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Original article

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An adaptation strategy to urban heat: Hospital rooms with radiant cooling accelerate patient recovery

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Keywords: chronic obstructive pulmonary disease, acute exacerbation, air condition, heat stress, activity tracking

Social media summary:
A radiant cooling system in hospital patient rooms provides clinical benefits for patients with respiratory disease exacerbations during summertime. Patients hospitalised in rooms with air-convection free radiant cooling were discharged earlier.

ABSTRACT

Background: Patients with respiratory diseases are vulnerable to the effects of heat. Therefore, it is important to develop adaptation strategies for heat exposure. One option is to optimize the indoor environment. To this end, we equipped hospital patient rooms with radiant cooling. We performed a prospective randomized clinical trial to investigate potentially beneficial effects of the hospitalisation in rooms with radiant cooling on patients with a respiratory disease exacerbation.

Methods: Recruitment took place in June, July, and August 2014 to 2016 in the Charité – Universitätsmedizin Berlin, Germany. We included patients with COPD, asthma, pulmonary hypertension, interstitial lung disease, and pneumonia. 62 patients were allocated to either a standard patient room without air conditioning or a room with radiant cooling set to 23°C (73°F). We analysed the patients' length of stay with a Poisson regression. Physiological parameters, fluid intake, and daily step counts were tested with mixed regression models.

Results: Patients hospitalised in a room with radiant cooling were discharged earlier than patients in standard rooms ($p=0.003$). The study participants in chambers with radiant cooling had a lower body temperature ($p=0.002$), lower daily fluid intake ($p<0.001$), higher systolic blood pressure ($p<0.001$), and an increased daily step count ($p<0.001$).

Conclusion: The results indicate that a radiant cooling system in hospital patient rooms provides clinical benefits for patients with respiratory disease exacerbations during the warm summer months, which may contribute to an earlier mobilization. Radiant cooling is commended as a suitable adaptation strategy to reduce the clinical impact of climate warming.

Introduction

Heat waves increase the number of emergency department visits by patients with pneumonia, influenza, bronchitis, emphysema, and chronic obstructive pulmonary disease (COPD) [1]. High temperatures are associated with more respiratory symptoms [2] and hospitalisations, especially in the elderly population [3]. A previous study with COPD patients showed a reduction in exercise capacity, lung function, and a worsened disease status during heat stress [4]. In view of the global climate change, we have to prepare for even more intense and more frequent heat waves in the future [5]. Therefore, it is important to develop adaptation strategies.

After studying the effects of heat on COPD patients, McCormack and colleagues concluded that indoor environmental conditions should be optimized to protect this vulnerable high-risk group [6]. An analysis by Braga et al. demonstrated a positive effect of central air conditioning to reduce respiratory and cardiovascular deaths during hot days [7]. Another study by Petkova and colleagues on urban heat-related mortality in the United States of America attributed a rapid adaptation to heat since the 1970s to increased access to air conditioning [8].

As part of developing and evaluating an adaptation strategy to increasing urban heat, we equipped two hospital patient rooms with a radiant cooling system. Radiant cooling has the benefit of not requiring cool air circulation that might spread infection between patients. We initiated a prospective randomized clinical trial to investigate the benefits of regulating hospital room temperature with a radiant cooling on a primary outcome measure of length of hospital-stay, and secondary outcomes including cardiovascular and respiratory parameters, clinical improvement, and physical activity. We chose the length of stay in the hospital as the primary outcome as it is important to patients and is an important cost in the treatment of COPD exacerbations [9].

Methods

Study design

The prospective randomized controlled clinical trial was registered in the WHO compliant registry Deutsches Register Klinischer Studien (German Clinical Trials Register, DRKS00004931) on 26th April 2013. The study was approved by the ethics committee of the Charité – Universitätsmedizin Berlin (EA1/279/11). We performed the study according to the principles of the Declaration of Helsinki. Written informed consent was obtained from every participating patient.

Recruitment took place from 1st June 2014 to 31st August 2016 in the Charité – Universitätsmedizin Berlin, Germany. To exclude patients with a possible exposure to cold temperatures from the study, recruitment was paused from the beginning of September to the end of May in each year.

The study population consisted of patients with respiratory diseases, hospitalised due to an acute episode of worsening respiratory symptoms that warranted treatment (which we termed an exacerbation). We included patients with COPD, asthma, pulmonary hypertension (PAH), interstitial lung disease (ILD), and pneumonia who presented acutely at an emergency room or were directly referred to the hospital by a local physician. Trained physicians made the diagnosis according to current guidelines. COPD diagnosis and staging were based on post-bronchodilator spirometry results, according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification [10]. For the diagnosis of asthma, the 'Nationale Versorgungsleitlinien, 2. Auflage' were applied [11]. For PAH diagnosis, we used the guidelines from 2009 [12], which were updated during the study in 2015 [13]. ILD was diagnosed according to the 'S2K Leitlinie für Diagnose und Therapie der idiopathischen Lungenfibrose' [14]. The

diagnosis of pneumonia was made by use of 'Empfehlungen zur Therapie akuter Atemwegsinfektionen und der ambulant erworbenen Pneumonie' [15].

Exclusion criteria were lung cancer with a life expectancy of less than six months, a requirement for intensive care, unstable coronary disease, severe liver disease (Child-Pugh class C), severe kidney disease (Glomerular filtration rate $\leq$29 mL/min/1.73m^2), patient awaited lung transplantation, inability to fulfil the testing and examination procedures, or the expectation of a room change before discharge. To avoid a bias in the results due to including the same patient multiple times, patients with repeated hospital admissions during the recruitment phase were included once only. Figure 1 shows the CONSORT diagram for the study; in total, we analysed the data of 62 patients.

Study setting and randomization

We equipped two hospital patient rooms with capillary tube mats for air convection free temperature control (Clina Cooling Inc. by service provider S & L Kühldecken und Heizungssysteme GmbH und Co. KG, Mittenwalde, Germany). In a pilot phase prior to the study, most patients perceived 23°C to be a comfortable temperature. 21°C and 22°C caused discomfort in several patients, who complained that the room was cold for them. Therefore, the radiant cooling system was set to maintain a room temperature of 23°C (73°F). The system served for temperature control only and did not modulate humidity. Both chambers with radiant cooling were shared rooms on the 4th floor, one for two, the other for three patients. For the control group, we used standard patient rooms of equal architecture in the same building on the 3rd and 4th floor, with equal conditions concerning daylight, position to the sun and nursing staff.

The randomization was planned by the Coordinating Centre for Clinical Studies of the Charité – Universitätsmedizin Berlin to ensure allocation concealment towards the study personnel until the moment of assignment. To prevent selection bias, patients

were allocated to the two room types according to a randomization list. Occasionally, new patients were allocated to the room with the only vacant bed to ensure separation by sex. This was a "real-world" study performed under conditions typical of a busy clinical department of pneumology.

Sample size calculations

Prior to this study, there were no data available on the effect size of radiant cooling on length-of-stay of hospitalised patients on which to base a power calculation. Our sample size was determined by as many patients as possible within the timescale and financial budget of the project.

Data collection and endpoints

Length of stay

The primary endpoint of the study was the patients' length of stay in the hospital. Patients were discharged by the physician who considered amongst a number of factors including whether the patient was free of fever (≤ 37.2°C), had a reduction in dyspnoea, cough, and sputum, had a forced expiratory volume in 1s (FEV_1) >15% predicted, and was hemodynamically stable (blood pressure >90mmHg, heart rate <100bpm).

Questionnaires

The COPD Assessment Test (CAT™, GlaxoSmithKline copyright 2009) was used to evaluate the disease status of the COPD patients [16]. We also applied the Modified British Medical Research Council Questionnaire for Dyspnoea (mMRC) to assess symptom severity [17–19]. The patients answered both questionnaires at hospital admission and prior to discharge.

Physiological measurements

In physiological studies of heat stress, core body temperature, heart rate, and average skin temperature are used as indicators of heat strain [20]. Heat causes vasodilation that will require increases in cardiac output and heart rate to maintain blood pressure and perfusion. The passive exposure to mild heat (28.8°C to 37.5°C) has been studied by Pallubinsky et al. [21]. Their study showed that after acclimation, core body temperature and sweating decreased, and blood pressure was lowered. We included similar endpoints into our study, although instead of sweating, we monitored the patients' fluid intake.

We measured the patients' weight with a scale (Kern & Sohn GmbH, Balingen-Frommern, Germany) at admission and on the last day of hospitalisation. The body temperature was determined every morning in the patients' ear with a remote medical thermometer (B. Braun Melsungen AG, Melsungen, Germany). At the same time, blood oxygen saturation and heart rate were measured by pulse oximetry (Medtronic, Minneapolis, MN, USA). Blood pressure was determined with an automatic sphygmomanometer (ROESER Medical GmbH, Essen, Germany). Daily Fluid intake was monitored by the nursing staff according to a mandatory standardized protocol.

Activity tracking

Upon hospital admission, patients were equipped with the activity tracking device Withings Pulse O_2™ (Nokia Solutions and Networks GmbH & Co. KG, Munich, Germany) to record daily step counts. The study participants were instructed to wear the activity tracker on their non-dominant wrist and to only take it off for showering or bathing.

Meteorological data

The daily maximum and minimum outdoor temperatures illustrated in supplementary figure S2 were obtained through the website of the German Meteorological Office

(Deutscher Wetterdienst, www.dwd.de). The temperatures were measured by a meteorological station located in the urban area of Berlin at 48 m above sea level on 52.47°N and 13.40°E, the former Berlin-Tempelhof airport area.

Statistical analysis

The statistical analysis was performed with IBM SPSS Statistics version 25 (IBM Corporation, Armonk, NY, USA). The supplementary figure S2 was plotted using GraphPad Prism version 4 (GraphPad Software, San Diego, CA, USA). Data were descriptively analysed and reported as median, minimum, and maximum values. To compare the control and intervention group, we applied Mann-Whitney U tests and chi-squared tests. Wilcoxon signed-rank tests were used to compare the data collected at admission and at discharge on the same patient. Length of stay was analysed as the dependent variable of a Poisson regression with room type as independent variable. The relationships between length of stay and sex, age, body mass index, smoking status, and medication were also examined. Mixed effects linear regression models were used to investigate the effect of room type on the repeated measures of body temperature, blood pressure, heart rate, oxygen saturation, daily fluid intake, and daily step count, with adjustment for sex, age, BMI, and smoking status as covariates. P-values less than 0.05 were considered statistically significant.

Results

Study population

The characteristics of the two study groups are reported in table 1.

The study participants were mainly COPD patients, often with a coexistent respiratory condition. Of the six included patients without a COPD, two patients each were

admitted to the hospital with an acute episode of worsening respiratory symptoms of pneumonia, asthma, or interstitial lung disease. Patients allocated to the different room types were of similar age, sex, smoking status, and diagnosed respiratory conditions. Patients in the rooms with radiant cooling had a significantly higher BMI (p=0.024. Mann-Whitney U test).

During June, July, and August, the daily temperatures in the standard patient rooms varied between 21.5°C and 28.2°C, with an average value of 24.0°C, while the radiant cooling system maintained a stable room temperature of 23.0°C. A box-and-whisker plot of the temperatures in the two room types is provided as supplementary figure S1. The outdoor temperatures are illustrated in the supplementary figure S2.

Comparison of control and intervention group

Figure 2 and table 2 show the results for the primary outcome measure, length of hospital stay, which was significantly shorter for patients hospitalised in a room with radiant cooling compared to patients residing in a standard room (p=0.003, Poisson regression). A multivariate Poisson regression model with both control and intervention group combined showed that length of stay was independent of sex (p=0.290), smoking status (p=0.157), and body mass index (p=0.235). The patients' age influenced the hospitalisation duration (p=0.047); with each year of age increasing stay by 1.1% (95% CI 1.000 to 1.022).

Table 2 shows the results for questionnaires on health status (CAT) and dyspnoea severity (mMRC), in the two room types.

Table 3 summarizes the patients' disease status and weight at admission and at discharge from the hospital. The CAT score of the COPD patients improved during the hospital stay, regardless of the patient room type (w/o cooling p=0.016; with cooling

p=0.001, Wilcoxon signed-rank test). We recorded no significant weight changes during the patients' stay at the hospital.

The results of the mixed regression modelling are displayed in table 4. The study participants in the rooms with radiant cooling had a higher systolic blood pressure ($p<0.001$), lower body temperature ($p=0.002$), lower daily fluid intake ($p<0.001$), and an increased daily step count ($p<0.001$). Supplementary table S1 provides information on minimum, maximum, and median values of the recorded physiologic parameters.

Figure 3 shows the activity tracking results, illustrating the higher daily step counts for patients in the radiant cooled room compared to the daily step count of patients hospitalised in conventional rooms. Daily step count data were provided by 8 patients from the control group and 14 intervention group patients. Data was only provided by patients who agreed to be monitored at hospital admission and who were ambulatory.

A comparison of the patients' medication at hospital discharge by room type using chi-squared tests revealed differences in the frequencies of treatment, with less treatment with systemic corticosteroids ($p=0.046$) and angiotensin-converting-enzyme inhibitors ($p=0.001$) in the room with radiant cooling (shown in table 5). Time to discharge was not related to treatment with systemic corticosteroids ($p=0.395$), nor angiotensin-converting-enzyme inhibitors ($p=0.830$) in a multivariate Poisson regression model.

Discussion

Length of stay

The main finding of our study is that patients with a respiratory disease exacerbation during the warm summer season could be discharged significantly earlier from hospital if their patient room was equipped with a radiant cooling system. This agrees with Shajahan and colleagues who recently reviewed the scientific evidence for the effects of indoor environmental parameters on medical outcomes [22]. They reported that heating, ventilation, and air conditioning (HVAC) systems would enhance the patients' healing process and reduce the length of hospital stay if appropriately designed, though most of the research was based on simulation. Our study translates the theoretical and climatic chamber studies into the hospital setting and therefore provides much needed real-world evidence. Lomas et al. investigated the resilience of buildings in the United Kingdom of Great Britain and Northern Ireland to climate change [23]. Their analysis of the thermal comfort in a hospital includes the statement that radiant cooling is a useful way to enhance thermal resilience at relatively low energy demand.

COPD Assessment Test (CAT)

The summary of our study results in table 2 shows that the patient cohorts in both room types had a comparable CAT score at admission ($p=0.556$). At discharge, the median CAT score had improved in both groups (room w/o cooling $p=0.016$; with cooling $p=0.001$). This emphasizes that the control and intervention group had a comparable health status at admission and discharge.

Physiological measurements and daily step-count tracking

In the radiant cooling arm of our study, we observed a lowered body temperature and fluid intake, indicative of less heat stress, and higher systolic blood pressure suggestive

of less vasodilation of surface blood vessels in the cooling environment. The higher daily step count of patients hospitalised in the radiant cooled rooms could be explained by an earlier mobilization. The mechanism by which climate control will benefit patients is unknown but cooling during warm weather might reduce breathlessness. The impact of cold air on COPD patients has been previously investigated by Spence et al. [24]. An experiment with 19 COPD patients showed a reduced breathlessness score after cycle ergometry exercise when breathing cold air compared to room air and an improved peak exercise performance. Schwartzstein and colleagues found that a flow of cold air directed against the face reduced breathlessness in 16 healthy study participants [25]. The mMRC dyspnoea score did not capture an improvement of the clinical status between admission and discharge in our study, likely to the limited number of steps from zero to four points.

Limitations

The temperature of the room could not be hidden from the patient or healthcare professionals treating the patient, and thus this is an un-blinded study. However, objective clinical parameters suggest a speedier recovery. The radiant cooling system did not regulate air humidity. We did not measure humidity in the rooms, nor calculated any indices expressing perceived temperatures.

Despite randomization, there was an imbalance between weight and BMI in room allocation with a median BMI of 27 in the intervention group compared to a median BMI of 23 in the control group (see table 1). This imbalance occurred by chance, the room allocation was not stratified for any patient characteristics. Subsequent studies should use a case-control matching or stratify for sex, age, and BMI at randomization. Nevertheless, our results showed no dependency between BMI and length of stay ($p=0.235$, Poisson regression).

In a previous study, we were able to show that patients with pulmonary hypertension have a decreasing daily step count with rising maximum outdoor temperature ($r=-0.47$, $p<0.001$) [26]. Therefore, we chose step counts as an endpoint of our present study not only as a measure for early mobilization, but also as an indicator of heat stress. Due to a poor compliance of some patients to wear the activity tracker 24 hours a day, we were unable to compare daytime and night-time movements.

It is known that comorbidity increases vulnerability to the effects of heat [27]. Our study was too small to examine cardiovascular and metabolic comorbidities admitted with an exacerbation of their respiratory disease. We would recommend that future studies should also focus more on multi- or comorbidity.

Conclusion

The results indicate that radiant cooling systems in hospital patient rooms provide clinical benefits for patients with respiratory disease exacerbations during warm summer months and contribute to an earlier mobilization. Equipping patient rooms with air-convection free radiant cooling is commended as a suitable adaptation strategy to reduce the clinical impact of a warming climate.

Acknowledgements

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Support statement

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Conflict of interest

CW received grants from the Deutsche Forschungsgemeinschaft during the conduct of the study and personal fees from MSD, AstraZeneca, Bristol-Myers Squibb, GlaxoSmithKline, Takeda, and BERLIN-CHEMIE outside the submitted work. GCD reports grants from AstraZeneca, as well as personal fees from AstraZeneca, the American Thoracic Society, and FWO, Flanders, outside the submitted work. UL received personal fees from AstraZeneca, BERLIN-CHEMIE, Boehringer Ingelheim, Bristol-Myers Squibb, GlaxoSmithKline, Novartis, and Roche.

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Figure legends

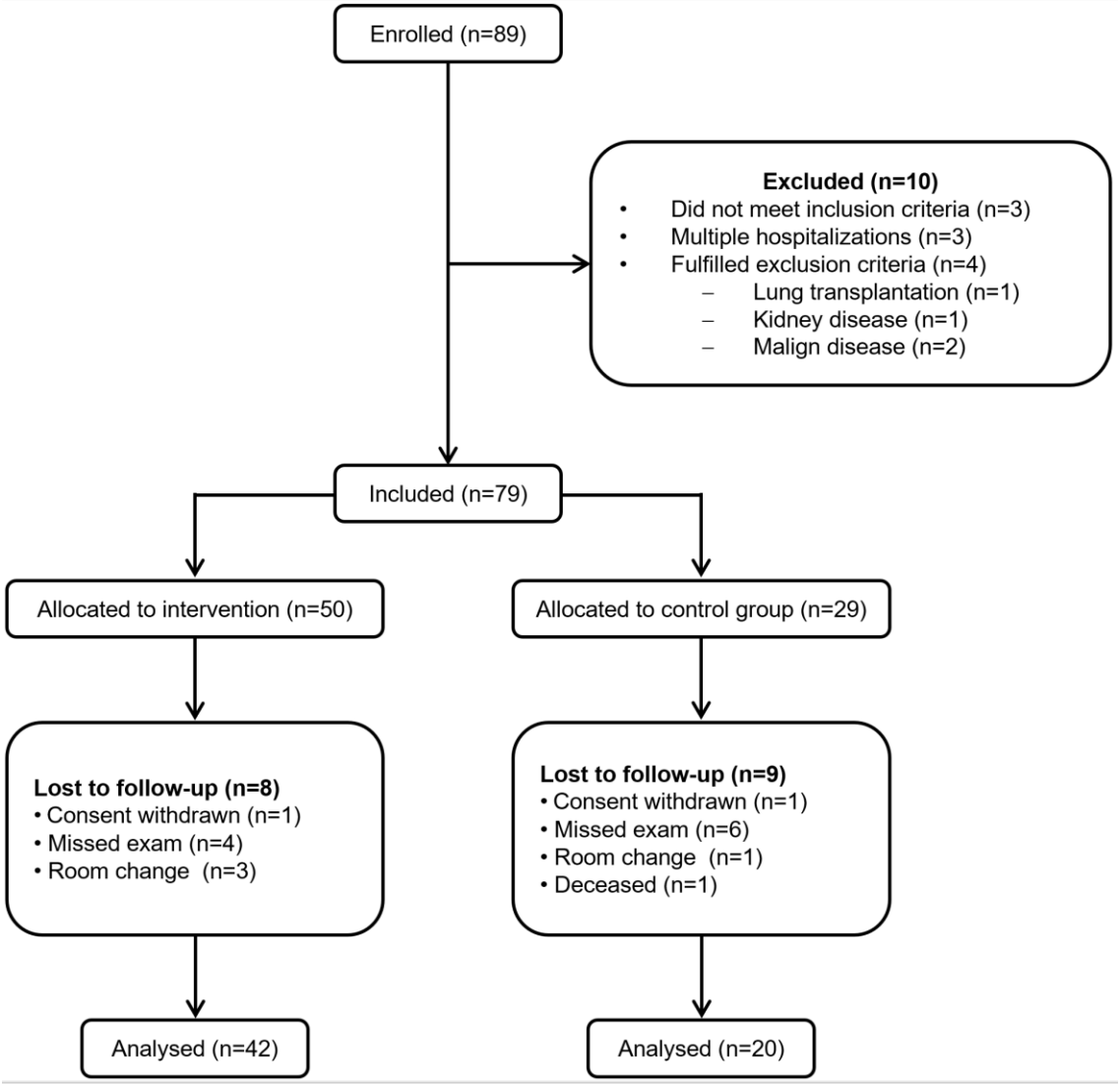

Figure 1. Study flowchart.

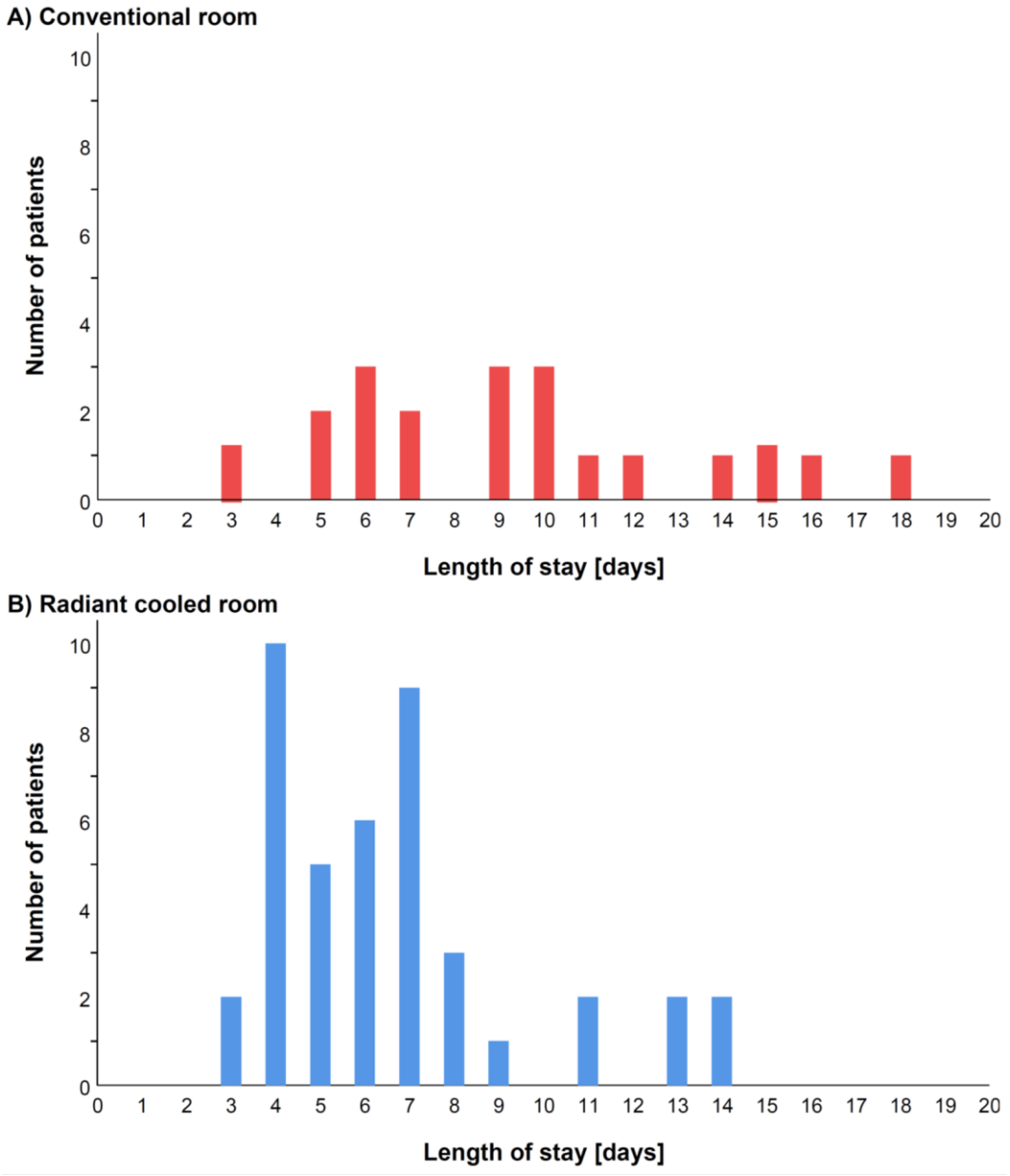

Figure 2. Length of hospital stay in each group.

The upper panel A illustrates the length of hospital stay in the conventional patient rooms. The lower panel B shows the hospitalisation duration in the rooms with radiant cooling.

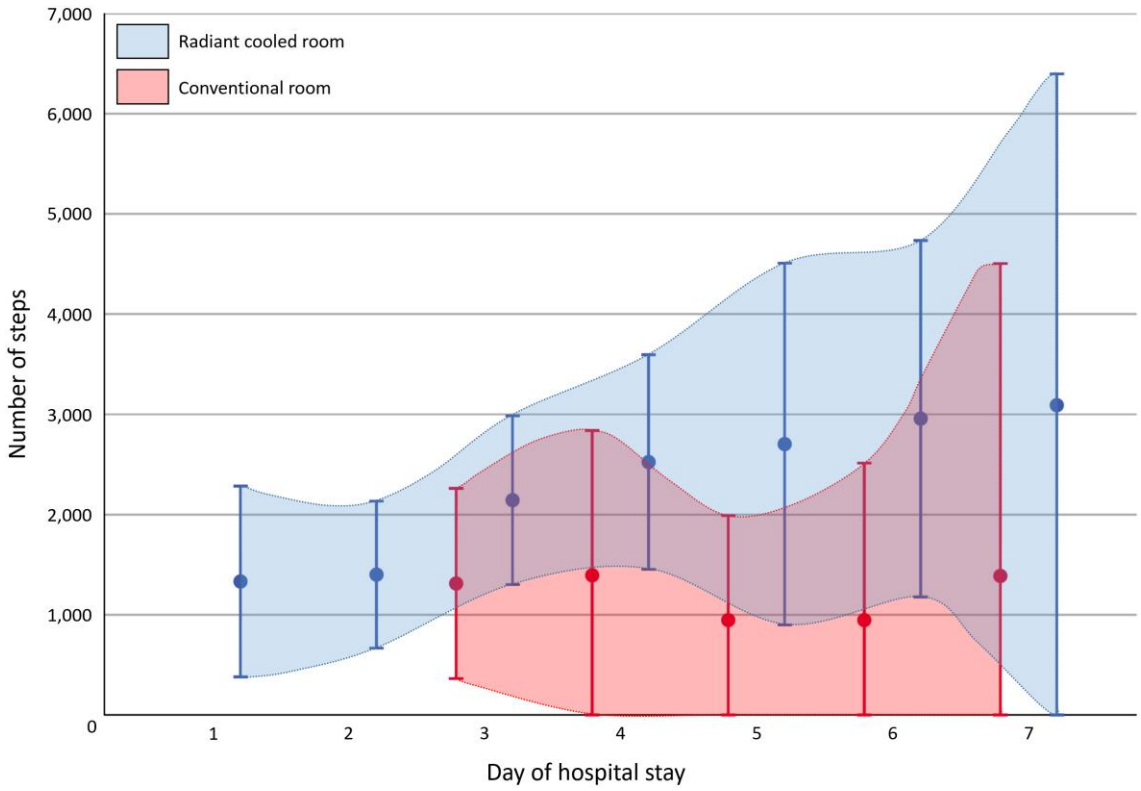

Figure 3. Activity tracking results.

Displayed are mean values of step counts (dots) and 95% confidence intervals (whiskers). The activity data originate from the following number of patients: day 1, n=9; day 2, n=10; day 3, n=18; day 4, n=16; day 5, n=13; day 6, n=10; day 7, n=9.

Table 1 Characteristics of the different patient cohorts hospitalised in rooms with or without radiant cooling

Parameter	**Room without radiant cooling**	**Room with radiant cooling**	**P value**
Patients included, n	20	42	–
Female, n (%)	9 (45.0%)	11 (26.2%)	0.139
Age, years, median (range)	65 (48-84)	66 (32-85)	0.757
BMI, kg/m^2, median (range)	23 (17-53)	27 (16-42)	0.024*
Smoker, %	–	10.3%[c]	0.320
Former smoker, %	83.3%[a]	79.5%[c]	0.320
Non-smoker, %	16.7%[a]	10.3%[c]	0.320
Diagnosed condition, n (%)			
COPD	19 (95.0%)	37 (88.1%)	0.390
GOLD 1	–	5.9%[d]	0.496
GOLD 2	14.3%[b]	20.6%[d]	0.496
GOLD 3	35.7%[b]	44.1%[d]	0.496
GOLD 4	50.0%[b]	29.4%[d]	0.496
GOLD A	–	–	0.563
GOLD B	50.0%[b]	40.0%[d]	0.563
GOLD C	–	–	0.563
GOLD D	50.0%[b]	60.0%[d]	0.563
Asthma	3 (15.0%)	7 (16.7%)	0.868
Pulmonary hypertension	4 (20.0%)	3 (7.1%)	0.135
Interstitial lung disease	2 (10.0%)	2 (4.8%)	0.433
Pneumonia	7 (35.0%)	6 (14.3%)	0.061
Neoplasia	1 (5.0%)	1 (2.4%)	0.585

Abbreviations: BMI, Body Mass Index; GOLD, Global Initiative for Chronic Obstructive Lung Disease. Comparisons were made by chi-squared test or Mann-Whitney U test. * $p<0.05$; [a], two patients did not disclose their smoking status, valid percent is reported; [b], missing data for six patients, valid percent; [c], three patients did not disclose their smoking status, valid percent, adds up to more than 100% due to rounding error; [d], missing data for eight patients, valid percent

Table 2 Comparison of patients' length of stay, clinical status, and body weight dynamics depending on the air conditioning status of the patient rooms

Parameter	Room without radiant cooling	Room with radiant cooling	P value
Length of hospital stay, median (range)	9 days (3 – 18)	6 days (3 – 14)	0.003
CAT, median (range)			
Admission	27 (15 – 36)	28 (11 – 38)	0.556
Discharge	23 (1 – 32)	23 (6 – 36)	0.864
mMRC, median (range)			
Admission	3 (1 – 4)	4 (0 – 4)	0.176
Discharge	3 (0 – 4)	3 (0 – 4)	0.812
Body weight, median (range)			
Admission	61 kg (44 – 152)	80 kg (48 – 138)	0.002**
Discharge	61 kg (44 – 100)	76 kg (46 – 110)	0.049*

Abbreviations: CAT, COPD Assessment Test; mMRC, Modified British Medical Research Council Questionnaire for Dyspnoea; * $p<0.05$; ** $p<0.01$

Table 3 Comparison of the clinical status and body weight dynamics between admission and discharge of the patients

Parameter	Admission	Discharge	P value
CAT, median (range)			
Room without cooling	27 (15 – 36)	23 (1 – 32)	0.016*
Room with cooling	28 (11 – 38)	23 (6 – 36)	0.001**
mMRC, median (range)			
Room without cooling	3 (1 – 4)	3 (0 – 4)	1.000
Room with cooling	4 (0 – 4)	3 (0 – 4)	0.149
Body weight, median (range)			
Room without cooling	61 kg (44 – 152)	61 kg (44 – 100)	0.715
Room with cooling	80 kg (48 – 138)	76 kg (46 – 110)	0.102

Abbreviations: CAT, COPD Assessment Test; mMRC, Modified British Medical Research Council Questionnaire for Dyspnoea; * $p<0.05$; ** $p<0.01$

Table 4 Results of mixed effects regression modelling

	P values of independent variables				
Dependent variables	**Age**	**Sex**	**BMI**	**Smoking status**	**Room type**
Body temperature[a]	0.270	0.064	0.083	0.155	0.002**
Blood pressure[b]					
Systolic	<0.001***	<0.001***	0.044*	0.001**	<0.001***
Diastolic	<0.001***	<0.001***	0.623	0.089	0.162
Heart rate[b]	<0.001***	0.415	0.081	0.768	0.760
Oxygen saturation[b]	0.071	0.471	0.645	0.258	0.163
Daily fluid intake	0.090	<0.001***	0.010*	0.141	<0.001***
Daily step count	<0.001***	<0.001***	0.083	0.797	<0.001***

Abbreviations: BMI, Body Mass Index; Smoking status: smoker/former smoker/non-smoker; [a] measured in the morning with an ear thermometer; [b] measured in the morning; * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 5 Patients' medication by room type

Treatment	Room without radiant cooling	Room with radiant cooling	P value
LABA, n (%)	12 (60%)	33 (79%)	0.205
LAMA, n (%)	13 (65%)	28 (67%)	0.892
SABA, n (%)	8 (40%)	26 (62%)	0.149
SAMA, n (%)	5 (25%)	11 (26%)	0.992
ICS, n (%)	9 (45%)	27 (64%)	0.213
Systemic corticosteroid, n (%)	12 (60%)	15 (36%)	0.046*
Methylxanthine, n (%)	1 (5.0%)	11 (26%)	0.057
Leukotriene antagonist, n (%)	0 (0.0%)	2 (4.8%)	0.333
Angiotensin-II-receptor antagonist, n (%)	1 (5.0%)	7 (17%)	0.222
ACE inhibitor, n (%)	12 (60%)	8 (19%)	0.001**
Beta blocker	7 (35%)	13 (31%)	0.650
Diuretic	9 (45%)	20 (48%)	0.986

Abbreviations: LABA, Long-acting beta$_2$-agonist; LAMA, Long-acting muscarinic antagonist; SABA, Short-acting beta$_2$-agonist; SAMA, Short-acting muscarinic antagonist; ICS, Inhaled corticosteroid; ACE, Angiotensin converting enzyme. Comparisons were made by chi-squared test. * $p<0.05$; ** $p<0.01$

Supplementary Information for

An adaptation strategy to urban heat: Hospital rooms with radiant cooling accelerate patient recovery

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Supplementary tables and figures

Table S1 Physiologic parameter data measured in the patient cohorts hospitalised in rooms with or without radiant cooling

Parameter	**Room without radiant cooling**	**Room with radiant cooling**
Body temperature[a], °C, median (range)	36.0 (35.0-37.7)	35.8 (34.5-37.2)
Blood pressure[b], mmHg, median (range)		
Systolic	120 (95-160)	130 (100-180)
Diastolic	70 (55-90)	75 (59-100)
Heart rate, beats/minute, median (range)	80 (50-108)	80 (40-130)
Oxygen saturation, %, median (range)	96 (80-100)	94 (81-98)
Daily fluid intake, litre, median (range)	2.1 (1.0-4.0)	1.7 (0.9-2.8)

Abbreviations: [a] measured in the morning with an ear thermometer; [b] measured in the morning

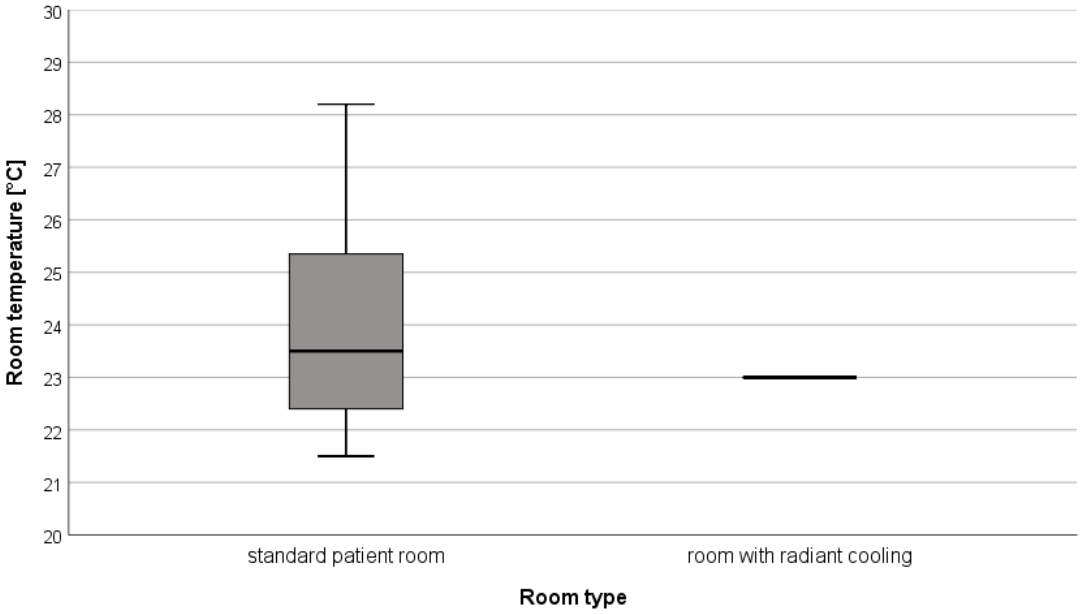

Figure S1. Room temperatures during the study period.

The box-and-whisker plot shows the observed maximum (upper whisker, 28.2°C), minimum (lower whisker, 21.5°C), and median (solid black line, 23.5°C and 23.0°C) temperature values measured in the patient rooms.

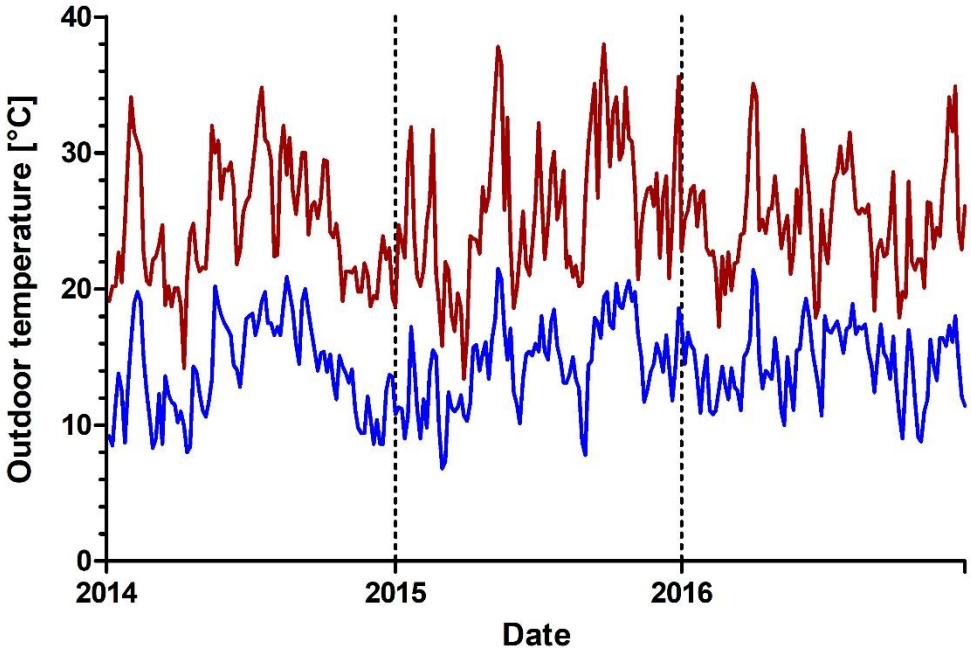

Figure S2. Outdoor temperatures during the study period.

The upper red line shows the daily maximum temperatures measured in Berlin, Germany during the summer months of June, July, and August 2014, 2015, and 2016. The lower blue line illustrates the daily minimum temperatures. Data source: German Meteorological Office (Deutscher Wetterdienst).