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How many automatic external defibrillators do South Korean golf courses need?

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Abstract

Purpose: This study was to examine public access defibrillator (PAD) deployment on some golf courses and to analyze automatic external defibrillators (AEDs) demand by appropriate distance. **Research design, data, and methodology:** We conducted telephone interview on 124 golf courses in Gyeonggi and Gangwon province in South Korea. The area within 3 minutes by 3 minutes for retrieval and 1 minute for shock and 1.5 minutes by the American Heart Association (AHA) recommendation for community AED placement were calculated as $3.14 \times 162m^2$ and $3.14 \times 100m^2$. **Results:** The average area was $1,811,481.8m^2$, and 29 (42.7%) in below $999,999m^2$, 75 (60.5%) in 1,000,000 to $1,999,999m^2$, 12 (9.7%) in 2,000,000 to $2,999,999m^2$ took up. The average retrieval time was 161.8 seconds, and 5 (4.1%) in below 90 seconds, 10 (8.0%) in 91 to 180 seconds took up a small part. AED demands according to 3 and 1.5 retrieval minutes were 2,602 and 6,986 respectively. Average AED demands per golf course were 21.0 and 56.3 respectively on 124 golf courses. **Conclusions:** The numbers of AED needed in South Korean golf course were 5,880 to 15,764. To ensure defibrillation on the golf courses, the supply and distribution of AEDs should be strengthened.

Keywords: Public Access Defibrillator (PAD), Deployment, Demand, Retrieval Minute, Distribution.

JEL Classifications: I11, I12

1. Introduction

About 300,000 people die a year in South Korea, as in other countries, the death toll rises with age according to the Statistics Korea. Out-of-hospital cardiac arrests (OHCAs) transported by Gyeonggi Fire Services were most frequent among home (69.4%), followed by commercial & leisure facility (6.3%), road & highway (5.6%), health facility (4.9%), residence (2.6%), public place (1.4%), industrial facility (1.1%), educational facility (0.4%). On the other hand, ROSC rates were highest among educational facility (50.0%), followed by industrial facility (23.4%), commercial & leisure facility 19.2%). The raw data showed that golf course was not separated from that, however, it was probably included in the commercial & leisure facility with other data. Not only was the golf course not specified, but also because sport facility was not specified by the Gyeonggi Disaster and Safety Headquarters. However, arrest-to-shock by Gyeonggi Fire Services took 11 minutes, and automatic external defibrillators (AEDs) applications by laypersons were only 1.9% (Uhm & Kim 2014; Ahn, Shin, Suh, Cha, Song, Kim, Lee, & Ong, 2010). According to the above study, there was only 1 AED use. AED uses by bystanders need to be promoted (Uhm & Kim, 2018).

The American Heart Association (AHA) recommended that public access defibrillators (PADs) should be installed if there is a reasonable frequency of 1 AED use in 5 years (20%) (AHA, 2000). By application of the Emergency Medical Service Act (EMS Act) in South Korea, more than 40,000 AEDs have been installed in public places including public health and medical institutions, ambulances, apartment houses according to 2018 Statistics Annual

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Report of the National Emergency Medical Center (NEMC). However, the golf course in South Korea does not regally require AED installation until now. Nevertheless, there is a need to have AED on golf course because of the nature of golf course. Usually golf courses are located in the suburbs, so they are far from squads and emergency medical centers, and golfers are relatively old. So, the possibility of cardiac arrest is constant, however, it may take longer to provide defibrillation.

Because brain damage begins at 4-5 minutes after cardiac arrest, normal sinus rhythm should be resumed within 4 minutes. So, CPR and AED are delivered within 4 minutes. To give defibrillation within 4 minutes, AED shall be located within 3 minutes for retrieval and within 1 minute for shock. Demand analysis was performed based on AED deployments within 3 and 1.5 minutes distance. Furthermore, even the golf courses installed with AEDs should have their own PAD program to enable early defibrillation before brain damage begins. Therefore, AEDs should be located at a certain distance plus easily accessible to public. Also, AEDs should be installed according to golf course size. This is expected that it will contribute to the in time to do defibrillation and the bettered survival rate. Until now, there has been no study on the cardiac arrests or the defibrillations in South Korean golf course, and there has been no study regarding AED on the golf course. In this study, we examined AED deployment on some golf courses and analyzed AED demand by appropriate distances.

2. Literature Review

This study revealed that the cost per quality-adjusted life year (QALY) gained is $30,000 for AED deployment compared with emergency medical services equipped with AED (EMS-D) care, and $62,000 for AED on a golf course where there is 0.1 cardiac arrests annually. AED deployment costs less than $50,000 per QALY gained provided that the annual probability of AED use is 12% or greater. The current AHA guidelines (20%) are overly restrictive. This paper gives reasons for why AEDs should be deployed on golf courses, and grounds for overcoming the cost problem (Cram, Vijan, & Fendrick, 2003).

According to the AHA recommendation on deploying AED, golf course was selected as a cardiac arrest high-risk site along with several other venues. The telephone survey found that 39% of golf courses had about 2 AEDs. However, cost was a major problem of golf course not installing AED. This paper also suggests the justification for deploying AEDs to golf courses, however, didn't present how to overcome the cost problem (Bartimus, Rea, & Eisenberg, 2004).

1 Arrest per 64 courses per year or 1 arrest per 33.5 courses per golf season (May and October) has occurred. When seasonally adjusted, the cardiac arrest rate on Michigan golf courses was similar to that of other public locations. Almost all patients (96.2%) were male, mean age 66.3, 68% had shockable rhythm. Mean interval call-to-EMS (emergency medical service) arrival at the patient was about 10 minutes. Although AEDs were available at 9 courses (22.5%), they were only placed on 2 patients (22.2%) prior to EMS arrival. Sustained ROSC was obtained in 12 patients (30.0%). Therefore, the mortality rate was 70.0%. The study mentioned that AED use was rare even when available. Since the shockable rhythm appeared high, it is deemed that if AED are applied actively, it will contribute to the improvement of ROSC on golf course (Deutsch, Paternoster, Putman, Fales, & Swor, 2004).

The longest time necessary to reach the most remote point on the course was between 4 and 5 minutes in all courses. Neither public nor private golf courses were well equipped to respond to cardiac arrest. It was a study regarding the time needed to provide emergency care in some golf courses, however, it did not propose the proper placement of AEDs to quickly implement defibrillation (Lucas, Davila, Waninger, & Heller, 2006).

By mathematical optimization techniques, cardiac arrest coverage was computed and verified to be superior to the population-guided deployment. The mean distance from a cardiac arrest to the AED was 281m. Geographic clusters of cardiac arrests could be easily identified and prioritized with the use of mathematical modeling. This study suggested that optimized AED deployment could increase cardiac arrest coverage and decrease distance to the closest AED. It suggests that location of cardiac arrest and distance of AED are important (Chan, Li, Lebovic, Tang, Chan, Cheng, Morrison, & Brooks, 2013).

In application of PAD installed at apartment houses, shorter retrieval time was positively affected by smaller number of households and larger number of AEDs. Policy facilitating PAD deployment and utilization could be optimized to golf courses having different situations such as location and user (Uhm & Kim, 2018).

This study was regarding cardiac arrest during sport practice. It was a low-incidence event, as it was commonly witnessed to have a high survival rate compared to general non-hospital cardiac arrest. Since cardiac arrests could be easily witnessed by other golfers or caddies, the deployment of defibrillators enables survival rate to be improved (Grazioli, Escalada, Serratosa, Medallo, Gutierrez, Sitges, & Brugada, 2018).

It was revealed that although there was increasing number of AEDs, underutilization of PAD was related to delivery distance and time-dependent availability. The retrieval radius was shorter in urban than rural area, in the day than night time. Conventional methodology using linear estimates of distance to the nearest AED underestimates the actual retrieval distance. These results raise the need to deploy AEDs on golf courses in rural area, and PAD program based on the actual travel distance will enable the use of AEDs on golf courses (Deakin, Anfield, & Hodgetts, 2018).

In public locations, the chance of bystander defibrillation decreased sharply after the first 100 m (retrieval radius) while the chance of bystander defibrillation was poor for any distance in residential areas. These findings mean that the AED coverage area is far more limited than the AHA guidelines. In the study, other factors not stated such as non-shockable rhythm, non-witnessed arrest, non-accessible place, and non-capable to apply might affect negatively bystander defibrillation (Sondergaard, Hansen, Pallisgaard, Gerds, Wissenberg, Karlsson, Lippert, Gislason, Torp-Pedersen, & Folke, 2018).

Despite the unequivocal efficacy of bystander defibrillation it is an intervention that overall is infrequently used in OHCA. There are many barriers to bystander defibrillation. The study systematically classified barriers as to bystander's capability, opportunity (location, accessibility) and motivation to perform defibrillation. So, deploying AEDs at locations that are easily accessible and well-recognized becomes more important (Resuscitation Editorial, 2018).

The AED strategy yielded an additional 0.26 QALYs for an incremental increase in cost of $13,793 per individual, and yielded an incremental cost-effectiveness ratio of $53,797 per QALY gained. The presence of AEDs on golf courses has some effect on incremental cost-effectiveness ratio except very low incidence rates (Andersen, Holmberg, Granfeldt, James, & Caulley, 2019).

Several measures were proposed to improve defibrillation, including drone-delivered AED as well as optimization of AED deployment and mobile application to locate the nearest AED. It seems that the use of drone-delivered AED will be easy to apply on golf course with few obstacles. It is expected that if it is able to cover large areas with drone-delivered AED, it will be able to reduce the cost of deploying AED (Delhommea, Njeime, Varlet, Pechmajou, Benameurg, Cassani, Derkennej, Jostj, Lamhautk, Marijon, Jouven, & Karam, 2019).

3. Methodology

In September 2019, 5 investigators conducted telephone interview on 124 golf courses in Gyeonggi and Gangwon province in South Korea. Also, this survey was based on telephone number, location, area from the internet homepage of the Korea Golf Course Business Association. The content of the investigation was consisted of general information regarding the golf courses and AED installation. Before obtaining consent from the golf courses, the investigators offered information regarding the purpose of the study and confidentiality.

The collected data were calculated using the SPSS 21.0 for Windows (IBM Inc., New York, USA) at α=.05. For summarizing the content of the survey, frequency (%) for non-continuous variables, and average for continuous variables were calculated.

As the brisk walking speed was 1.8m/s, the return walking distance will have to be 324m in order to keep retrieval time for 3 minutes. In other words, AED shall be located within 162m radius. As $S=\pi r^2$, the area within 3 minutes can be calculated as 3.14×162m^2. An AED was required for every 82,406m^2 of golf course.

When 100m coverage radius is applied on the basis of the maximum distance, AED could be transported by bystander in 1.5 minute walk as outlined in the AHA recommendation for community AED placement (Aufderheide, Hazinski, Nichol, Steffens, Buroker, McCune, Stapleton, Nadkarni, Potts, Ramirez, Eigel, Epstein, Sayre, Halperin, & Cummins, 2006). Thus, every 100m radius shall have an AED, and the walking speed was calculated as 1.1m/s. As S=πr^2, the area within 1.5 minutes can be calculated as 3.14×100m2. In other words, an AED was required for every 31,400m^2 of golf course.

If drone-delivered AEDs is deployed in the clubhouse on the basis of the prototype medical drones flown up to 100 kph (Claesson, Bäckman, Ringh, Svensson, Nordberg, Djärv, & Hollenberg, 2017), the area within 1.5 and 3 minutes can be calculated as 3.14×2,500m^2 and 3.14×5,000m^2 respectively, In other words, an AED was required for every 19,625,000m^2 and 78,500,000m^2 of golf course.

Assuming that the clubhouse equipped with an AED is placed in the center of the golf course, and the clubhouse is requested the AED over the mobile phone at the arrest site, the retrieval time will be $\sqrt{S}/\sqrt{\pi} \div 1.8$m/s or $\sqrt{S}/\sqrt{\pi} \div 1.1$m/s.

4. Results

AEDs installed in South Korea were highest among public facility 11,602 (28.3%), followed by apartment over 500 houses 10,665 (26.1%), ship 5,050 (12.3%), public health & medical institution 4,099 (10.0%), ambulance 2,094 (5.1%), apartment under 500 houses 1,374 (3.4%), commercial facility 1,136 (2.8%), hotel & leisure facility 1,040 (2.5%) according to 2018 Statistics Annual Report of the NEMC <Table 1>.

Table 1: Installed location of automatic external defibrillator in South Korea

Location	AED(%)
Public facility	11,602(28.3)
Apartment over 500 houses	10,665(26.1)
Ship	5,050(12.3)
Public health & Medical institution	4,099(10.0)
Ambulance	2,094(5.1)
Apartment under 500 houses	1,374(3.4)
Commercial facility	1,136(2.8)
Hotel & Leisure facility	1,040(2.5)
Transportation facility	719(1.8)
Train	496(1.2)
Health-related facility	461(1.1)
Airport & Airplane	268(0.7)
Others	1,924(4.7)
Overall	40,928

Note: AED; automatic external defibrillator

The average hole of 124 golf courses surveyed was 26.3, and 53 (42.7%) in below 18 hole, 39 (31.5%) in 19 to 27 hole, 24 (19.4%) in 28 to 36 hole took up. The average area was 1,811,481.8m^2, and 29 (42.7%) in below 999,999m^2, 75 (60.5%) in 1,000,000 to 1,999,999m^2, 12 (9.7%) in 2,000,000 to 2,999,999m^2 took up. Total 91 AEDs surveyed were installed only 0.7 per golf course, and there were 72 (58.0%) golf courses without AED, 30 places (24.2%) installed with 1 AED, 13 (10.5%) with 2 AEDs. The average retrieval time was 161.8 seconds, and 5 (4.1%) in below 90 seconds, 10 (8.0%) in 91 to 180 seconds took up a small part. However, it could not confirm the retrieval time which will take much longer in the golf course without AED <Table 2>.

Table 2: General characteristics of automatic external defibrillator in South Korean golf course N=124

Golf course	N(%)	M(SD)
Hole		26.3(9.3)
-18	53(42.7)	
19-27	39(31.5)	
28-36	24(19.4)	
+45	8(6.4)	
Area(m^2)		1,811,481.8 (2,248,896.2)
-999,999	29(23.4)	
1,000,000-1,999,999	75(60.5)	
2,000,000-2,999,999	12(9.7)	
+3,000,000	8(6.4)	
AED installed	91	0.7(1.1)
0	72(58.0)	
1	30(24.2)	
2	13(10.5)	
+3	9(7.3)	
AED retrieval time(s)*		161.8(162.5)
-90	5(4.1)	
91-180	10(8.0)	
+181	37(29.8)	
N/A	72(58.1)	

Note: M(SD); mean(standard deviation), AED; automatic external defibrillator, N/A; not available
*applying brisk walking speed of 1.8m/s based on shuttling between arrest golfer and AED deployed at the center of golf course

Table 3: Demands for automatic external defibrillator according to the retrieval time

Demand	N(%)	M(SD)
AED needed on criteria Ⅰ * (per 82,406m^2)	2,602	21.0(27.3)
0	2(1.6)	
1-9	13(10.5)	
10-19	68(54.8)	
20-29	28(22.6)	
30-39	6(4.8)	
+40	7(5.7)	
AED needed on criteria Ⅱ ** (per 31,400m^2)	6,986	56.3(71.8)
0	2(1.6)	
1-9	3(2.4)	
10-19	4(3.2)	
20-29	14(11.4)	
30-39	29(23.4)	
40-49	25(20.1)	
50-59	21(16.9)	
60-69	9(7.3)	
+70	17(13.7)	

Note: M(SD); mean(standard deviation), AED; automatic external defibrillator
*area within 3 minutes calculated as 3.14×162m^2
**area within 1.5 minutes calculated as 3.14×100m^2

AED demand per golf course 82,406m^2 according to 3 retrieval minutes was 2,602, and there were 2 (1.6%) golf courses in no more need for AED, 13 (10.5%) golf courses in 1 to 9 AEDs, 68 (54.8%) golf courses in 10 to 19 AEDs, 28 (22.6%) golf courses in 20 to 29 AEDs, etc. AED demand per golf course 31,400m^2 according to 1.5 retrieval minutes was 6,986, and there were 2 (1.6%) golf courses in no more need for AED, 3 (2.4%) golf courses in 1 to 9 AEDs, 4 (3.2%) golf courses in 10 to 19 AEDs, 14 (11.4%) golf courses in 20 to 29 AEDs, 29 (23.4%) golf courses in 30 to 39 AEDs, 25 (20.1%) golf courses in 40 to 49 AEDs, 21 (16.9%) golf courses in 50 to 59 AEDs, etc. <Table 3>.

Demands of AED in South Korean golf course were derived from number of golf courses×21.0 AEDs and ×56.3 AEDs. The numbers of AED needed in South Korean golf course were calculated as 5,880 according to the former, and 15,764 according to the latter <Table 4>.

Table 4: Demands for automatic external defibrillator according to the golf course

Province	Golf course	AED demand	
		Needed on criteria Ⅰ *	Needed on criteria Ⅱ **
Gyeonggi and Gangwon	138	2,898	7,769
Chungcheong	37	777	2,083
Gyeongsang	54	1,134	3,040
Jeolla	26	546	1,464
Jeju	25	525	1,408
Overall	280	5,880	15,764

Note: AED; automatic external defibrillator
*golf course×21.0 AEDs per golf course derived from 82,406m^2
**golf course×56.3 AEDs per golf course derived from 31,400m^2

5. Discussion

Hotel & leisure facility in installed location of AED according to the NEMC accounted for 2.5%. The raw data showed that golf course was not separated. However, it was probably included in the hotel & leisure facility with. In accordance with the EMS Act, it does not regally require AED registration. Therefore, some of the AEDs installed on the golf courses may have been missing. Moreover, OHCA and ROSC in the golf course were not classified and studied in South Korea. It is inferred that the golf course might be included in the commercial & leisure facility which has 6.3% at OHCA and 19.2% at ROSC.

According to some studies on defibrillation in America golf course, it could infer the situation in South Korean golf course. The AHA recommends deploying AED on golf course which was a cardiac arrest high-risk site. However, cost was a major problem of golf course not installing AED (Bartimus et al., 2004). When seasonally adjusted, the rate of OHCA on Michigan golf courses was similar to that of other public locations. Almost all patients (96.2%) were male, mean age 66.3, 68% had shockable rhythm. Although AEDs were available at 9 courses, they were only placed on 2 patients prior to EMS arrival. If rapid defibrillation was applied, more golfers could be saved (Deutsch, et al., 2004). Since cardiac arrests could be easily witnessed by other golfers or caddies, the deployment of defibrillators enables survival rate to be improved (Grazioli et al., 2018).

There were only 0.7 AED per golf course, and 58.0% golf courses without AED, 24.2% installed with 1 AED, 10.5% with 2 AEDs. The average retrieval time was 161.8 seconds, and 4.1% in below 90 seconds, 8.0% in 91 to 180 seconds took up a small part for practical defibrillation in South Korea. Therefore, it would be difficult to apply defibrillation before brain death when cardiac arrest occurs at the golf courses. On the other hand, the longest time necessary to reach the most remote point on the course was between 4 and 5 minutes in all courses in America. It was a similar situation each other not able to quickly implement defibrillation (Lucas et al., 2006). In viewpoint of the cost per quality-adjusted life year (QALY), it cost $62,000 for AED on a golf course where there is 0.1 cardiac arrests annually (10%). AED deployment costs less than $50,000 per QALY gained provided that the annual probability of AED use is 12% or greater. The current AHA guidelines (20%) are overly restrictive. According to the study, it will also be cost-effective for QALY in South Korean golf course. Therefore, we should actively review the placement of AED on the golf course (Cram, et al., 2003).

AED demand per golf course 82,406m^2 according to 3 retrieval minutes was 2,602. AED demand per golf course 31,400m^2 according to 1.5 retrieval minutes was 6,986. Demands of AED in South Korean golf course were derived from number of golf courses×21.0 AEDs and ×56.3 AEDs. The numbers of AED needed in South Korean golf course were calculated as 5,880 according to the former, and 15,764 according to the latter. Because conventional methodology using linear estimates of distance to the nearest AED underestimates the actual retrieval distance, the numbers of AED to be deployed will have to be close to 15,764 rather than 5,880. The shorter travel distance will be able to more use of AED on golf course (Deakin et al., 2018). The chance of bystander defibrillation decreased sharply after the first 100 m (retrieval radius) in public locations, while the chance of bystander defibrillation was poor for any distance in residential areas. The findings indicate that the AED coverage area is far more limited than anticipated (Sondergaard et al., 2018).

6. Conclusions

The numbers of AED needed in South Korean golf course are 5,880 to 15,764. Having AEDs in line with these conditions is not only an economic burden, but also a management challenge. However, to ensure defibrillation on the golf courses, the supply and distribution of AEDs should be strengthened. It is worth considering the AED that utilizes the latest new technology including drone-delivered AED as well as optimization of AED deployment and mobile application to locate the nearest AED. It seems that the use of drone-delivered AED will be easy to apply on golf course with few obstacles. It will be able to reduce the cost of deploying AED. They could possibly fly directly to a victim location using a cell phone GPS as a target in South Korea. The delivery of AED using drones is expected to reduce demand for AED. However, studies on the proper delivery radius are needed.

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