Mismatches Between the Number of Installed Automated External Defibrillators and the Annual Rate of Automated External Defibrillator Use Among Places

Je Hyeok Oh, MD, PhD;[1] Gyu Chong Cho, MD, PhD;[2] Seung Mok Ryoo, MD, PhD;[3] So Hyun Han, PhD;[4] Seon Hee Woo, MD, PhD;[5] Yong Soo Jang, MD, PhD;[6] Youngsuk Cho, MD, PhD;[2] Minseob Sim, MD, PhD;[7] Oh Hyun Kim, MD, PhD[8]

1. Department of Emergency Medicine, Chung-Ang University College of Medicine, Seoul, Republic of Korea
2. Department of Emergency Medicine, Kangdong Sacred Heart Hospital, Hallym University College of Medicine, Seoul, Republic of Korea
3. Department of Emergency Medicine, University of Ulsan College of Medicine, Asan Medical Center, Seoul, Republic of Korea
4. National Medical Center, National Emergency Medical Center, Seoul, Republic of Korea
5. Department of Emergency Medicine, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea
6. Department of Emergency Medicine, Kangnam Sacred Heart Hospital, Hallym University College of Medicine, Seoul, Republic of Korea
7. Department of Emergency Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea
8. Department of Emergency Medicine, Yonsei University Wonju College of Medicine, Gangwon-do, Republic of Korea

Correspondence:
Gyu Chong Cho, MD, PhD
Department of Emergency Medicine
Kangdong Sacred Heart Hospital
Hallym University College of Medicine
150, Sungan-ro, Gangdong-gu, Seoul 05355
Republic of Korea
E-mail: emdrcho@hallym.or.kr

Abstract

Aim: In South Korea, the law concerning automated external defibrillators (AEDs) states that they should be installed in specific places including apartment complexes. This study was conducted to investigate the current status and effectiveness of installation and usage of AEDs in South Korea.

Methods: Installation and usage of AEDs in South Korea is registered in the National Emergency Medical Center (NEMC) database. Compared were the installed number, usage, and annual rate of AED use according to places of installation. All data were obtained from the NEMC database.

Results: After excluding AEDs installed in ambulances or fire engines (n = 2,003), 36,498 AEDs were registered in South Korea from 1998 through 2018. A higher number of AEDs were installed in places required by the law compared with those not required by the law (20,678 [56.7%] vs. 15,820 [43.3%]; P <.001). Among them, 11,318 (31.0%) AEDs were installed in apartment complexes. The overall annual rate of AED use was 0.38% (95% CI, 0.33-0.44). The annual rate of AED use was significantly higher in places not required by the law (0.62% [95% CI, 0.52-0.72] versus 0.21% [95% CI, 0.16-0.25]; P <.001). The annual rate of AED use in apartment complexes was 0.13% (95% CI, 0.08-0.17).

Conclusion: There were significant mismatches between the number of installed AEDs and the annual rate of AED use among places. To optimize the benefit of AEDs in South Korea, changes in the policy for selecting AED placement are needed.

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Keywords: automated external defibrillators; electric defibrillation; law; out-of-hospital cardiac arrest; South Korea

Abbreviations:
AED: automated external defibrillator
NEMC: National Emergency Medical Center
OHCA: out-of-hospital cardiac arrest
PAD: public access defibrillation

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Introduction

When defibrillation was performed by the public access defibrillation (PAD) program, the survival rate of out-of-hospital cardiac arrest (OHCA) increased significantly.[1–3] Therefore, resuscitation guidelines recommend placement of automated external defibrillators (AEDs) in public areas such as airports, railway stations, bus terminals, sport facilities, shopping malls, offices, and casinos. In South Korea, a law on AEDs (the Emergency Medical Service Act, Article 47, Paragraph 2 [hereafter referred to as "the Act"]) was established in 2007 and stated that AEDs should be installed and managed in specific places (Table 1).[4] In addition, since 2018, a penalty of 500,000 to 1,000,000 Korean Won (420 to 840 USD) was imposed when AEDs were not installed in places required by the Act. Furthermore, by establishing a Good Samaritan Law in 2008 (the Emergency Medical Service Act, Article 5, Paragraph 2), the legal basis for a PAD program was established.[4]

To support the law on AEDs, since 2010, the Ministry of Health and Welfare in South Korea (Sejong, South Korea) has provided guidelines for PAD placement and management.[5] According to the guidelines, installation and usage of AEDs are reported to a public health center by the chief manager of each installed AED, and data are managed by the National Emergency Medical Center (NEMC; Seoul, South Korea). However, the current status of AED placement, usage, and rate of use in South Korea has not been reported. This study was conducted to investigate the current status and effectiveness of installation and usage of AEDs in South Korea. In particular, this study compared the distribution of AEDs and rate of AED use among provinces and places of installation.

Facilities	In Detail
Public Health and Medical Institutions	National Medical Center, Seoul National University Hospital, other national university hospitals, provincial hospitals, or local public hospitals
Ambulances	Ambulances managed by the National 119 Emergency Rescue Service
Aircraft and Airports	Airplanes or helicopters or airships for passenger transport
Trains	Passenger cars
Ships	Ships where tonnage ≥20 tons
Apartment Complexes	Apartment complexes with ≥500 households
Multi-User Facilities	Waiting rooms at train stations (gross area ≥2,000 m^2 or daily average passengers ≥10,000 persons in last year) except for subway stations
	Waiting rooms at bus terminals (gross area ≥2,000 m^2 or daily average passengers ≥3,000 persons in last year)
	Port waiting rooms (gross area ≥2,000 m^2 or daily average passengers ≥1,000 persons in last year)
	Casinos (gross area ≥2,000 m^2)
	Racecourses
	Regattas or bicycle race tracks
	Prisons, junior correctional institutions, detention centers, foreigner detention centers, youth detention centers
	Stadia or sports complexes (stands ≥5,000)
	Central administrative agencies
	City halls and provincial government buildings

Table 1. Places for which Automated External Defibrillator Installation is Required by the Emergency Medical Service Act, Article 47, Paragraph 2

Methods

Study Design

This was a retrospective analysis of the prospectively collected NEMC public database. Data were collected from the manager of installed AEDs by officers in the public health centers and transferred to the database. The data regarding installation of AEDs were subsequently open to the public via a website or smartphone application (E-GEN) designed by the Ministry of Health and Welfare. The data on AED usage are also freely available upon request. All data including installation and usage of AEDs were provided as Excel files (Microsoft Corporation; Redmond, Washington USA) from NEMC. This study analyzed data on AED installation collected from 1998 through 2018 and data on AED usage collected from 2012 through 2018.

Compositions of the Dataset

The dataset concerning AED installations included the year of installation, province, name and address of the place of installation, and category of place (whether the place was required or not by the Act). The dataset concerning AED use included usage date (year, month, day, and time); information regarding the place of usage (province, place, and category); and qualifications of the user (non-medical first responders, medical personnel, and unknown). Data on place of installation were divided by 17 major and 110 minor classifications for the purpose of analysis (Supplementary Material, Table S1; available online only). Characteristics regarding places of installation were divided into three areas (public, residential, and other). Among 17 major classifications, public institutions, educational institutions, multi-user facilities, sports facilities, industrial facilities, commercial facilities, gaming facilities, roads and highway service stations, terminals and waiting rooms for public transportation, and correctional facilities were regarded as public areas. Apartment complexes, detached houses, and multi-housing facilities were regarded as residential areas. Medical institutions, transport vehicles, and assisted living/nursing homes were regarded as other areas.

Variables

The number of installed AEDs and rate of use were compared according to province, place of installation, category of place, and characteristics of installed places. As periods of AED use differ, usage of AEDs was compared by using the annual rate of use ([total cases of AED use/total duration of AED use in year] × 100).

Statistical Analysis

Descriptive statistics are reported as mean (95% confidence interval) and categorical variables are reported as frequency (percentage). Differences of frequencies according to time, province, and place were analyzed using one-sample chi-squared tests. Differences in the annual rate of use according to province and place of installation were analyzed using an independent-sample *t* test, analysis of variance, Mann–Whitney *U* test, or Kruskal–Wallis test according to the normality of distribution. Data normality was analyzed using the Shapiro–Wilk test or Kolmogorov–Smirnov test. A P value <.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS version 25.0 (IBM Corp.; Armonk, New York USA).

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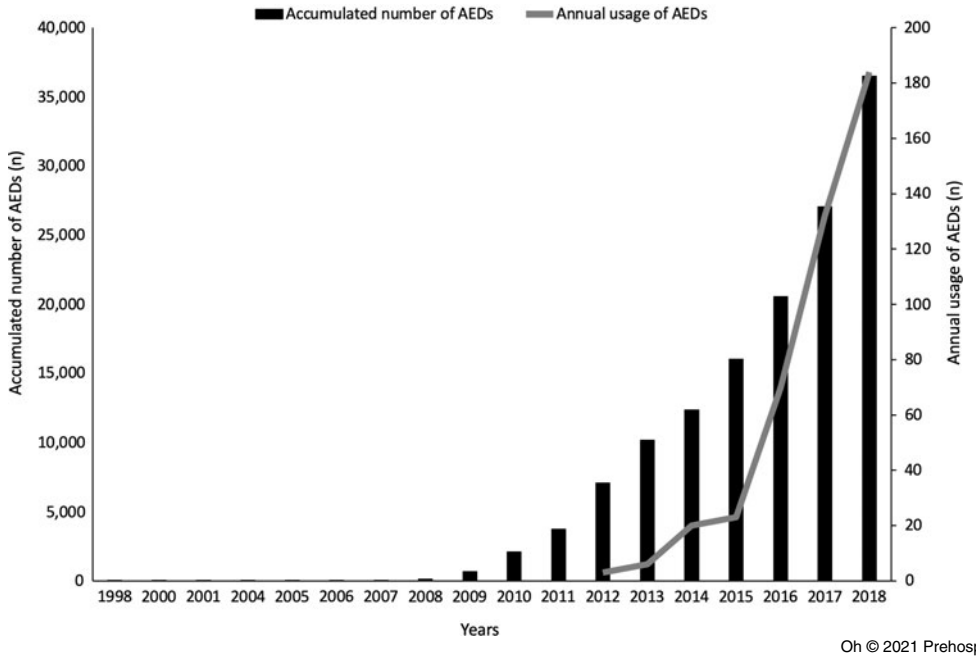

Figure 1. Changes in the Installation and Usage of Automated External Defibrillators in South Korea. Abbreviation: AED, automated external defibrillator.

Ethics Statement

This study was exempted from Institutional Review Board approval because it did not include human subjects or personal information (exemption No. 2003-006-19306). All data are open to the public and freely available upon request.

Results

The accumulated number of installed AEDs from 1998 through 2018 was 38,501. Of those, AEDs installed in ambulances or fire engines (n = 2,003) were excluded from the analysis. The accumulated number of incidents of AED usage from 2012 through 2018 was 3,753. After excluding the usage of AEDs installed in ambulances or fire engines (n = 3,315), 438 incidents of AED usage were analyzed.

Descriptive Data

The accumulated number of installed AEDs and annual incidents of AED usage increased every year from 1998 to 2012 (Figure 1). In total, 36,498 AEDs were in place in 2018, and the annual incidents of AED usage reached 184 cases in 2018. Considering the province of installation, AEDs were unequally distributed throughout the nation (Supplementary Material, Figure S1; available online only). Among 36,498 AEDs, 15,385 (42.2%) were installed in Seoul and Gyeonggi-do Province (7,760 [21.3%] and 7,625 [20.9%], respectively). Among the different provinces, in 2018, the number of installed AEDs per 100,000 population was the highest in Jeju (196 AEDs/100,000 population), followed by Jeollanam-do (138 AEDs/100,000 population; Supplementary Material, Figure S2; available online only). Considering the 17 major places of installation, the number of installed AEDs was the highest in apartment complexes, followed by transport vehicles (11,318 [31.0%] and 5,308 [14.5%], respectively; Supplementary Material, Figure S3; available online only). Considering the 110 minor places of installation, 16,007 (43.9%) AEDs were installed in apartment houses and ships (11,318 [31.0%] and 4,689 [12.8%], respectively; Supplementary Material, Figure S4; available online only).

Usage of AEDs

The overall annual rate of AED use was 0.38% (95% CI, 0.33-0.44). When evaluated by province, the annual rate of AED use was the highest in Jeju (1.12% [95% CI, 0.52-1.73]), followed by Daegu (0.64% [95% CI, 0.21-1.08]; Supplementary Material, Figure S5; available online only). Although a plurality of AEDs was located in Seoul and Gyeonggi-do, the annual rate of AED use in Seoul and Gyeonggi-do was only 0.56% (95% CI, 0.44-0.69) and 0.19% (95% CI, 0.12-0.26), respectively. Based on the 17 major places of installation, the annual rate of AED use was highest in assisted living/nursing homes (8.64% [95% CI, 3.64-13.65]), followed by terminals and waiting rooms for public transportation (2.26% [95% CI, 1.58-2.94]; Supplementary Material, Figure S6; available online only). The annual rate of AED use in apartment complexes and transport vehicles was only 0.13% (95% CI, 0.08-0.17) and 0.14% (95% CI, 0.04-0.25), respectively. Based on the 110 minor places of installation, the annual rate of AED use was highest in sanatoria (9.15% (95% CI, 3.80-14.51; Supplementary Material, Figure S7; available online only).

Comparison of Required and Non-Required Places

A higher number of AEDs were installed in places required by the Act compared with those not required by the Act (20,678 [56.7%] versus 15,820 [43.3%]; P <.001). However, the annual rate of AED use was significantly higher in non-required places than in required places (0.62% [95% CI, 0.52-0.72] versus 0.21% [95% CI, 0.16-0.25]; P <.001; Figure 2).

Comparison of Public and Residential Areas

A higher number of AEDs were installed in public areas compared with that in residential areas (15,395 [42.2%] versus 11,432 [31.3%]; P <.001; in addition, 1,671 [26.5%] AEDs were installed

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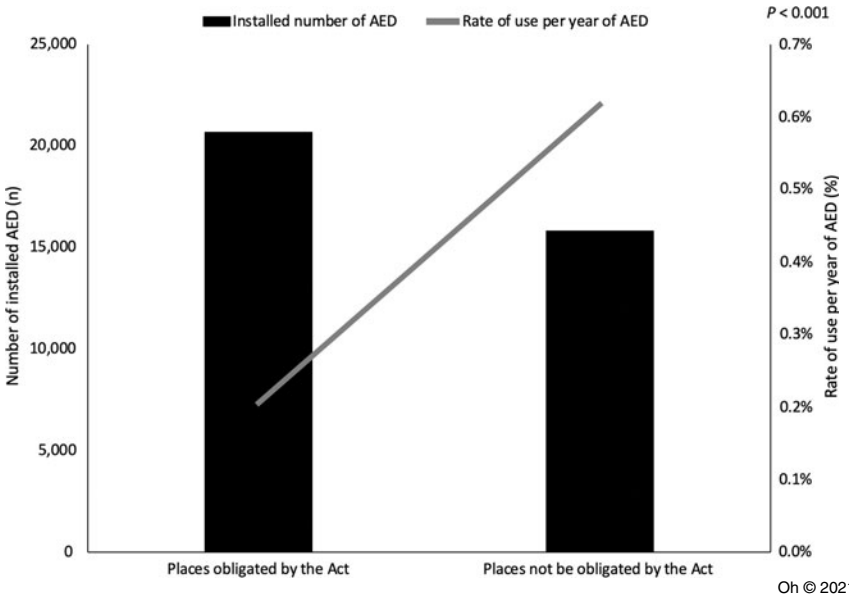

Figure 2. Comparison of the Places Required by Law and Places Not Required by Law.
Abbreviations: AED, automated external defibrillator; the Act, Emergency Medical Service Act, Article 47, Paragraph 2.

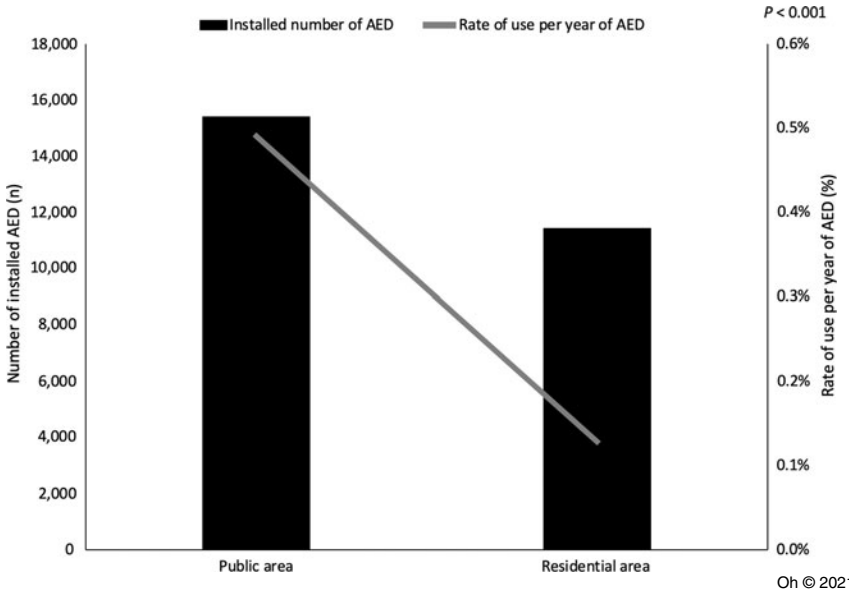

Figure 3. Comparison of Automated External Defibrillator Use in Public Areas and Residential Areas.
Abbreviation: AED, automated external defibrillator.

in other areas). The annual rate of AED use was also significantly higher in public areas than in residential areas (0.49% [95% CI, 0.41-0.57] versus 0.13% [95% CI, 0.08-0.17]; $P < .001$; Figure 3).

Variations in AED Usage According to Time of Day

Most incidents of AED usage occurred during daytime (06:00-21:00; 90.4%; Supplementary Material, Figure S8; available online only).

Discussion

Although the effectiveness of the PAD program has been confirmed several times,[6–11] to the best of the authors' knowledge, the present study is the first to investigate the current status and effectiveness of placement and usage of AEDs in South Korea. In a systematic review, the median survival to hospital discharge ratio when PAD was performed by lay persons after OHCA was 53%.[12] Therefore, proper placement of AEDs throughout the nation is essential for the success of the PAD program.

The current study confirmed that the number of installed AEDs in South Korea increased rapidly after two important laws (the law on AEDs and the Good Samaritan Law) came into effect. The strategy of using laws to establish a PAD program has been effective in increasing the absolute number of installed AEDs in South Korea. However, the current study discovered several problems.

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First, there were mismatches between the number of installed AEDs and the annual rate of AED use among provinces and places. For example, there was an extremely low rate of AED use in Gyeonggi-do, where a large number of AEDs were installed in apartment complexes (4,472 [58.6%]). The annual rate of AED use in apartment complexes was extremely low. Consequently, the overall annual rate of AED use in Gyeonggi-do decreased. Although the Act dictated installation of AEDs in apartment complexes with ≥500 households, the Act did not propose a minimum number of AEDs. Therefore, some apartment complexes installed an AED in every building, and others installed AEDs in only one or two buildings, especially in the control office. This inconsistent strategy contributed to a different distribution of AEDs in provinces. In contrast, in Jeju Province, only 15 (1.2%) AEDs were installed in apartment complexes.

Second, there was an excess number of AEDs installed in residential areas (31.3% of all AEDs). In Japan[13] and Copenhagen,[14] the percent of AEDs installed in public areas was 82.4% and 94.2%, respectively. Although 60%-80% of cardiac arrest occurs at home, the effectiveness of AEDs was low in residential areas because of fewer witnessed arrests, lower bystander cardiopulmonary resuscitation rate, and fewer shockable rhythms than that in public areas.[1,15] In addition, several studies reported that there were no advantages when AEDs were applied in residential area, even in the home of high-risk patients.[16,17] On the contrary, many studies showed a survival benefit of AED in public areas.[11,15,16] Therefore, a redistribution of AEDs in South Korea is needed to maximize their effectiveness.

Third, because the Act requires installation of AEDs on ships when the tonnage is ≥20 tons, an excess number of AEDs were installed on ships. However, the annual rate of AED use on ships was only 0.15%. As a result, in South Korea, 16,007 (43.9%) AEDs were placed in areas with low usage, such as apartment complexes and ships.

Fourth, there was a mismatch in the number of installed AEDs and the annual rate of AED use between places for which installation was required by the Act and places for which installation was not required. Although the number of AEDs in required places was larger than that of non-required places, the annual rate of AED use was significantly higher in non-required places. This result suggests that places designated by the Act are not as effective.

Placement of AEDs without guidance or evidence regarding effectiveness can result in ineffective installation.[14,18] Muraoka, et al recommended six locations for installation, including workplaces, railway stations, hospitals, homes for the aged, other playgrounds, and golf courses, considering the incidence of cardiac arrest, the ratio of ventricular fibrillation, and good neurological outcomes.[19] Several places in the current study showed a higher annual rate of AED use, such as sanatoria, banks, subway stations, civilian medical facilities, senior centers, other playgrounds, resorts, other multi-housing facilities, and swimming pools. Among these, only other multi-housing facilities (comprising housing facilities, including those for individuals who are homeless or disabled) were classified as residential areas. Accordingly, the annual rate of AED use was higher than that of apartment complexes. With the exception of sanatoria and civilian medical facilities, all places were classified as public areas. Patterns regarding the time of AED use also showed that most PAD is delivered in the daytime. Overall, previous evidence and present data show that AEDs should be placed in public places where there is a higher probability of a witnessed cardiac arrest during the day.[3]

Limitations

The present study has several limitations. First, only data regarding AED usage were analyzed and not outcome data from patients. In addition, a reported incident of AED use does not certify completion of PAD, as there was an inability to discriminate between simply attaching the pads and actually delivering the shock. Therefore, evidence level of the results was limited. Second, the guidelines state that the manager of installed AEDs should report when AEDs are used. However, there is no fine or penalty if the manager fails to report AED use. Therefore, there is a possibility of missing incidents of AED usage. In addition, there was no penalty for the reporting of AED installation or use in places where AED installation was not mandatory by law (non-required places). Therefore, data on AEDs in such places could be missing. Third, although qualification of the AED user was included in the dataset, 208 (47.5%) cases reported use by unknown rescuers. Therefore, differences in qualifications could not be analyzed according to provinces and places.

Conclusions

There were significant mismatches between the number of installed AEDs and the annual rate of AED use among places. To optimize the benefit of AEDs in South Korea, changes in the policy for selecting AED placement are needed.

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Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X20001508

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