Optimization of Public Access Defibrillators Compared to Actual Deployment: An In Silico Trial

Christopher L. F. Sun, BASc [a], Lena Karlsson, MD[b,c], Christian Torp-Pedersen, MD [d], Fredrik Folke, MD, PhD[b,c], Timothy C. Y. Chan, PhD [a,e]

[a] Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Canada; [b] Department of Cardiology, Copenhagen University Hospital Gentofte, Copenhagen, Denmark; [c] Emergency Medical Services Copenhagen, University of Copenhagen, Denmark; [d] Department of Cardiology and Epidemiology/Biostatistics, Aalborg University Hospital, Aalborg, Denmark; [e] Rescu, Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, Canada..

Background

• Out-of-hospital cardiac arrest (OHCA) is a significant public health issue. Automated external defibrillator (AED) can increase survival from public-location cardiac arrest, but are often placed in areas of low risk and limited temporal availability.
• Mathematical optimization can improve AED placements, but a controlled experiment against current placements has not been conducted before.

Objective

• We conduct the first *in silico* trial of a public AED intervention in Copenhagen, Denmark to prospectively compare OHCA coverage provided by AEDs located using two different mathematical optimization models (interventions) to the real-life AED placements in Copenhagen (control) from October 2007 to December 2016.

Methods

• **Study population and data sources:** We identified all public OHCAs of presumed cardiac cause and deployed AEDs (Danish AED Network) during Oct. 2007 – Dec. 2016 in Copenhagen.

• **Control Group: A**ctual AED placements from Oct. 2007 – Dec. 2016.

• **Intervention Groups:** We divided the study period into consecutive, disjoint 30-day time periods and determined the number of actual AEDs (control) placed in each time period. Using optimization models trained on historical OHCAs (1994-2007), we determine the optimal locations to place an equal number of AEDs as in the control group in each time period, accounting for previously optimized AEDs placements and OHCA data up until that time period (Figure 1). Two different intervention arms were considered for comparison: 1) AED placements with actual availability (based on building hours of operation) and 2) AED placements with 24/7 availability.

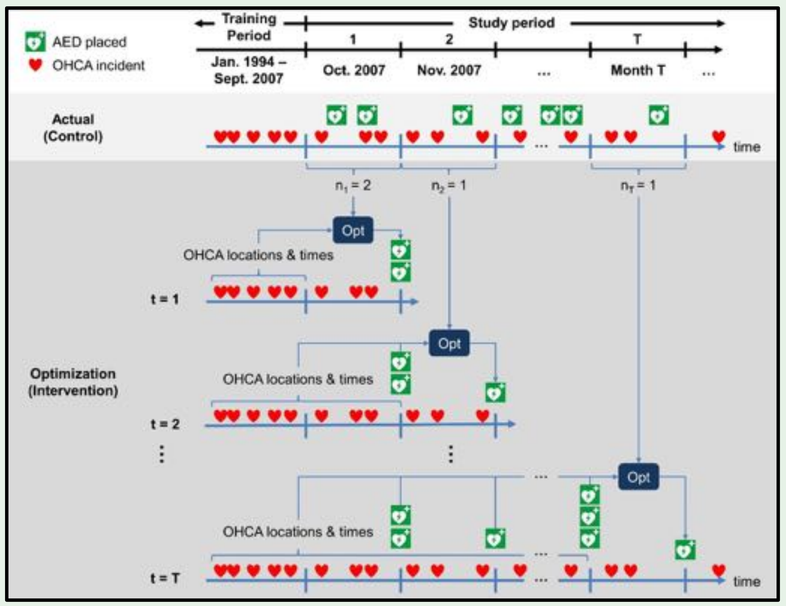

Figure 1. An illustration of the optimization approach to determining AED locations compared to the actual AED placements.

Methods

•**Primary outcome:** The approaches were evaluated on *actual coverage*: the total number of OHCAs that occurred within 100 m straight-line distance from an available AED after it was placed.

•**Analysis:** McNemar's test for paired data was used to test for significant differences between the control and interventions in the primary outcome of OHCA coverage at the end of the study period.
•We also estimated an increase in 30-day survival probability due to increased OHCA coverage by the interventions using the law of total probability.

Results

•We identified 1,573 AEDs as of 2016 that were placed between Oct. 2007 - Dec. 2016. From Oct. 2007 - Dec. 2016, 673 public OHCAs occurred (Table 1).

OHCA Characteristics*	Training set for optimization model Jan. 1994 to Oct. 2007 (n=1405)	Study Period Oct. 2007 to Dec. 2016 (n=673)
Median age, y (IQR)	63 (50 – 75)	64 (53 – 75)
Men	60 (48 – 71)	62 (52 – 72)
Women	74 (59 – 81)	74 (60 – 82)
Male sex, n (%)	1062 (75.6)	498 (76.3)
Shockable initial heart rhythm, n (%)	522 (37.2)	286 (42.5)
30-day survival**, n (%)	228 (17.3)	192 (31.3)
Bystander OHCA Characteristics†	-	Jan. 2008 to Dec. 2016 (n=653)
Bystander-witnessed arrest†, n (%)	-	438 (69.9)
Received bystander CPR†, n (%)	-	440 (70.4)
Received bystander defibrillation†, n (%)	-	94 (14.6)

Table 1. Baseline Characteristics of Public OHCAs in Copenhagen.

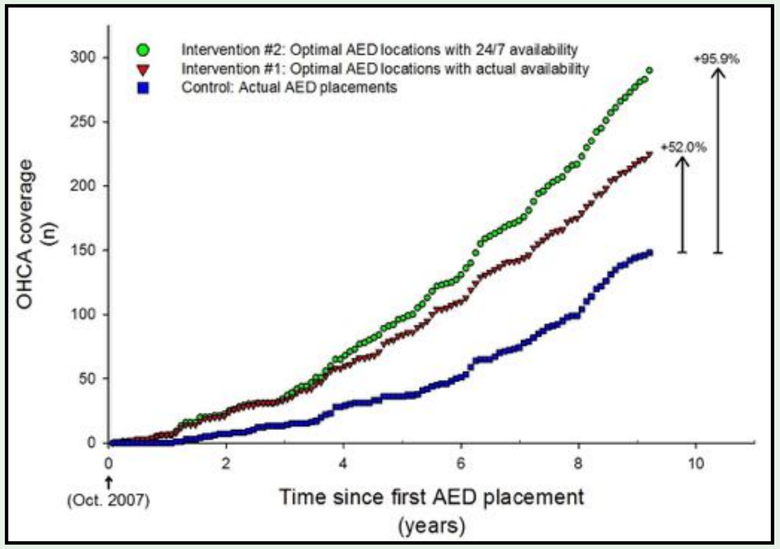

Figure 2. Evolution of OHCA coverage over the study period of the actual AED placements (control) and the two AED optimization approaches (interventions). Total coverage of each optimization approach was significantly greater than the actual AED placements (McNemar, P<0.001).

Results

• **Primary Outcome:** AEDs in the control group covered 22.0% (148 of 673 OHCAs) of all OHCAs in the study period. Optimal AED placements from intervention #1 and #2 covered 33.3% (225 of 673) and 43.1% (290 of 673).

•**Impact on 30-day Survival:** Survival of covered and not covered OHCAs by actually placed AEDs was 42.1% (65/133) and 28.3% (136/481).
• Overall survival probability was estimated to be 32.9% for intervention #1 and 34.2% for intervention #2, corresponding to increases of 5.1% and 9.3%, compared to the control group (31.3% - Table 1).

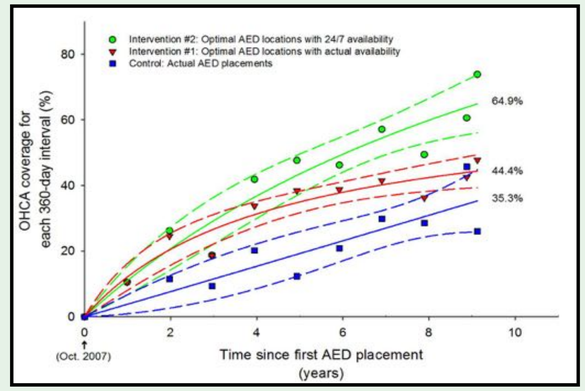

Figure 3. The percent of OHCAs covered over 360-day intervals of the actual AED placements (control) and AED optimization approaches (interventions).

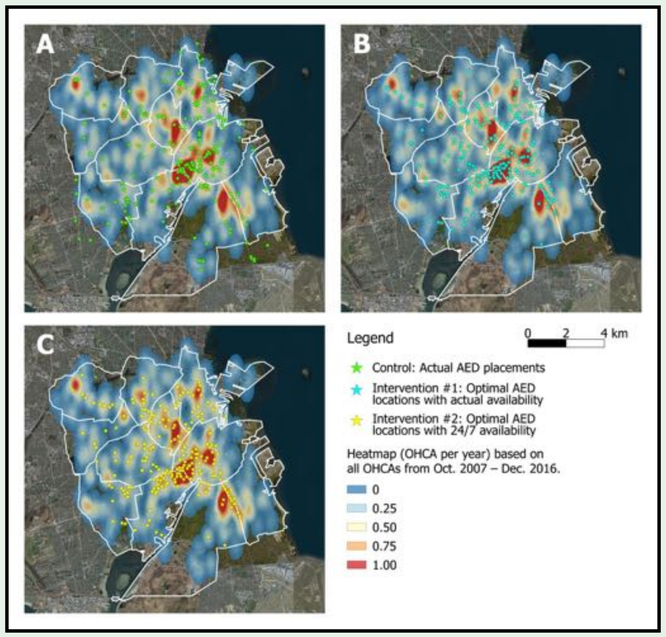

Figure 4. Actual (A), intervention #1 (B) and intervention #2 (C) AED placements up to the end of the 30th time period (Oct. 2007 - April 2010).

Conclusion

•Mathematically optimized AED placements increased OHCA coverage by approximately 50%-100% over actual AED placements in Copenhagen.
•Optimization can serve as the foundation for an AED placement strategy to improve survival from OHCA.

Disclosures| None

Email: christopher.sun@mail.utoronto.ca