






## Special Issue



# Estimation of Supply and Demand for Cardiologists in Korea

Mira Kim , PhD<sup>1,\*</sup>, Kyunghee Chae , PhD<sup>1,\*</sup>, Ju Mee Wang , PhD<sup>2</sup>,  
Arum Choi , PhD<sup>1</sup>, Jang-Whan Bae , MD, PhD<sup>3</sup>, Keon-Woong Moon , MD, PhD<sup>4</sup>,  
and Sukil Kim , MD, PhD<sup>1</sup>

<sup>1</sup>Department of Preventive Medicine, School of Medicine, The Catholic University of Korea, Seoul, Korea

<sup>2</sup>The Korean Cardiac Research Foundation, Seoul, Korea

<sup>3</sup>Department of Internal Medicine, Chungbuk National University Hospital, Chungbuk National University, College of Medicine, Cheongju, Korea

<sup>4</sup>Department of Internal Medicine, St. Vincent's Hospital, The Catholic University of Korea, Suwon, Korea

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### Correspondence to

Sukil Kim, MD, PhD

Department of Preventive Medicine, School of Medicine, The Catholic University of Korea, 222, Banpo-daero, Seocho-gu, Seoul 06591, Korea.

Email: sikimmd@catholic.ac.kr

### Keon-Woong Moon, MD, PhD

Department of Internal Medicine, St. Vincent's Hospital, The Catholic University of Korea, 93, Jungbu-daero, Paldal-gu, Suwon 16247, Korea.  
Email: cardiomoon@gmail.com

\*Mira Kim and Kyunghee Chae contributed equally as first authors.


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### ORCID iDs

Mira Kim 


<https://orcid.org/0000-0002-5286-6012>

Kyunghee Chae 

<https://orcid.org/0000-0003-2030-0847>

Ju Mee Wang 

<https://orcid.org/0000-0002-5125-5949>

Arum Choi 

<https://orcid.org/0000-0002-5532-0103>

<https://e-kcj.org>

## AUTHOR'S SUMMARY

Shortage of cardiologists has become a major concern in addition to a low doctor-to-population ratio in Korea compared to Organization for Economic Cooperation and Development average. We estimated supply and demand for cardiologists based on inflow and outflow of cardiologists and temporal changes in the volume of cardiac services. Findings revealed an increasing demand but a diminishing supply, highlighting the need for additional cardiologists. By 2032, 561 more cardiologists are estimated to be needed to maintain the same level of cardiac care as in 2022 and the number of emergency patients per cardiologist will increase by nearly 50%.

## ABSTRACT

**Background and Objectives:** The objective of this study was to estimate the supply and demand for cardiologists in Korea and provide evidence for healthcare policy to ensure a stable and adequate workforce for optimal cardiovascular disease management.

**Methods:** Past trends of inflow and outflow of cardiologists were used to make crude projections, which were then adjusted based on demands of services to obtain final projections. Inflow of cardiologists was estimated using second-order polynomial regression and demand for cardiology care was estimated using linear regression.

**Results:** There were 1,139 active cardiologists who were under the age of 65 in clinical practice in Korea. The estimated number of cardiologists from 2022 to 2040 showed that the number of cardiologists would peak at 1,344 in 2032 and gradually decrease thereafter. We also estimated an increase of 947,811 cases of heart-related procedures annually from 2023 to 2032. The number of heart-related procedures per cardiologist would increase 1.4 times from 12,964 in 2023 to 17,862 in 2032. The estimated number of emergency patients per cardiologist under 50 years old would almost double from 544 in 2022 to 987 in 2032.

**Conclusions:** We expect significant shortage of cardiologists in Korea within the next 10 years. The number of emergency patients per cardiologist will increase by nearly 50%, leading to high individual workload for cardiologists. To prevent this imbalance between supply and demand, an organized and collective approach by the specialty of cardiology is imperative to produce a balanced workforce.

**Keywords:** Cardiologist; Health Services Needs and Demand; Workforce

Jang-Whan Bae 

<https://orcid.org/0000-0003-1362-9804>

Keon-Woong Moon 

<https://orcid.org/0000-0003-2726-3209>

Sukil Kim 

<https://orcid.org/0000-0001-9730-9845>

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### Conflict of Interest

The authors have no financial conflicts of interest.

### Data Sharing Statement

The data generated in this study is available from the corresponding authors upon reasonable request.

### Author Contributions

Conceptualization: Kim S, Moon KW, Bae JW; Data curation: Chae K, Kim M, Choi A; Formal analysis: Chae K; Funding acquisition: Kim S; Investigation: Kim S, Moon KW, Bae JW; Methodology: Kim S, Kim M, Chae K, Choi A; Project administration: Kim M, Chae K, Choi A; Resources: Kim M, Chae K, Wang JM, Choi A; Supervision: Kim S, Moon KW, Bae JW; Validation: Kim S, Moon KW, Bae JW, Wang JM; Writing - original draft: Kim M, Chae K, Wang JM; Writing - review & editing: Kim S, Moon KW, Bae JW.

## INTRODUCTION

The number of percutaneous coronary intervention (PCI) per 100,000 populations had increased from 1,342 in 2009 to 1,626 in 2012 and 1,953 in 2019 in Korea.<sup>1)</sup> Among patients who underwent PCI, those aged between 60 and 80 accounted for 67.3% of total cases.<sup>2)</sup> This is a concerning trend, especially considering that the proportion of population aged 65 and over is expected to increase from 15.7% in 2020 to 25.0% in 2030 and 39.8% in 2050 in Korea.<sup>3)</sup>

Despite an average annual growth rate of doctors per 1,000 populations in South Korea of 3.4% between 2000 and 2019,<sup>4)</sup> there is a growing concern regarding a shortage of cardiologists. The demand for cardiology services is increasing. However, the supply of qualified professionals is not keeping pace. In 2019, only 40 internal medicine doctors applied for cardiology fellowships across the country, which was the lowest number in the past decade.<sup>5)</sup> In 2022, only 48 applicants applied for cardiology fellowship training. To exacerbate the situation, 73% of Korean cardiologists have reported experiencing burnout,<sup>6)</sup> which is significantly higher than burnout rates of cardiologists in the USA (35.4%)<sup>7)</sup> and Korean thoracic and cardiovascular surgeons (51.7%).<sup>8)</sup>

Several academic societies and national bodies in the USA,<sup>9)10)</sup> Canada,<sup>11)</sup> and Spain<sup>12)</sup> have investigated supply and demand of cardiology workforces. However, such research has not yet been carried out in Korea. Ensuring an appropriate healthcare workforce is a long-term policy goal. Efficient workforce management is crucial for providing quality care.

The purpose of this study was to estimate the supply and demand for cardiologists, and to provide evidence to inform healthcare policy decisions that will ensure a stable supply and adequate number of cardiologists for optimal management of cardiovascular disease.

## METHODS

### Ethical statement

This study was approved by the Institutional Review Board (IRB) of Seoul St. Mary's Hospital (IRB No. MC22EISI0081). The requirement for written informed consent was waived due to its retrospective nature.

### Data source

Multiple sources of data were used in this study. To determine the number of cardiologists, membership lists of the Korean Society of Cardiology, Korean Society of Interventional Cardiology, and the Korean Association of Internal Medicine were used. To estimate the demand for cardiology care, we used claims data from the Health Insurance Review & Assessment Service (HIRA). HIRA provides information on the volume of heart-related therapeutic and diagnostic procedures performed in Korea.

Procedures used in this study included: 1) estimating the current number of active cardiologists, 2) projecting potential changes in numbers of cardiologists entering and leaving the field (inflow and outflow), and 3) estimating the demand for cardiology care. These projections were based on past trends as well as potential future developments.

## Methods of measurement

### *Current number of active cardiologists*

We defined cardiologists as those who were accredited with the qualification of cardiologist. As of 2022, 1,392 cardiologists were officially registered in the Korean Association of Internal Medicine.

The age and workplace information of cardiologists were needed to estimate the number of cardiologists. However, the list from the Korean Association of Internal Medicine did not have age information. The members list of the Korean Society of Cardiology had age information of some cardiologists. For the rest of cardiologists, we inferred the age based on the graduation year which are usually available at the cardiologists' affiliated hospital websites or directly contacted cardiologists who had consented to share their age information via email.

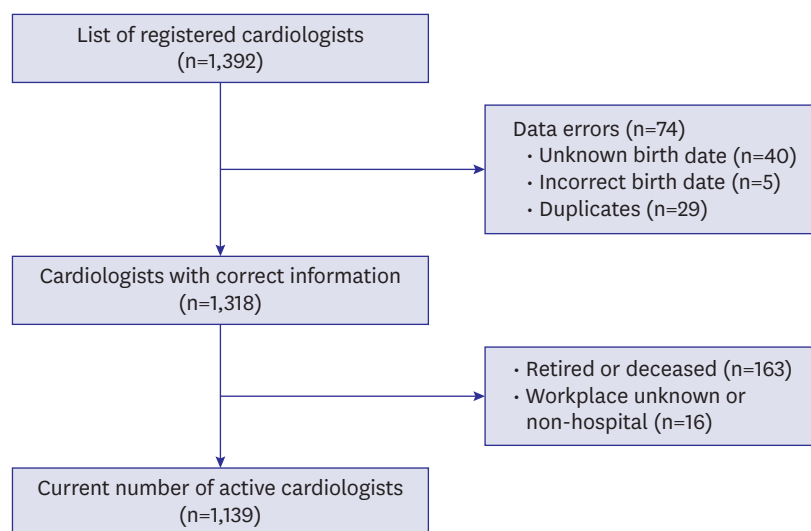
After excluding 74 cardiologists due to unknown or incorrect birth dates and duplicates, data of 1,318 cardiologists were considered valid. Of these, 163 were retired or deceased and 16 had unknown workplace or did not work in a hospital, leaving a total of 1,139 active cardiologists for this study (**Figure 1**).

### *Crude estimates of inflow and outflow/attrition*

The number of physicians who possessed cardiologist board certification from 2002 to 2021 was utilized to forecast the future supply of cardiologists for the period of 2023-2043. Linear regression and second-order polynomial regression were employed in this analysis. The attrition rate was determined based on the number of cardiologists who would reach the retirement age of 65 from 2023 to 2040. However, other reasons for attrition could not be estimated.

### *Estimation of demand for cardiology care*

We selected heart-related therapeutic and diagnostic procedures mainly performed by cardiologists. Two cardiologists reviewed and confirmed the list of the procedures. There were 187 heart-related procedures, among which 65 procedures were included in the analysis since they were found to be mainly performed by cardiologists although these procedures were



**Figure 1.** Current number of active cardiologists.

supposed to be performed by the radiology department (**Supplementary Table 1**). Resource based relative value scale (RBRVS) was used as the weight of each heart-related procedure.

#### *Estimation of demand for emergency care*

The volume of emergency care refers to the number of emergency patients. We used National Emergency Department Information System database, a nationwide emergency medical care database in Korea to estimate the number of emergency patients.

To estimate the number of cardiologists required in the emergency department, the number of patients who visited the emergency room from 2016 to 2019 (excluding data during the coronavirus disease 2019 pandemic) with chief complaints or symptoms of chest pain, dyspnea, palpitations, or fainting was used. Total related sign and symptom code was 156. Detailed code information is shown in **Supplementary Table 2**.

#### *Estimation of the required number of cardiologists*

Firstly, the mean volume of heart-related procedures per cardiologist was calculated based on the number of heart-related procedures performed in 2019. It was assumed that out of 1,155 cardiologists as of 2022, 1,139 active cardiologists (98%) performed heart-related procedures in 2019. Since it was difficult to obtain active cardiologist data in 2019, the number of active cardiologists in 2022 was used. Considering an increasing trend in the number of cardiologists by year, it was estimated that the number of active cardiologists in 2022 would exceed the number of active cardiologists in 2019.

#### *The number of heart – related procedures per cardiologist*

$$= \frac{\text{The volume of heart – related proedures in 2022 (estimates)}}{\text{The number of cardiologist available for heart – related proedures in 2022}}$$

$$12,574 = \frac{14,321,543}{1,139}$$

A total of 12,574 heart-related procedures (weighted value based on RBRVS) were equivalent to the amount of treatment performed by 10,000 electrocardiograms (0.13 RBRVS), 3,000 magnetic resonance imaging (1.39 RBRVS), 600 coronary angiographies (8.19 RBRVS), 50 PCI (24.2 RBRVS), and 20 Radiofrequency Ablation (50.18 RBRVS) in one year (**Supplementary Table 3**).

Next, the demand for cardiology care was estimated using regression analysis based on heart-related procedure data from 2010 to 2019. This analysis was used to predict the number of heart-related procedures for the next 10 years (2023–2032). To calculate the number of additional cardiologists required each year, the estimated number of heart-related procedures was divided by the number of heart-related procedures per cardiologist.

### **Statistical analyses**

Second-order polynomial regression was used to estimate the inflow of cardiologists, and Linear regression analyses was used to estimate the demand for cardiology care. SAS Enterprise Guide 7.12 was used as the statistical analysis tool.

#### *The number of cardiologists required*

$$= \frac{\text{The volume number of heart – related proedures}}{\text{The estimated volume of heart – related procedures per cardiologist}}$$

## RESULTS

### Estimation of supply of cardiologists

The future supply of cardiologists was estimated by adding the inflow to and subtracting outflow from the current active number of 1,139 cardiologists. **Figure 2** shows estimated number of cardiologists from 2022 to 2040. The number of cardiologists will increase until 2032. It will then gradually decrease thereafter. There will be a continuous decrease in inflow from 2022 to 2032, while the outflow increases each year after 2029, with more than 30 cardiologists retiring (outflow) annually. Consequently, the additional number of cardiologists becomes negative in 2032 (**Supplementary Table 4**). The estimated number of cardiologists was calculated using prediction intervals to determine the lower and upper values (**Supplementary Figure 1**).

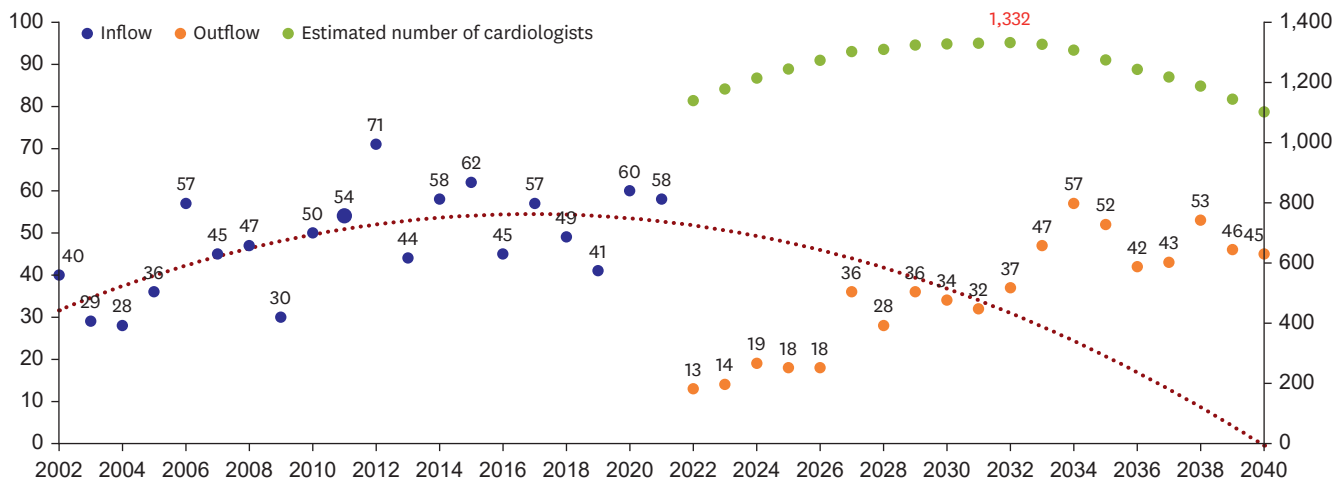
### Estimation of demand for cardiology care services

**Figure 3** displays results of both second-order polynomial regression and linear regression analyses on the estimated volume of heart-related procedures. Although the R-squared value of the polynomial was higher, we chose to adopt the linear equation as a more conservative approach.

Total RBRVS units of heart-related procedures increased from 5 million in 2010 to 17.85 million in 2021. During the same period, the number of patients who received heart-related procedures also increased from 8.8 million to 16.5 million. We predict that the number of heart-related procedures will increase by 947,811 cases annually from 2023 to 2042.

### Estimation of the required number of cardiologists

**Figure 4** shows the estimated number of cardiologists required and the number of heart-related procedures per cardiologist from 2023 to 2032, covering the next 10 years. We made a prediction of the required number of cardiologists assuming that we will continue to receive medical care at the same level as in 2022. Based on the estimated number of cardiologists (1,178) and the number of required cardiologists (1,214), an additional 36 cardiologists will be needed in 2023 and 561 will be required in 2032 to maintain the same level of cardiac



**Figure 2.** Estimated number of cardiologists (2022–2040). The inflow of cardiologists refers to the number of physicians who have passed the cardiologist board certification exam between 2002 and 2021. The outflow of cardiologists is the number of cardiologists who will reach the retirement age of 65 between 2023 and 2040. The estimated number of cardiologists was calculated by adding the inflow to and subtracting the outflow from the current active number of cardiologists.

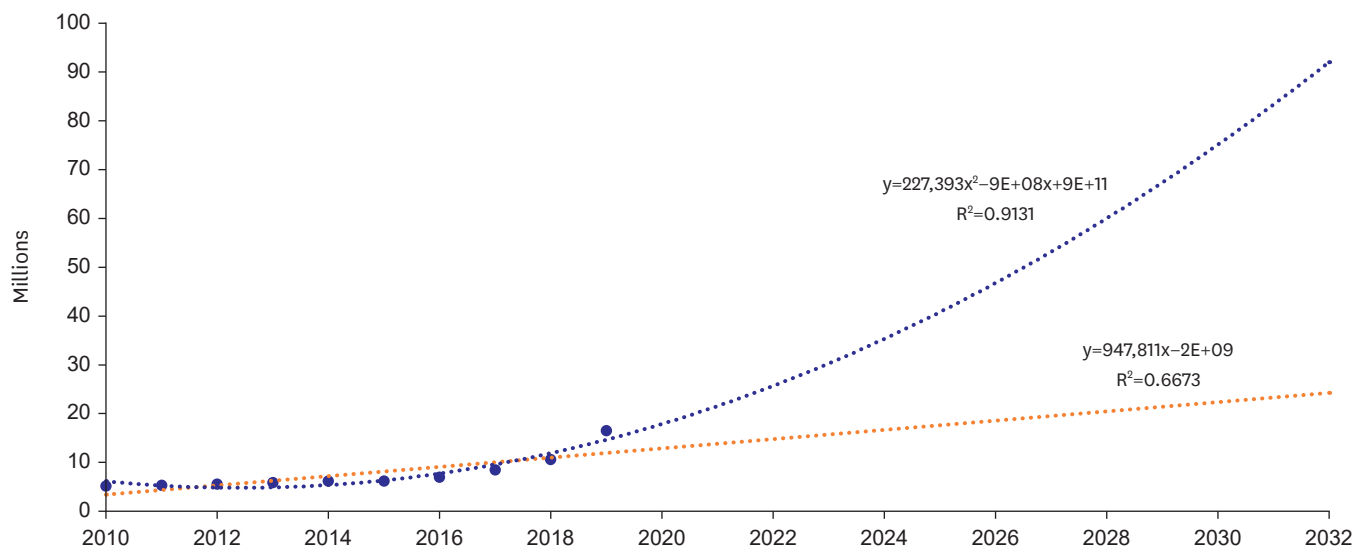


Figure 3. Estimated volume of heart-related procedures. The blue dotted line represents second-order polynomial regression and the yellow dotted line represents linear regression analyses on the estimated volume of heart-related procedures.

care as in 2022. Furthermore, the number of heart-related procedures per cardiologist is expected to increase from 12,964 in 2023 to 17,862 in 2032, representing a 1.4-fold increase in labor intensity of cardiologists. The estimated number of heart-related procedures per cardiologist was calculated using prediction intervals to determine the lower and upper values. (Supplementary Figure 2).

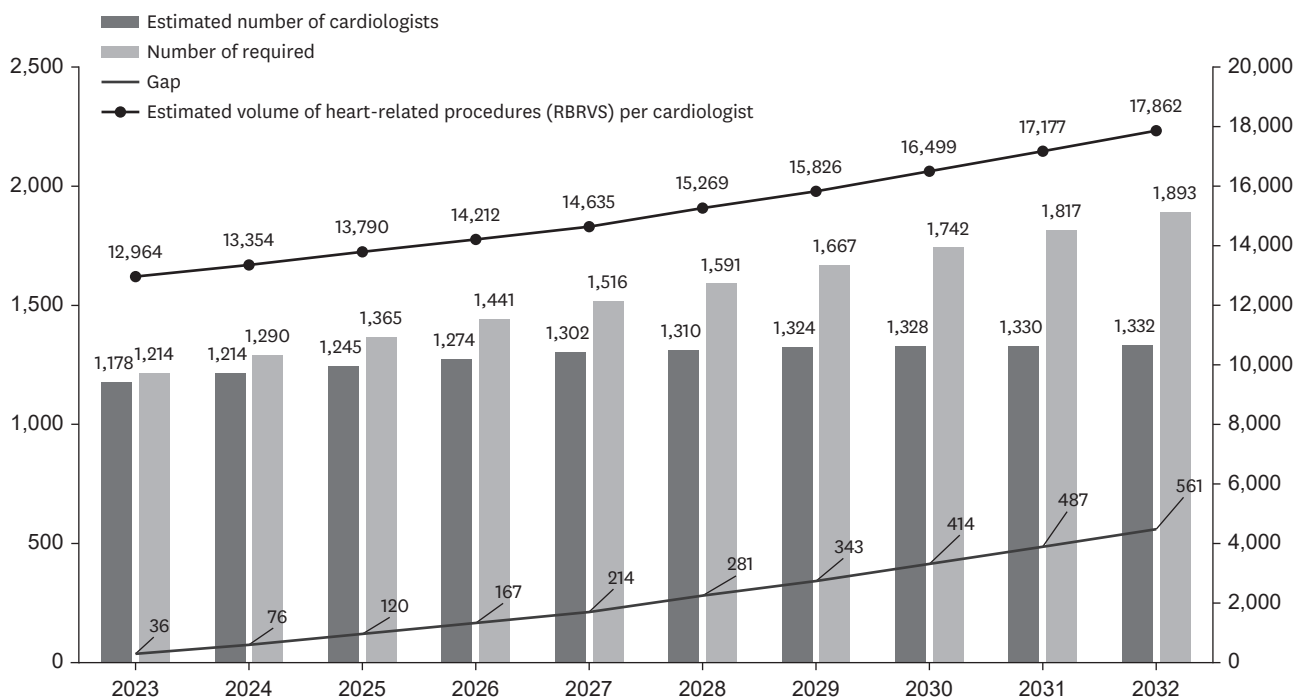
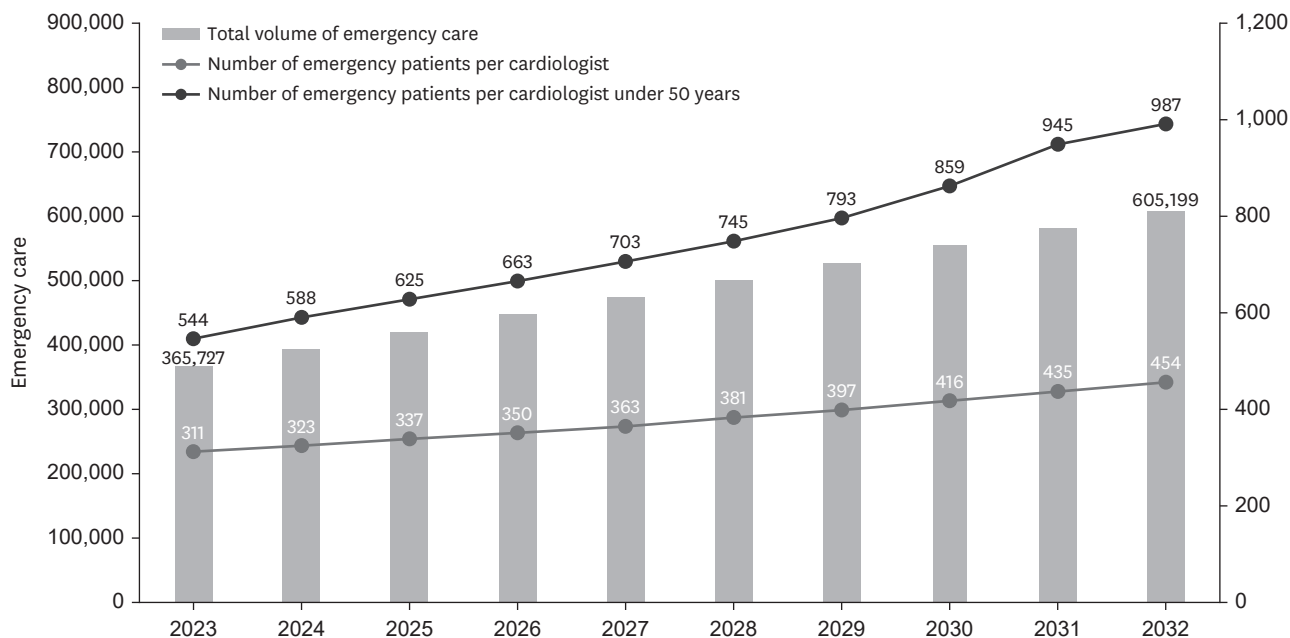


Figure 4. Estimated number of cardiologists required for heart-related procedures and estimated volume of procedures per cardiologist. The dark gray bar represents the estimated number of cardiologists. The light gray bar represents the required number of cardiologists. The gray solid line indicates the gap between the 2. The black solid line represents the estimated volume of heart-related procedures per cardiologist. RBRVS = resource based relative value scale.



**Figure 5.** Estimated number of emergency patients per cardiologist. The gray bar represents total volume of emergency care. The light gray solid line represents the number of emergency patients per cardiologist. The dark gray solid line indicate the number of emergency patients per cardiologist under 50 years old.

### Estimation of the number of emergency care

Unlike treatment of patients with chronic diseases such as cancer, cardiology treatment requires many emergency procedures. Thus, the number of cardiologists must meet the demand for emergency care rather than procedural care.

**Figure 5** shows the estimated number of emergency patients per cardiologist. The estimated number of emergency patients per cardiologist under 50 years old who could be on call 24/7 almost doubled from 544 in 2022 to 987 in 2032.

## DISCUSSION

In 2022, there were 1,139 active cardiologists in Korea, meeting 100% of the estimated national demand. The number of cardiologists is projected to reach its peak of 1,332 in 2032, after which it is expected to gradually decline. Based on the number of cardiologists and the volume of heart-related procedures in 2022, there would be a shortage of 36 cardiologists by 2023 and 561 by 2030. In the next decade, there will be a 166% increase in the number of cardiologists needed to provide cardiac care at the current level. The number of emergency patients per cardiologist will increase by about 50%, leading to high individual workload for cardiologists.

It is important to note that the estimation of the number of cardiologists presented in this study is only a reasonable approximation. There are no official data available for comparison. Currently, there are 3 main sources of information regarding the number of cardiologists in Korea. The first source is the Korean Society of Cardiology, which has data on members who are voluntarily registered. However, it is difficult to identify which members are currently practicing as cardiologists or have never practiced as cardiologists as its data do not show whether members are accredited with the qualification of cardiologist.

The second source is the Korean Society of Interventional Cardiology, which has a register of its members. Since its membership is voluntary, not all cardiologists are included. The register provides realistic information on age and place of work as well as surveys of specific working conditions for cardiologists. Lastly, there might be other data sources available that were not considered in this study, which could provide additional information on the number of cardiologists in Korea.

The Korean Association of Internal Medicine maintains a database of members who have been accredited as cardiologists. However, it's important to note that these members might not necessarily represent the total number of cardiologists in the country. The reason for this is that the qualification of cardiologist must be renewed every 5 years. There might be cases where some cardiologists delay or do not renew their accreditation.

Furthermore, it is important to verify the workplace of cardiologists who are not working in hospitals as they are excluded from active cardiologists. However, there were cases where verification could not be made. Since many cardiologists registered with the Korean Association of Internal Medicine also have membership in other related societies, information on cardiologists held by each organization were compared to update their workplace information. In cases where the workplace did not match despite the same person, the latest workplace information was found by checking the hospital website.

However, only 72.5% of cardiologists were found on hospital websites, with 85.5% of 725 cardiologists in university hospitals, 60.6% of 310 in general hospitals, and 17.8% of 101 in clinics. Cardiologists who could not be verified on hospital websites might not actually work in hospitals (meaning they are not clinically active). As a result, the number of heart-related procedures per cardiologist might have been underestimated. The required number of cardiologists might have been overestimated for the same reason.

While data from the register of cardiologists of the Korean Association of Internal Medicine might have underestimated the real number of cardiologists in Korea, it could still serve as a valuable starting point for addressing the issue of the cardiologist supply in the country.

It is widely acknowledged that there is a shortage of cardiologists in Korea. This problem has been exacerbated by a significant decline in the number of applicants for cardiology training programs. According to data from the Korean Academy of Medical Science, the number of applications for internal medicine training exceeded the available training slots by about 140%.<sup>5)</sup>

However, since then, the number of applicants has steadily decreased. In both 2015 and 2016, less than 100% of total available spaces were filled. Although the application rate has gradually increased since 2017 and now averages at 104%, quota fill rate, the percentage of available quotas or positions that have been successfully filled or occupied, remains slightly below 100%. This suggests that there is still a gap between the number of cardiologists needed and the number of available positions for training.

Efforts to prevent the decline of internal medicine residents include shortening the length of internal medicine residency training period from 4 to 3 years. This resulted in twice as many internal medicine specialists as usual in 2020. However, the number of applications for cardiology subspecialties did not increase.<sup>5)</sup>



The number of cardiologists per million populations is lower in Korea than in other countries. As of 2022, there were only 22.1 cardiologists per million in Korea, whereas there were 41 in German, 59 in Taiwan, and 102 in USA.<sup>13)14)</sup>

The shortage of cardiologists will be further heightened by the increasing age of cardiologists who will be retiring in the coming decade. The average age of cardiologists in Korea was 45.7 years old and more than 76% of respondents aged over 40. Cardiologist between 50–59 years old accounted for 35.4% of active workforce. Those aged 60 years or more make up nearly 7.1%. Overall, while there were some variations in the age distribution of cardiologists by country, there was a trend towards an aging workforce in many countries, potentially leading to a shortage of cardiologists.<sup>15-17)</sup>

Population aging also has a significant impact on the shortage of cardiologists. The elderly population is expected to drive an increased demand for cardiologists because cardiovascular diseases are frequently occurring diseases in the elderly, as identified by the Organization for Economic Cooperation and Development.<sup>18)</sup>

According to the estimates of this study, the number of heart-related procedures in individuals aged 65 and above was 5,509,057 in 2023, and it is projected to increase to 8,066,510 in 2032, representing a 46.4% increase (**Supplementary Figure 3**).

Timely reperfusion therapy is a critical component of treatment for patients with myocardial infarction. Current clinical guidelines emphasize a symptom-to-balloon time of 120 minutes or less and a door-to-balloon time of 90 minutes or less.<sup>19)20)</sup> However, according to studies on current status of PCI in Korea,<sup>21)22)</sup> the median door-to-balloon time was 62 minutes (interquartile range [IQR], 47–82 minutes), indicating that reperfusion treatment was being performed within the recommended time frame, the symptom-to-door time was 94 minutes (IQR, 52–185 minutes). In addition, 29.1% of patients received reperfusion treatment within 2 hours of symptom onset and 54.1% of patients received treatment within 3 hours.

For myocardial infarction patients to receive reperfusion treatment within 2 hours of symptom onset, there must be a hospital within 30 minutes of the patient's location that is capable of providing reperfusion treatment within 90 minutes after the patient arrives. This presents a challenge in Korea, particularly in rural areas where the nearest hospital might be far away, making it difficult for patients to receive timely treatment.

Several limitations need to be addressed when interpreting results of this study. Firstly, the number of cardiologists needed to meet demand might have been overestimated. We calculated the number of heart-related procedures per cardiologist by dividing the total number of cardiologists by the total number of heart-related procedures performed each year. However, we considered all active cardiologists in 2022, including those working in clinics who might not perform as many heart-related procedures as those working in higher-level medical institutions such as general or tertiary hospitals. Therefore, the number of heart-related procedures per cardiologist might have been underestimated due to inclusion of these cardiologists.

Secondly, we estimated the inflow of cardiologists and found that the trend of decrease was larger than the actual decrease due to the use of second-order polynomial regression analysis. Therefore, we only provided estimates up to the next 10 years.

Thirdly, the outflow of cardiologists might have been underestimated, which could result in an overestimation of the number of active cardiologists. We defined the criterion for outflow of cardiologists as reaching the retirement age of 65 without considering outflow due to other reasons before reaching the age of 65. Additionally, cardiologists aged 65 or younger who had studied abroad or moved to other institutions were excluded from the count of active cardiologists, which could also result in an underestimation of outflow.

Lastly, the data used to estimate the volume of emergency care covers a 4-year period from 2016 to 2019, which results in a lower explanatory power for the model than that of heart-related procedural care estimated using a 10-year data set. Furthermore, it is worth noting that the volume of emergency care may have been overestimated to some extent, as not all heart-related emergency patients receive treatment from a cardiologist.

In conclusion, Korea is anticipated to face a significant shortage of cardiologists in the coming decade. To prevent this imbalance between supply and demand, an organized and collective approach by the specialty of cardiology is imperative to produce a balanced workforce. The goal should be to approximate the decline in cardiologist supply with the projected growth in cardiology patient volume in Korea. By taking a proactive approach, the specialty of cardiology can ensure that adequate resources and training are available to meet needs of patients with heart disease in the years to come.

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This manuscript reflects the views of the authors and do not necessarily represent the views of *Korean Circulation Journal* or the Korean Society of Cardiology.

## SUPPLEMENTARY MATERIALS

### Supplementary Table 1

The list of heart-related procedures

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### Supplementary Table 2

Signs and symptom codes for cardiac emergency patients

[Click here to view](#)

### Supplementary Table 3

Example of the amount of treatment performed by a cardiologist for each type of treatment for 1 year

[Click here to view](#)

### Supplementary Table 4

Inflow and outflow of cardiologist (2022–2038)

[Click here to view](#)

### Supplementary Figure 1

Estimated number of cardiologists (lower, upper).

[Click here to view](#)

### Supplementary Figure 2

Estimated volume of heart-related procedures (RBRVS) per cardiologist (lower, upper).

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### Supplementary Figure 3

Future population ratio and estimated number of heart-related procedures for patients aged 65 and above (2023–2032).

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