL. A high level of CQ was achieved in patients with a low preoperative QoL score and a high EuroSCORE. This result was attributed to the more significant impact of surgical treatment on patients with relatively low QoL and higher disease severity. Studies investigating the QoL in CABG surgery have indicated that CABG surgery positively impacts and improves the patient's QoL (22,23). Our result of an increase in the QoL aligns with these prior studies.

Our CQ assessment results revealed that the presence of comorbidity significantly affects the CQ results negatively. Numerous studies within CABG surgery literature indicate that comorbidities are associated with elevated risks of adverse health outcomes, complications, and extended inpatient days following CABG surgery (20,24-26).

The findings showed that there was a significant difference between the high-CQ level and low-CQ level patients in the use of the FFP. Particularly, it was noted that low-CQ level patients required more FFP. 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 (27,28). Our finding using FFP affects the CQ negatively is in line with the findings of these studies.

The longer duration of CPB and CC in patients with relatively low CQ levels is consistent with the CABG surgery literature. Multiple studies have reported that prolonged CPB and CC duration during CABG surgery are linked to unfavorable clinical outcomes, substantially elevating the risks of mortality and morbidity (26,29). This particular study identified a statistically significant difference in the number of bypassed vessels between patients with low-CQ and high-CQ levels in the RES and CES. Consistent with this research, previous studies in the field of CABG surgery have shown the effect of differences in the number of vessels bypassed on patients' clinical prognosis (29). However, the effects of vessel numbers on CQ need to be examined in more detail to determine CQ improvement points on this issue.

The strength of this study is that the entire healthcare cycle is analyzed simultaneously at the patient scale to assess CQ. This allowed us to determine the relationship between structure, process, and outcome and to identify improvement points to increase CQ. To measure the efficiency of a process using the NDEA method, the variables used in the research should be representative of the service and be influenced by direct action. However, the availability and reliability of data, and the ability to capture variation in application, limit the choice of measures. It was planned to include as an output variable the influence of the surgeon and other staff who performed the operation and their influence on the operation process. However, the variables related to the characteristics of the surgeon and other staff were accepted as constants and were not included in the study because of the inability to measure direct effects on the patient's level of health and the lack of sufficient data. These data are not available and each patient is operated on by different doctors and teams. DEA models, developed using the results of measurements of the impact of the surgeon and other team members, can be used to evaluate the performance of doctors and health professionals.

In conclusion; this study assessed CQ with the NDEA on a patient scale, encompassing the structure, process, and outcome quality measures across the entire healthcare cycle of CABG surgery. We determined the CQ improvement points to increase CQ. The NDEA (two-stage) model facilitated the assessment of CQ analyzing multiple measures simultaneously, and demonstrated its potential as a valuable tool for assessing and enhancing CQ in healthcare contexts. During the research, the patients with the best CQ level were determined, and patient profiles with lower CQ were created.

The ICU 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 suggests using multiple measures simultaneously in the evaluation of the CQ. The study also recommends the use of the NDEA as a method for evaluation and conducting further studies on quality improvement points determined from the results of the analysis.

ETHICS COMMITTEE APPROVAL

* The study was approved by the Ankara University Health Sciences Sub-Ethics Committee (Date: 06.12.2018 and Number: 218).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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