JERN Journal of Education and Research in Nursing

Original Article
DOI:10.5152/jern.2022.01328

Procedural Factors Affecting Nurses' Workload and Laboratory Efficiency in the Interventional Cardiology

Özlem Kaçar[1], Mahmure Aygün[2]

[1]Department of Nursing, Biruni University Graduate Education Institute, İstanbul, Turkey
[2]Department of Nursing, Biruni University Faculty of Health Sciences, İstanbul, Turkey

Abstract

Background: Interventional cardiology nursing is a highly specialized nursing specialty in which knowledge and skills from various nursing disciplines such as cardiovascular, intensive care, and operating room nursing are combined. The study was conducted to analyze the procedural factors affecting the workload of interventional cardiology nurses and to determine incompatibilities between supply and requirements in terms of manpower planning and laboratory efficiency.

Methods: The study was designed as prospective, observational, and descriptive. The data were collected between May 1 and 30, 2019, in cardiac catheterization laboratory with single operating room. Regarding 4 different interventional procedures, records have been kept about "clinical data for procedures, perioperative nurse functions and workload" and the relationship between those data has been analyzed.

Results: In the study, a total of 39 procedures were observed. Mean fluoroscopy times, total nurse workloads, and room turnover times were, respectively, 7.1 ± 2.8, 34.7 ± 9.5, and 9.1 ± 2.7 minutes in coronary angiography, 34.4 ± 23.17, 91.2 ± 51.9, and 15.6 ± 6.6 in percutaneous coronary intervention, 61.9 ± 22.6, 124.6 ± 28.7, and 22.0 ± 3.7 in permanent pacemaker implantation, and 111.6 ± 26.2, 187.3 ± 45.8, and 41.3 ± 20.1 in peripheral vascular interventions. About 41.02% of the procedures took place between 10 AM and 1 PM, when there were 3 nurses in the unit. Between 1 PM and 3 PM and between 3 PM and 5 PM when the number of nurses in the unit was 4, the percentage of procedures that took place was 20.5% and 17.9%, respectively. In the peripheral vascular interventions, postoperative nursing workload was found to be higher ($P < .001$).

Conclusion: Workload of interventional cardiology nurses are higher than total operation and fluoroscopy times. The operating room turnover time shortens if the number of circulating nurses involved in procedures increases. In order to improve the efficiency and productivity of these units, it is recommended to consider "fluoroscopy times and nurse workloads in different procedures," "distribution of procedures during the day," and "the room turnover times."

Keywords: Interventional cardiology, cardiac catheterization, nurse workload

Introduction

Although interventional cardiology is a relatively new concept, today it is a medical field that exceeds conventional surgery in the field of cardiovascular diseases. Over the past 2 decades, there have been significant advances and increases in the variety of procedures performed in the field of percutaneous cardiovascular interventions and the number of patients treated with these procedures. The scope of practice of interventional cardiology is no longer limited to coronary interventions alone. The procedures have expanded to include cardiac rhythm management, treatment of structural heart diseases, and peripheral vascular interventions (PVI). The main reasons for this axis shift in the treatment of cardiovascular diseases can be identified as aging population, advances in imaging technologies, efficiency and reliability of interventional procedures, advances in operator techniques, and the use of percutaneous coronary intervention (PCI) as the first emergency treatment strategy in patients with myocardial infarction.[1-2]

Cardiac catheterization laboratories (CCL) are procedure rooms with high-efficiency imaging systems, where complex percutaneous catheter-based interventions are performed for diagnosis and treatment. These laboratories provide services in different categories in terms of facility, infrastructure, and equipment. "Full-service laboratories" perform a wide variety of diagnostic and interventional procedures in hospitals with cardiovascular surgery on site. "Hospital laboratories without on-site cardiac surgery" offer

The presented article was prepared based on the findings of Özlem Kaçar's master's thesis titled "Responsibilities and Workload Analysis of Cardiac Catheterization Laboratory Nurses", which was accepted on 24.07.2019

Cite this article as: Kaçar Ö, Aygün M. Procedural factors affecting nurses' workload and laboratory efficiency in the interventional cardiology. *J Educ Res Nurs.* 2022;19(2):208-219.

Corresponding author: Mahmure Aygün
E-mail: maygun@biruni.edu.tr

Received: May 12, 2020
Accepted: November 30, 2020

limited diagnostic and interventional procedures. The third group that is "hospital-based laboratories" are units where only diagnostic procedures and certain peripheral interventions are performed, and no coronary interventions take place. Safe and optimal implementation of procedures performed in cardiac catheterization laboratories requires a multidisciplinary approach. This team consists of physicians (medical director, operator, and physician assistant), nurse (nurse manager and nursing staff), non-nursing staff (technical manager and radiologic technologist), anesthesia personnel, medical physicist, and ancillary staff (technical support staff and procurement/purchasing specialist) equipped with the education, knowledge, and experience specified in the guidelines.[3-5]

The trend of diagnosis and treatment of cardiovascular diseases with percutaneous cardiovascular interventions has led to the emergence of a different field of education and expertise for nurses. This specialty is called "interventional cardiology nursing." Interventional cardiology nursing is a highly specialized nursing specialty in which knowledge and skills from various nursing disciplines such as cardiovascular, intensive care, and operating room nursing are combined. In this highly technological field, nurses work as a scrub or circulating nurse to support different procedures in the perioperative processes. They are responsible for several complex clinical tasks, such as the preparation and management of patients, equipment, and supplies. Nurses working in these units are expected to know cardiovascular anatomy–physiology, advanced life support, basic electrocardiogram, cardiovascular drugs, anesthesia sedation, vascular catheters, and radiation safety. In terms of skills proficiency, they need to be skilled in intravenous infusion, creation, and maintenance of a sterile field, management of sheath area, hemostasis-compression dressing, and patient monitoring. In CCL where there are no physician assistants, radiologic technologists, and anesthesiologists/technicians, nurses undertake the duties of this personnel. For this reason, CCL nurses must know the complex technical structure and material properties of the procedures. They also assist the operator during the procedure. With the development of new technologies and interventional procedures in the future, these roles and responsibilities will undoubtedly change and improve.[4-7]

For safe patient care and avoiding and managing adverse events that occur during the procedure, both qualitative and quantitative qualifications of the personnel working in CCL are important. The number of non-physician staff per procedure should be considered in terms of the effectiveness and efficiency and costs of these units. In general, it is recommended that 1 or 2 staff be at the table for each procedure and additionally 2 staff for circulation, monitoring, and documentation tasks.[5] However, these general recommendations do not clearly explain the sufficient number of non-physician staff for different and/or more complicated procedures. In addition, there is not sufficient data in the literature on the relationship between CCL caseload and the distribution of the cases during the day and shift planning, room turnover rate, and the number of personnel.[6]

Given the conditions brought on by developing and changing cardiovascular interventions, it is necessary to determine the current state of the workforce in CCL to make appropriate plans and provide efficient and effective health care.

The study aimed to determine the scope of practice for interventional cardiology nurses, the workloads for these practice areas, the distribution of workloads in different procedures, and the procedural features affecting the workloads. It is believed that the study results will contribute to the literature on issues in CCL such as: 1. Planning the nurse workforce in accordance with their workload; 2. Developing standards for nurse workload-employment; 3. Planning the nursing employment with an evidence-based; 4. Developing projections for the resolution of the detected inconsistencies.

Methods

Aim

The study was conducted to determine the responsibilities and the scope of practice of CCL nurses as a scrub and circulating nurse to determine the changes in nurse workload in different interventional procedures and to develop recommendations for manpower planning related to caseload-nurse workload.

Type of Study

It is a prospective, observational, descriptive study. Study data were collected between May 1 and May 30, 2019.

Location and Characteristics of Study

Cardiac catheterization laboratories, where the study was conducted, was a "full-service laboratory" with a single room and provided service with SIEMENS biplane angiography system. Eight cardiologists worked in the unit, and there were no cardiology physician assistants. Except for the nurse manager, 7 nurses worked in three 7-hour shifts in the laboratory (unit had a schedule of 2 nurses between 8 AM and 10 AM, 4 nurses between 10 AM and 1 PM, 6 nurses between 1 PM and 3 PM, 4 nurses between 3 PM and 5 PM, and 2 nurses between 5 PM and 8 PM). Due to radiation exposure, staff used a month of medical leave additional to their annual leave period. Moreover, as a result of the excused absence due to illness, etc., the number of nurses varied according to the days. Every day, a nurse was on standby duty. There were no radiologic and surgical technologists in the laboratory, and the duties and responsibilities of these technologists were carried out by CCL nurses. Cardiac catheterization laboratories experience of nurses on duty varied between 6 months and 5 years. The patients were admitted to a 21-bed coronary intensive care unit for hospitalization before the procedure and for follow-up and treatment after the procedure. The coronary intensive care unit and CCL teams were different. Laboratory nurses were not responsible for patient care after the procedure. Laboratory throughput was an average of 6 cardiovascular diagnoses/treatments interventions per day.

Sampling

Since the study was based on the duty and workload analysis of CCL nurses, it was aimed to make at least 6 observations in different procedures performed in the relevant CCL for the generalizability of the results, and a total of 39 observations were made for 4 different interventional procedures in 1 month. Nineteen of these observations were coronary angiography (CA), 7 were PCI, 8 were permanent pacemaker implantation (PPMI), and 5 were PVI. Due to the insufficient number of patient appointments for PVI during the data collection period, 5 observations were made. The activities and workloads of the nurse manager and the additional activities of the nurses other than procedural activities were excluded from the study.

Data Collection Tools

For each process observed in the study, "general data form for interventional procedure", "unit general preparation procedures workload form," and "nurse workload form for procedural activities" were filled.

General Data Form for Interventional Procedure

Variables in this form are procedure type, procedure time, number of nurses in the unit at the time of the procedure, total procedure time (time between patient's entry and exit to the unit), operation time to fluoroscopy time (time between vascular access and the end of the procedure), room turnover time (determined through the total workload of the scrub and circulating nurses in the postoperative period), type of patient admissions to the unit (appointment, inpatient, and emergency), the intervention area, the completion status of the procedure, the anesthesia sedation type, the preoperative anticoagulant treatment, use of emergency drugs during the procedure, use of contrast media, contrast media volume, procedural complications, and conditions affecting the duration of the procedure (additional activities and unexpected problems).

Cardiac catheterization laboratory nursing activities were assessed in 2 groups as "unit general preparation procedures" and "procedure-specific nursing activities" applied at the start of the working day.

Unit General Preparation Procedures Workload Form

Seven activities assessed in this workload are "appointment list control, the entry on scheduling board, daily division of labor," "getting the angiography device ready for the procedure (turning on the device and testing the motion control)," "turning on the computers," "inventory count (inventory control for number and content of equipment required for procedures carried out during the day, missing inventory request)," "control of other medical devices and emergency equipment (defibrillator control, emergency cart drug and supply control, and O_2 and aspiration equipment preparation)." The averages of 5-day records of the time spent on each of these activities constituted "general preparation procedures workload."

Nurse Workload Form for Procedural Activities

Three different interventions were observed for each procedure to determine the pool of "procedure-specific nursing activities." Procedural activities were grouped as preoperative, intraoperative, and postoperative activities within the workflow. The activities in each group were further divided as activities of scrub and circulating nurses who participated in the procedure. A total of 27 nursing activities were identified: 6 for the scrub and 7 for the circulating in the preoperative period, 3 for the scrub and 3 for the circulating in the intraoperative period, 4 for the scrub and 4 for the circulating in the postoperative period (Table 1).

The time spent on each nursing activity was assessed and recorded by a researcher participating in the procedure using a stopwatch. The average workload for each interventional procedure group was calculated separately for the pre-intra and postoperative periods and the scrub/circulating nurses.

Ethics

The study complies with the principles set out in the Declaration of Helsinki.[8] To conduct the study, written permission was obtained from Biruni University Non-Interventional Research Ethics Committee (date: March 29, 2019, decision no: 2019/27-04) and the hospital where the study was conducted.

Data Analysis

R software program was used for the statistical analysis of the study findings. For the descriptive statistics of the variables, mean and standard deviation were used for continuous variables, and median values software program was used for the statistical analysis of the study findings. For the descriptive statistics of the variables, mean and standard deviation was performed for the variables that did not show a normal distribution in the same groups. Bonferroni method was used in post hoc analysis. The difference and significance levels of the relationships were accepted as $P < .05$, $P < 0.01$, and $P < .001$.

Results

In this study, 61.5% of the patients were male, the mean age was 62.58 ± 11.58, and 66.7% were patients with an appointment. Data for the interventional procedure are provided in Table 2. About 48.7% of the 39 interventional procedures observed were CA, 17.9% were PCI, 20.5% were PPMI, and 12.8% were PVI. About 71.8% of the cases were local anesthesia-only procedures while 28.2% were performed under local anesthesia + conscious sedation. Contrast volume was <100 mL in all coronary angiographies, 100-199 mL in 71.4% of PCI, and >200 mL in 80.0% of PVI. The vessel type was femoral artery in all CA and PCI, subclavian vein in PPMI, and femoral artery in PVI (failed brachial access in 2 cases). Total procedure time and operation time were 23.8 ± 8.9 and 7.15 ± 2.80 for CA, respectively, 51.7 ± 22.5 and 34.4 ± 23.17 for PCI, and 90.2 ± 25.2 and 61.93 ± 22.6 minutes for PPMI cases. Total procedure time and fluoroscopy time (140.6 ± 30.8 and 111.6 ± 26.2 min) in PVI were found to be statistically significantly higher than the other groups ($P < .001$). Room turnover times were 9.1 ± 2.7 for CA, 15.6 ± 6.6 for PCI, 22.0 ±3.7 for the PPMI group, and 41.3±20.1 for PVI.

The numerical distribution of the procedures during the day, the number of nurses present in the unit at these time intervals, and the number of nurses working shifts in the routine work plan of CCL are presented in Figure 1. About 10.25% of the procedures were performed between 8 AM and 10 AM and the number of nurses present in the unit was 2. The value distributions were 41.02% and 3% between 10 AM and 1 PM, respectively, 21.5% and 4% between 1 PM and 3 PM., 17.94% and 4% between 3 PM and 5 PM; 10.25% and 2% between 5 PM and 8 PM.

Cardiac catheterization laboratories scrub workloads are shown in Table 3. The preoperative scrub workload was found to be 7.7 ± 3.1 minutes for CA, 10.0 ± 3.6 minutes for PCI, 16.6 ± 4.7 minutes for PPMI, and 7.6 ± 2.3 minutes for PVI. The preoperative scrub workload in the permanent pacemaker implantation group was statistically significantly higher than the other groups ($P < .001$). The intraoperative scrub workload was found to be 8.1 ± 3.0 minutes for CA, 34.0 ± 25.3 minutes for PCI, 66.0 ± 27.1 minutes for PPMI, and 113.6 ± 25.9 minutes for PVI, and a statistically significant difference was found between the groups in the direction of PVI ($P < .001$). The postoperative scrub workload was 3.3 ± 1.0 minutes in CA cases; 4.0 ± 1.0 minutes in PCI, 7.3 ± 2.2 minutes in PPMI, 8.6 ± 8.6 minutes in PVI, and the difference was found to be statistically significant ($P < .001$). It was determined that the total scrub workload was higher in PVI with 129.8 ± 29.7 minutes compared to other groups ($P < .001$).

Workloads of circulating nurses are presented in Table 4. The preoperative circulating workload was 8.9 ± 3.74 minutes in CA, 11.0 ± 4.04 minutes in PCI, 15.6 ± 5.07 minutes in PPMI, and 11.2 ± 3.11 minutes in PVI. The preoperative circulating workload in the PPMI group was found to be higher than the other groups ($P < .001$). Intraoperative circulating workload (CA, PCI, PPMI, and PVI, respectively) were 0.5 ± 0.5, 20.5 ± 26.4, 4.2 ± 2.3, and 15.8 ± 9.6 minutes, and the workload in PCI was found to be higher than the other groups ($P < .001$). Postoperative

Table 1. Cardiac Catheterization Laboratory Nursing Activities

Flow	Duty	Cardiac Catheterization Laboratory Nursing Activities	Workload (minutes)
Preoperative	**Scrub**	1. Wearing lead shielding devices for radiation safety 2. Surgical preparation (hand scrubbing, mask, cap, sterile gown), procedure table preparation (sterile table preparation, washing of catheters-sheath to prevent air embolism, local anesthetic drug preparation, etc.) 3. Procedure area antisepsis and covering 4. Placing lead shielding panels and devices, sterile covering 5. Manifold preparation, contrast media preparation, air control in the set, placing the angiography device in the HEAD side position, radiation dose adjustment of the device, guide wire and other devices preparation 6. Assisting the physician in donning of sterile attire	
	Circulating	1. Request and delivery of the patient from ICU, checking the standard preoperative patient medical records and the checklist 2. Placing and positioning the patient on the table, informing about the procedure connecting the patient to the monitor, recording the vital signs 3. Patient entry to the angiography device 4. Wearing lead shielding devices 5. Administering the requested drug treatment 6. Supply and preparation of material-drug necessary for the procedure 7. Assisting scrub personnel in donning sterile attire	
İntraoperative	**Scrub**	1. Time-out: Patient identity, procedure, signed consent, allergy, antibiotic, procedure area, approval of pre-wash, special equipment needs supply, etc. 2. Simultaneous procedures (assisting the physician, catheter manipulation, movements of the angiography device and procedure table, settings of the imaging angles, administration of contrast media, dose tracking of the given contrast agent, monitoring of the cardiovascular and hemodynamic status of the patient, communication with the patient) 3. Emergency (cardiac arrest, respiratory arrest, vagal reaction, etc.) and complication management (directing the team, ensuring patient and team safety)	
	Circulating	1. Administering procedural sedation and patient monitoring, providing nasal O_2 support 2. Supply and preparation of additional drugs ordered during the procedure 3. Supply of necessary additional equipment	
Postoperative	**Scrub**	1. Removing patient covers, informing and educating the patient 2. Postoperative procedure area management (placement of radial pressure dressing and site cleaning for radial interventions; Dressing closure on sheath and site cleaning for brachial interventions; Closure with sheath fixation suture and site cleaning for femoral interventions), compression and dressing 3. Left/right pectoral area cleaning and dressing for permanent pacemaker implantation 4. Switching device location to PATIENT TRANSFER mode	
	Circulating	1. Patient transfer, patient delivery to ICU or service nurse after the procedure 2. Taking records of the procedures in the nurse observation form (procedure, bleeding, complications, drugs administered, vital signs, presence of sheath, etc. catheter left on the patient) 3. Sending image records to the PACS system, printing on a CD, deleting the patient record from the angiography device for the next procedure, entry of consumables, drugs, etc on the PROBEL system, records of non-consumable equipment 4. Preparation and control of CCL for the next operation (waste management, cleaning)	

circulating workloads (CA, PCI, PPMI, PVI, and respectively) were 5.8 ± 1.9, 11.6 ± 5.8, 14.6 ± 2.8, and 32.7 ± 15.2 minutes, and the workload was higher in PVI ($P < .001$). Similarly, the total circulating workload was found to be higher in PVI with 59.7 ± 19.8 minutes compared to other groups ($P < .001$).

The total workloads of CCL scrub and circulating nurses according to the procedures are provided in Table 5. The perioperative workload was found to be 34.7 ± 9.5 minutes for CA, 91.2 ± 51.9 minutes for PCI, 124.6 ± 28.7 minutes for PPMI, and 187.3 ± 45.8 minutes for PVI. It was established that the type of intervention with the highest total workload was PVI, and the difference between the groups was statistically significant ($P < .001$). In CAs, 48.1% of the total nurse workload was related to preoperative preparations. The effect of intraoperative workload on total workload was 25.3% for the CA group, 59.7% for PCI, 56.4% for PPMI, and 67.9% for PVI. The percentage of postoperative

JERN 2022; 19(2): 208-219
DOI:10.5152/jern.2022.01328

Table 2. Clinical data for interventional procedures

Procedure Groups	Number of Cases n (%)	Anesthesia-sedation: Local-only n (%)	Anesthesia-sedation: Local+ conscious sedation n (%)	Contrast media volume: <100 ml n (%)	Contrast media volume: 100-199 ml n (%)	Contrast media volume: >200 ml n (%)	Vessel Type: TFA n (%)	Vessel Type: TBA n (%)	Vessel Type: SV n (%)	Procedure time: Total procedure time (Minute) Mean±SD (min-max)	P	Procedure time: Operation time (Minute) Mean±SD (min-max)	P	Room turnover time Ort ± SD (min-max)
CA	19 (48.7)	19 (100.0)	0 (0.00)	19 (100.0)	0 (0.00)	0 (0.00)	19 (100.0)	0 (0.00)	0 (0.00)	23.8±8.9 (15.0-56.0)	<0.001	7.15±2.80 (4.0-15.0)	<0,001	9.1±2.7 (6.0-15.0)
PCI	7 (17.9)	6 (85.7)	1 (14.3)	0 (0.00)	5 (71.4)	2 (28.5)	7 (100.0)	0 (0.00)	0 (0.00)	51.7±22.5 (31.0-95.0)		34,4±23,17 (16.0-77,0)		15.6±6.6 (6.0-25.0)
PPMI	8 (20.5)	0 (0.00)	8 (100.0)	2 (25.0)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	8 (100.0)	90.2±25.2 (65.0-130.0)		61.93±22.6 (41.0-96.0)		22.0±3.7 (15.0-27.0)
PVI	5 (12.8)	3 (60.0)	2 (40.0)	0 (0.00)	1 (20.0)	4 (80.0)	5 (100.0)	2 (5.12)	0 (0.00)	140.6±30.8 (105.0 -180.0)		111.6±26.2 (80.0-142.0)		41.3±20.1 (20.0-70.0)
Total	39 (100)	28 (71.8)	11 (28.2)	21 (53.8)	6 (15.3)	6 (15.3)	31 (79.5)	2 (5.12)	8 (20.51)					

Procedure groups: CA: Coronary angiography / PCI: Percutaneous coronary intervention / PPMI: Permanent pacemaker implantation / PVI: Peripheral vascular intervention
Vessel Type: TFA: Transfemoral artery / TBA: Trans-brachial artery / SV: subclavian vein
Total procedure time: Time between patient's entry and exit to CCL
Operation time: Time between vascular access and the end of the procedure
Room turnover time: The time from the end of the procedure to the exit of the patient from CCL (*Calculated through the total workload of postoperative scrub + circulating nurses*)
P: Anova Test , <0.001
Post HOC Analyses: As a result of the Post Hoc analyses performed between the two group averages in terms of total procedure time and operation time, it was determined that CA had the shortest time while PVI had the longest.

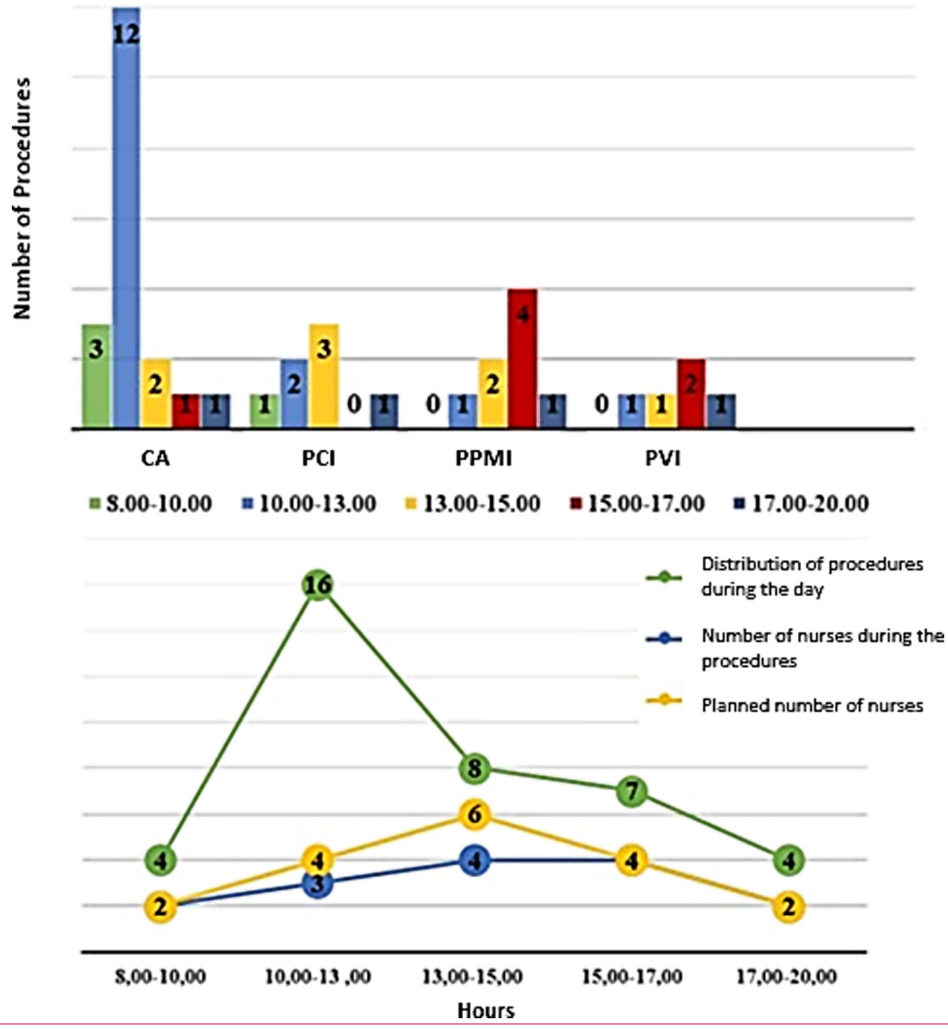

Figure 1 . The distribution of the procedures according to the time intervals during the day, the number of actual and planned nurses. CA: coronary angiography; PCI: percutaneous coronary intervention; PPMI: permanent pacemaker implementation; PVI: peripheral vascular intervention.

workload effect on total workload was determined to be 26.2% in CA and 22.0% in PVI. The mean "scrub and circulating nurse workloads" of 39 observed procedures were found to be 82.89 ± 61.76 (min: 21.00 and max: 234.00) minutes.

The distribution of CCL total nurse workload, total procedure time, and operation time are provided in Figure 2. Circulating + scrub total workload was 4.8 times the total procedure time in the CA group and 1.4 times the operation time. These values were 2.6 and 3.8 for PCI, respectively; 2.0 and 1.3 for the PPMI group; 1.6 and 1.3 for PVI

In addition to the workloads described above, the average workload, which was obtained after a 5-day observation of the "unit general preparation procedures" performed by the nurses at the start of the working day, was found to be 31.8 minutes.

Discussion

Coronary angiography and PCI were the most frequently performed procedures in CCL where the study was conducted. Similar to the study group, although the variety of procedures performed in cardiac catheterization laboratories differ depending on factors such as the conditions of the facility where the procedures are performed, operator experience, and procedure volumes, the most frequently performed procedures are CA and PCI. The main reasons why these procedures are often performed in CCL can be summarized as follows: 1. The increased prevalence of coronary artery disease; 2. The progressive nature of the illness; 3. The fact that CA and PCI are important options for the diagnosis, and treatment of coronary artery disease.[2,9]

Anesthesia Sedation

Although interventional cardiovascular procedures are minimally invasive and short, they cause anxiety, pain, and discomfort in patients. Therefore, different sedation and analgesia techniques such as procedural sedation, local anesthesia, or a combination are performed in CCL depending on the procedure type, patient needs, and operator experience. In the study group, all CA procedures and the majority of PCI and PVI were performed with local anesthesia only and sedation was not required. Conscious sedation was applied with

Table 3. Cardiac catheterization laboratory scrub nurse workload analysis and comparisons between groups

		Preoperative scrub nurse workload (Minute)		Intraoperative scrub nurse workload (Minute)		Postoperative scrub nurse workload (Minute)		Total (Preop.-Intraop.-Postop.) Scrub nurse workload (Minute)	
Procedure Group	n	Mean.±SD (Min-Max) Median	KW (X^2) P*	Mean.±SD (Min-Max) Median	KW (X^2) P*	Mean.±SD (Min-Max) Median	KW (X^2) P*	Mean.±SD (Min-Max) Median	KW (X^2) P*
CA	19	7.7±3.1 (3.0-16.0) 8.50	17.4 <0.001	8.1±3.0 (5.0-15.0) 7.50	29.61 <0.001	3.3±1.0 (2.0-5.0) 3.5	22.61 <0.001	19.2±5.61 (13.0-35.0) 18.00	30.81 <0.001
PCI	7	10.0±3.6 5.0-14.0 10.00		34.0±25.3 (7.0-81.0) 21.00		4.0±1.0 (3.0-5.0) 4.00		48.0±24.6 (25.0-96.0) 38.00	
PPMI	8	16.6±4.7 11.0-24.0 15.00		66,0±27,1 (43,0-112,0) 53.75		7.3±2.2 (4.0-11.0) 7.00		90.0±27.0 (64.0-131.0) 77.00	
PVI	5	7.6±2.3 5.0-10.0 7.00		113.6±25.9 (82.0-144.0) 117.0		**8.6±8.6** (5.0-20.0) 6.00		**129.8±29.7** (94.0-169.0) 133.00	

Procedure groups: CA: Coronary angiography / PCI: Percutaneous coronary intervention / PPMI: Permanent pacemaker implantation / PVI: Peripheral vascular intervention
P*: Kruskal-Wallis Test, <0.001
Post Hoc Analyses: As a result of Post Hoc analyses performed between two groups, the highest Preoperative scrub workload was found in PPMI, the highest Intraoperative scrub workload was in PVI, the highest Postoperative scrub workload was in PPMI, and the lowest Total Scrub workload was in CA, the highest was in PVI.

local anesthesia in all permanent pacemaker applications and nearly half of PVI. Unlike the study results, the study of Lavi et al[10] found that sedation was used more often (50% in CA and PCI, 53.1% in PPMI, and 33.6% in PVI).[10] Although an anesthesiologist is required to be on duty in CCL where especially more complex and long-term procedures are carried out, this practice is usually performed by nurses due to the absence of an appointed anesthesiologist or due to economic reasons, and it is called "nurse-administered procedural sedation

Table 4. Cardiac catheterization laboratory circulating nurse workload distributions and comparisons between groups

		Preoperative circulating nurse workload (Minute)		Intraoperative circulating nurse workload (Minute)		Postoperative circulating nurse workload (Minute)		Total (preop.-intraop.-postop.) circulating workload (Minute)	
Procedure	n	Mean±SD (Min-Max) Median	KW (X^2) P*	Mean±SD (Min-Max) Median	KW (X^2) P*	Mean±SD (Min-Max) Median	KW (X^2) P*	Mean±SD (Min-Max) Median	KW (X^2) P*
CA	19	8.9±3.74 (4.0-15.0) 8.00	11.05 <0.001	0.5±0.5 (0.0-2.0) 0.50	29.40 <0.001	5.8±1.9 (3.0-10.0) 6.00	24.72 <0.001	15.3±4.5 (8.0-25.0) 15.00	26.16 <0.001
PCI	7	11.0±4.04 (6.0-15.0) 11.00		20.5±26.4 (2.0-70.0) 10.00		11.6±5.8 (3.0-20.0) 10.00		43.2±30.2 (14.0-95.0) 34.00	
PPMI	8	15.6±5.07 (10.0-26.5) 15.00		4.2±2.3 (1.0-8.0) 5.00		14.6±2.8 (8.0-18.0) 15.00		34.6±6.2 (27.5-44.5) 34.00	
PVI	5	11.2±3.11 (8.0-15.0) 12.00		15.8±9.6 (7.0-30.0) 15.00		32.7±15.2 (15.0-50.0) 26.00		59.7±19.8 (35.0-89.5) 55.00	

Procedure groups: CA: Coronary angiography / PCI: Percutaneous coronary intervention / PPMI: Permanent pacemaker implantation / PVI: Peripheral vascular intervention
P*: Kruskal-Wallis Test, <0.001
Post Hoc Analyses: As a result of the Post Hoc analyses performed between two groups, the highest Preoperative circulating nurse workload was found in PPMI, the highest Intraoperative circulating nurse workload was in PVI, the highest Postoperative circulating nurse workload was in PVI, and the highest total circulating nurse workload was in PVI.

Table 5. Total workloads of scrub and circulating nurses in preoperative, intraoperative, and postoperative periods

	Preoperative period		Intraoperative period		Postoperative period		Perioperative period		
Procedure groups	Scrub+circulating total workload (minute)	Preoperative workload contribution to the total workload	Scrub+circulating total workload (minute)	Intraoperative workload contribution to the total workload	Scrub+circulating total workload (minute)	Postoperative workload contribution to the total workload	Scrub+circulating total workload (minute)	Comparison of total workload between procedures	The ratio of total nurse workload to operation times
	Mean±SD (min-max) Median	(%)	Mean±SD (min-max) Median	(%)	Mean±SD (min-max) Median	(%)	Mean±SD (min-max) Median	KW (X^2) P*	
CA (n=19)	16.7±6.5 (7.0-31.0) 16.50	48.1	8.8±3.1 (5.0-15.0) 8.00	25.3	9.1±2.7 (6.0-15.0) 8.50	26.2	34.7±9.5 (21.0-60.0) 34.50	30.02 <0.001	(34.7÷7.15) 4.85
PCI (n=7)	21.0±6.0 (13.0-29.0) 20.00	23.0	54.5±50.2 (11.0-151.0) 31.00	59.7	15.6±6.6 (6.0-25.0) 15.00	17.1	91.2±51.9 (52.0-191.0) 68.00		(91.2÷34.4) 2.65
PPMI (n=8)	32.3±8.9 (25.0-50.0) 28.50	25.9	70.3±27.4 (45.0-117.0) 59.25	56.4	22.0±3.7 (15.0-27.0) 22.25	17.6	124.6±28.7 (92.5-161.0) 110.50		(124.6÷61.,9) 2.01
PVI (n= 5)	18.8±3.5 (13.0-22.0) 20.00	10.0	127.2±29.7 (89.0-151.0) 147.00	67.9	41.3±20.1 (20.0-70.0) 32.00	22.0	187.3±45.8 (129.0-234.0) 201.00		(187.3÷111.6) 1.67

Procedure groups: CA: Coronary angiography / PCI: Percutaneous coronary intervention / PPMI: Permanent pacemaker implantation / PVI: Peripheral vascular intervention
P*: Kruskal-Wallis Test, <0.001
Post Hoc Analysis: As a result of the Post Hoc analyses performed between two groups, the lowest "Perioperative Scrub+circulating total workload" was found in CA and the highest was in PVI.

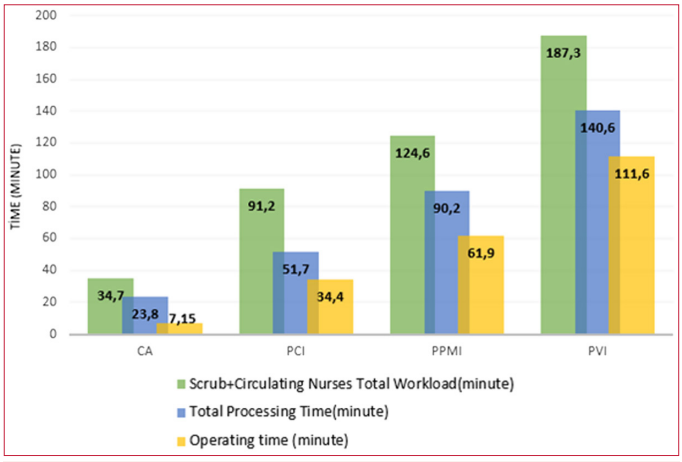

Figure 2. Distribution of total nurse workload, total procedure times and operation times in different procedures in CCL.

analgesia." In the study conducted by Convay et al[11], it was established that nurse-administered procedural anesthesia was much more common than anesthesiologist-directed sedation, especially in CA, PCI, and PPMI procedures in Australia and New Zealand.[11] In the CCL where the present study was conducted, procedural sedation was performed by nurses under the supervision of a physician. This situation makes it necessary for nurses working in CCL, where there is no anesthesiologist, to have knowledge and skills on procedural sedation, emergency management, drugs used, and patient monitoring. The issue should also be considered as a factor that increases the workload of CCL nurses.

Contrast Media

Since the contrast agent used in interventional cardiovascular procedures is excreted through the kidneys, it may cause damage to these organs. Although the risk of procedure-related, contrast-induced nephropathy varies depending on the type, concentration, and volume of the contrast media and patient comorbidities, the risk increases as the amount increases.[12] Cardiac catheterization laboratories nurses must assess and monitor the hydration status of patients during the perioperative period in terms of the relationship between contrast media volume, fluoroscopy time, and contrast-induced nephropathy. In the study by Pijls et al[13], contrast media volume for PCI was found to be higher with an average of 302 mL compared to the present study. Similar to our study data, contrast media volume for PCI was 185 mL (radial: 178 mL, femoral: 186 mL) in the study by Feldman et al[14] and 197.4 for PCI and 103.2 mL for CA in another study.[15] On the other hand, in the study by Kalish et al[16], the contrast volume reported for PVI was found to be less than the present study with 100 mL.

Vessel Type

Vessel selection for the procedures is determined according to the anatomical structure, patient needs, and physician preference. Although transfemoral artery (TFA) cannulation is traditionally preferred, there has been an increase in transradial artery (TRA) access in recent years.[17] It was observed that in CCL where the study was conducted, physicians preferred TFA as an intervention area. Similar to these results, there are studies in the literature in which TFA is used more often. In 1 study[14], this rate was 93.6%, and in the study by Dehmer et al[15], TFA was used in 92.7% of PCI and 91.2% of diagnostic procedures. However, different from our study results, recent studies showed that TRA route was used more. It was reported that TRA was used in 45% of PCI in the study by Ratib et al[18], in 85% of PCI in another study,[19] in 58.6% of CA and 42.8% of elective PCI in the study of Cağın et al.[20]

Total Procedure Time and Fluoroscopy Time

It was found that PVI was the procedure with the longest total procedure time and fluoroscopy time while CA was the shortest procedure type. Whether the procedure is diagnostic or interventional and the number of vessels and lesions treated in interventional procedures affect the duration of the procedure. In addition, different from single-vessel or single-lesion procedures, multi-vessel procedures double the procedure time. This may explain the differences in procedure times between the groups in the study. These differences between the varieties of the procedures in terms of the duration are an important aspect that should be considered when planning the need of the nurse on duty. Different from our study results, fluoroscopy time was found to be rather short in the study by Feldman et al[14] with 11.3 minutes in PCI, in the study of Dehmer et al[15] with 4.9 in CA and 14.5 in PCI, in the study by Fazel et al[21] with 2.6 minutes in CA and 10.1 minutes in PCI. When the time differences for PVI were assessed, the fluoroscopy time was determined to be 16 minutes in 1 study.[16] In another study on aortoiliac angioplasty and stenting procedures, the total operation time was 83.4 minutes and the fluoroscopy time was 27 minutes, and in a series of 2500 cases, the fluoroscopy time was found to be much shorter with 34.5 minutes compared to our study.[22,23] These results suggest that fluoroscopy times were longer in the CCL where the study was conducted compared to similar study results. Long fluoroscopy times should be assessed in terms of contrast media volume used for the patient and contrast-related adverse effects. In addition, it is necessary to examine the effect of long fluoroscopy times on "long-term small dose" occupational radiation exposure among staff and to consider it as a factor that increases the workload of nurses. In this study, we assessed the effect of fluoroscopy times on nurse workload with the formula "intraoperative nurse workload/total nurse workload." It was established that this effect was more than 50% in PCI, PPMI, and PVI procedures with a long intraoperative period. Physician experience–procedure volume relationship, which can lead to long fluoroscopy time, should also be considered in terms of the effectiveness and efficiency of CCL.

Distribution of Procedures and Nurses' Numbers According to Time Intervals

It was determined that nearly half of the procedures performed in CCL where the study was conducted were mostly between 10 AM and 1 PM and the majority of these procedures were CA. The number of nurses present in the unit at this time interval was 3. Although it was planned to have 6 nurses in the unit between the hours of 1 PM and 3 PM according to the routine work plan of CCL where the study was conducted, the number of procedures decreased to 8 at this time interval and there were 4 nurses in the unit during the work period. Similarly, although the number of procedures decreased to 7 between 3 PM and 5 PM, the planned and actual number of nurses was 4. When these data were evaluated, it was observed that there was a difference between the actual and planned number of nurses due

to reasons such as leave report, etc., and there was an inconsistency between the number of procedures and the number of nurses at the time intervals. Regarding these results, it could be concluded that the CCL, where the study was conducted, should be reinforced with more nurses during the 8 AM to 1 PM time interval when more procedures were performed, and the shifts should be rearranged accordingly. In this regard, it is recommended that the "number of nurses and shift planning" in CCL be arranged during the day according to the time intervals with high procedure volume. In the study by Reed et al[24] on increasing the efficiency of CCL, it was stated that the productivity of the nurses was improved after changing their work schedule from block to pyramidal system, and after setting back the laboratory work hours to 7.30 A.M. They also reported that with these changes, about 80% of the cases could be completed by 15.30 P.M. In the same study, the main reasons for procedure start time delays were identified as the insufficient number of nurses in the early hours of the day and communication problems within the CCL team. This problem was resolved by switching the number of nursing staff to a pyramidal scheduling structure.[24]

Cardiac Catheterization Laboratory Nurse Workloads

When the workloads for the determined practice areas of scrub nurses during the preoperative preparation process were examined, the longest scrub preparation time was found to be in the PPMI group. We believe that this difference is due to additional activities such as surgical hand scrubbing and assisting the operator in donning a sterile gown in PPMI, unlike other semi-sterile procedures. The duties of the intraoperative scrub nurse are instrumentation to the physician and simultaneous device manipulations during the procedure. In parallel with the fluoroscopy times, the lowest scrub nurse intraoperative workload was in the CA group and the highest was in PVI. When the workloads of the 6 practice areas that determine the postoperative scrub nurse workload were examined, the highest workload was found to be in the PVI group. This difference is because the scrub nurse assists the circulating nurse in cleaning the area intended for the operation site, dressing, and applying pressure dressing to prevent bleeding hematoma. In the study, the total average workload of scrub nurses was found to be higher in interventional procedures for treatment. Total scrub nurse workload in PVI was statistically significantly higher than the other 3 groups. The main reason for this difference is the length of fluoroscopy time and postoperative workload in this group. It is necessary to consider these time differences in staff planning of the scrub nurses in CCL where multiple laboratories exist and different interventions are performed. In addition, PVI procedures should be carefully assessed in terms of occupational radiation exposure associated with long fluoroscopy time, specific protection measures (protective equipment, filtration, the lowest dose possible, etc.), and radiation monitoring. Although studies in this area are generally discussed in terms of radiation exposure of the patient and the operator, it is also necessary to evaluate the situation in terms of scrub nurses.

When the preoperative workloads of circulating nurses were assessed, the shortest workload was in CA and the longest was in PPMI. This difference is due to the responsibilities of circulating nurses in preparing and administering drugs for sedation, providing nasal O_2 support to the patient since all PPMI procedures are performed with local anesthesia + conscious sedation, and due to the additional activities such as assisting the operator and scrub nurse in donning of sterile attire. The highest average intraoperative workload of circulating nurses was in the PCI group. This workload was associated with the presence of the circulating nurse in the operating room during the procedure in PCI, wearing lead shielding devices for emergency response, and drug-material supply following the protocols of the CCL where the study was conducted. When the postoperative workloads of the circulating nurses were evaluated, the shortest workload was in the CA group and the longest was in the PVI group. This workload difference is associated with the use of more numerous and expensive materials (thrombotic catheter, microcatheter, drug-eluting balloons, stent-grafts, specific guide wires, long sheaths, etc.) in PVI. Since the procedure records of these materials are detailed, they require a longer time. In addition, after PVI, circulating nurses work together with the scrub nurse for area closure (pressure dressing, raising-holding the patient's foot, etc.). These additional activities increase the postoperative circulating workload in PVI. When the total average workloads of circulating nurses were assessed, the highest value was found in the PVI group. Higher total circulating workload in PVI compared to the other 3 groups is especially associated with the excessive workload in the postoperative period.

The number of circulating nurses participating in the study was recorded. There was only 1 circulating nurse in 35.8% of the procedures. The number of circulating nurses was usually 2. There were 3 nurses in 1 procedure and 4 nurses in 1 procedure (in the preoperative phase of PVI). The more resources assigned to a task, the faster the procedure is completed. For this reason, it should be considered that circulating workload times will be longer in procedures where only 1 circulating nurse is included.

The shortest total workload of the cardiac catheterization laboratory scrub and circulating nurses was in the CA group and the longest was in the PVI group. In CA procedures, the effect of the preoperative workload on total nurse workload for the procedure was found to be 48.1%. In other interventional procedures, the effect of the intraoperative period on total workload was determined to be high. This situation is related to the effect of fluoroscopy times on the scrub nurse intraoperative workload, and as the fluoroscopy times gets longer, the nurse workload increases.

In addition to the mean total workload times (82.8 minute) found in this study, the mean workload of the general procedures performed by CCL nurses at the start of the working day was found to be 31.8 minutes. In this regard, the total mean workload was found to be 114.6 minutes, and this value was close to the mean workload of 103 minutes found in the study of Amorosoa et al.[25] "Diagnostic procedures" workload (65 minutes) and therapeutic procedures workload (131 minutes) reported in the same study were determined to be higher than the nurse workload in CA and PCI procedures in our study. This difference may be related to the method used in the workload calculation, the number of circulating nurses participating in the procedure, and the nursing activities assessed in the workload calculation. They also found that the average nurse workload time was 86 minutes for TRA access and 174 minutes for TFA access. They determined that CCL nurse workload was shorter in radial access, in elective procedures, in patients who underwent diagnostic procedures only, and in single-vessel PCI applications. They reported the independent determinants that increase the nurse workload as femoral access, failed radial access, multivessel interventions, interventional procedures, procedure time, and emergency procedures.[25]

In the study of Reed et al[24] on CA and PCI cases, room turnover time between cases (the time between the previous patient's discharge and the next patient's arrival at CCL) was found to be 20.5 minute for 2013, and after the improvements, it fell below the target <17 minutes in 2016 with 16.4 minutes. In this study, room turnover time was assessed through the total postoperative nurse workload. This time was 9.1 minutes in CA, 15.6 minutes in PCI, 22.0 minutes in PPMI, and 41.3 minutes in PVI. When the 2 studies were compared, it could be stated that the room turnover time was longer, especially in PPMI and PVI, and the number of circulating per operation should be increased to bring the operational efficiency closer to the desired levels. In the same study,[24] for the effectiveness and efficiency of CCL, nurses were asked to fill out a form in case of a room turnover time of >22 minutes and explain the reason for it. The reasons for the increased time between cases were identified as delays in patient preparation and recovery area (e.g. delays due to reasons such as signing the consent form, insertion of an intravenous catheter, and patient using the restroom). In addition, they found that communication problems among CCL nurses also caused delays. The reasons for the delays in the patient transfer were established as delays caused by the insufficient number of beds in the postoperative recovery room or service, delays in verbal communication and reporting between CCL and service nurses, and changes in the number of nurses working shifts. To avoid these delays, 3 nurses (or 2 nurses and a technician) were appointed to each CCL room with clearly defined duties (1 for admission of the new patient, another for the transfer of the old patient, and the third nurse to assist with the room turnover).[24] In our study, no data were collected on the reasons that block the flow of the procedures in CCL, and it is evident from the experience of researchers that similar problems are experienced from time to time. Therefore, it is recommended that further research be undertaken in this area.

When the results in Figure 2 and Table 5 were examined, CCL nurse workload was found to be higher than both the total procedure time and fluoroscopy times. This analysis can provide a better understanding of CCL nurse workload and help managers accurately define the workload when assigning nurses to CCL.

Conclusion

The total procedure times and fluoroscopy times of the procedures observed in the CCL where the study was conducted were found to be longer than the times in similar studies in the literature. Fluoroscopy times have a significant effect on nurse workload, especially in PCI, PPMI, and PVI. Fluoroscopy times closer to standard times will have an effect that reduces the workload. In addition, factors that affect the prolongation of fluoroscopy time such as the effect of long procedure times on the occupational radiation exposure of nurses and the vessel type used need to be examined in other studies.

There was a clear inconsistency between the procedure volumes and the planned number of nurses in the CCL where the study was conducted. We anticipate that if the 8 AM-3 PM time interval, in which 71% of the procedures take place, is supported by at least 4 nurses, the process turnover rates in CA and PVI can be increased. And in this case, long-term interventions such as PPMI and PVI can be pulled to earlier hours. And in this case, long-term interventions such as KPM and PVG can be pulled to earlier hours. Based on the results of the study, it can be stated that the time intervals with high procedure volume during the day and procedure types must be considered when planning the work hours of the nurses and the number of nurses for the relevant time intervals. These regulations are necessary for the efficient use of the workforce already employed in these units which require a great deal of effort.

As a result of the absence of a radiologic technologist and an anesthesiologist in the CCL where the study was conducted, the duties of this personnel were undertaken by nurses and therefore nurse workload increased. In this regard, each CCL should evaluate the duties and responsibilities of non-physician staff, their workloads, and the number of personnel for these workloads.

Room turnover times were found to be longer than those recommended in the literature, especially for PPMI and PVI. Increasing the number of circulating in these procedures will shorten the room turnover times and increase the efficiency of CCL. According to the results obtained from the study, it is recommended to support PPMI in the preoperative period, PCI in the intraoperative period, and PVI in the postoperative period with at least 3 circulating nurses.

The activities carried out by the nurses in the CCL where the study was conducted constituted a much higher workload than the total operation time and fluoroscopy times. Increasing the number of circulating nurses participating in the procedures and planning them as ≥2 will contribute to the sharing of activities, reduce the workload, shorten the room turnover times, and increase laboratory efficiency.

In future studies, it is recommended to examine the factors affecting fluoroscopy times for different interventional procedures, the relationships between "nursing activities, workload, and employment," and the relationships between fluoroscopy times and radiation dose exposures. Studies assessing the factors affecting the efficiency of CCL in terms of effectiveness, cost, health, and manpower planning will contribute to the development of evidence-based standards in this field.

Note: This research was presented as a master's thesis at Biruni University.

Ethics Committee Approval: Ethics committee approval was received for this study from the Biruni University The Non-Interventional Research Ethics Committee date: March 29, 2019, decision no: 2019/27-04.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Ö.K., M.A.; Design – Ö.K., M.A.; Supervision – X.X., X.X.; Resources – X.X.; Materials – X.X.; Data Collection and/or Processing – Ö.K.; Analysis and/or Interpretation – M.A.; Literature Search – Ö.K., M.A.; Writing Manuscript – Ö.K., M.A.; Critical Review – M.A.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

1. Faxon DP, Williams DO. Interventional cardiology current status and future directions in coronary disease and valvular heart disease. *Circulation*. 2016;133(25):2697-2711. [CrossRef]
2. Ibanez B, James S, Agewall S, et al. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J*. 2018;39:119-177. [CrossRef]
3. Bashore MT, Balter S, Barac A, et al. American College of Cardiology Foundation/Society for Cardiovascular Angiography and Interventions expert

consensus document on Cardiac Catheterization Laboratory standards update. *J Am Coll Cardiol*. 2012;59(23):2222- 2305. [CrossRef]
4. Intersocietal Accreditation Commission (IAC) Standards and Guidelines for Cardiovascular Catheterization Accreditation 2018. Available at: https://www.intersocietal.org/cath/standards/IACCardiovascularCatheterizationStandards2018.pdf.
5. Naidu SS, Aronow HD, Box LC, et al. SCAI expert consensus statement: 2016 Best practices in the cardiac catheterization laboratory: (Endorsed by the cardiological society of India, and sociedad latino americana de cardiologia ıntervencionista; affirmation of value by the Canadian association of ınterventional cardiology–association Canadienne de cardiologie d'intervention). *Catheter Cardiovasc Interv*. 2016;88(3):407-423. [CrossRef]
6. White K, Macfarlane H, Hoffmann B, et al. Consensus statement of standards for ınterventional cardiovascular nursing practice. *Heart Lung Cırc*. 2018;27(5):535-551. [CrossRef]
7. Hinterbuchner L, Coelho S, Esteves R, et al. A cardiac catheterisation laboratory core curriculum for the continuing professional development of nurses and allied health professions: developed by the education working group of the nurses and allied professions committee for the European association of percutaneous cardiovascular interventions (EAPCI) 2016. *EuroIntervention*. 2017;12(16):2028-2030. [CrossRef]
8. World Medical Association. Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310(20):2191-2194. [CrossRef]
9. Masoudi F, Ponirakis A, Lemos J, et al. Trends in U.S. cardiovascular care: 2016 report from 4. ACC National cardiovascular data registries. *J Am Coll Cardiol*. 2017;69(11):1428-1450. [CrossRef]
10. Lavi S, Jolly SS, Bainbridge D, Farah Manji VR, Ronit L. Sedation, analgesia, and anaesthesia variability in laboratory-based cardiac procedures: an international survey. *Can J Cardiol*. 2014;30(6):27-633. [CrossRef]
11. Conway A, Rolley J, Page K, Fulbrook P. Trends in nurse-administered procedural sedation and analgesia across cardiac catheterisation laboratories in Australia and New Zealand: results of an electronic survey. *Aust Crit Care*. 2014;27(1):4-10. [CrossRef]
12. Narula A, Mehran R, Weisz G, et al. Contrast-induced acute kidney injury after primary percutaneous coronary intervention: results from the HORIZONS-AMI substudy. *Eur Heart J*. 2014;35(23):1533-1540. [CrossRef]
13. Pijls NHJ, Fearon WF, Tonino PAL, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary ıntervention in patients with multivessel coronary artery disease. *J Am Coll Cardiol*. 2010;56(3):177-184. [CrossRef]
14. Feldman DN, Swaminathan RV, Kaltenbach LA, et al. Adoption of radial access and comparison of outcomes to femoral access in percutaneous coronary ıntervention an updated report from the national cardiovascular data registry (2007-2012). *Circulation*. 2013;127(23):2295-2306. [CrossRef]
15. Dehmer GJ, Weaver D, Roe MT, et al. A contemporary view of diagnostic cardiac catheterization and percutaneous coronary intervention in the United States: a report from the CATHPCI registry of the national cardiovascular data registry, 2010 Through June 2011. *J Am Coll Cardiol*. 2012;60(20):2018-2030. [CrossRef]
16. Kalish J, Eslami M, Gillespie D, et al. Routine use of ultrasound guidance in femoral arterial access for peripheral vascular intervention decreases groin hematoma rates. *Eur J Vas Surg*. 2015;61(5):1232-1238. [CrossRef]
17. Rao SV, Tremmel JA, Gilchrist IC , et al. Best practices for transradial angiography and intervention: a consensus statement from the society for cardiovascular angiography and intervention's transradial working group. *Catheter Cardio Inte*. 2015;83:228-236. [CrossRef]
18. Ratib K, Mamas MA, Anderson SG, et al. Access site practice and procedural outcomes in relation to clinical presentation in 439,947 patients undergoing percutaneous coronary intervention in the United Kingdom. *JACC-Cardio-Vasc Inte*. 2015;8(1):21-28. [CrossRef]
19. Reed GW, Tushman ML, Kapadia SR. Effective operational management in the cardiac catheterization laboratory. *J Am Coll Cardiol*. 2018;72(20):2507-2517. [CrossRef]
20. Üreyen ÇM, Coşansu K, Vural MG, et al. Is trans-radial approach related to an increased risk of radiation exposure in patients who underwent diagnostic coronary angiography or percutaneous coronary intervention? (The SAKARYA study). *Anatol J Cardiol*. 2019;22(1):5-12. [CrossRef]
21. Fazel R, Curtis J, Wang Y, et al. Determinants of fluoroscopy time for invasive coronary angiography and percutaneous coronary intervention: insights from the NCDRVR. *Catheter Cardio Inte*. 2013;82:1091-1105. (doi: [CrossRef])
22. Staniloae CS, Korabathina R, Yu J, Kurian D, Coppola J. Safety and efficacy of transradial aortoiliac interventions. *Catheter Cardiovasc Interv*. 2010;75(5):659-662. [CrossRef]
23. Manzi M, Cester G, Palena LM, Alek J, Candeo A, Ferraresi R. Vascular imaging of the foot: the first step toward endovascular recanalization. *RadioGraphics*. 2011;31(6):1623-1636. [CrossRef]
24. Reed GW, Hantz S, Cunningham R, et al. Operational efficiency and productivity improvement initiatives in a large cardiac catheterization laboratory. *JACC-CardioVasc Inte*. 2018:1-10. [CrossRef]
25. Amoroso G, Sarti M, Bellucci R, et al. Clinical and procedural predictors of nurse workload during and after invasive coronary procedures: the potential benefit of a systematic radial access. *Eur J Cardiovasc Nurs*. 2005;4(3):234-241. [CrossRef]