DIGITAL TECHNOLOGY

The Green Surgical Block 4.0: Automation of the operating theatre's climate conditions through a real-time patient-flow solution

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ABSTRACT

The energy consumed by surgery units constitutes a staggering part of the overall healthcare carbon footprint. Partly due to the demanding climate conditions necessitated by operating theatres (OTs), energy is also wasted because of poorly managed heating, ventilation and air-conditioning systems (HVACs) that consume up to 57% of the total energy used in a hospital. With their goal of optimising OTs' performance and reducing patient waiting lists, heads of surgery units worldwide do not dare to risk cancelling scheduled surgery because of problems with the OT environment conditions (ie temperature, humidity, pressure). Current solutions are monolithic, complex and completely disconnected from healthcare logic, failing to take into account the idiosyncrasy of hospitals. This article presents an innovation that uses real-time patient flow data to automate and optimise the OT's climate conditions.

KEYWORDS: operating theatre energy management, patient flow, real time location solutions, internet of things, green surgical block

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Introduction

Healthcare systems around the world are significant contributors to the national carbon footprint, with large public hospitals the largest energy spenders.[1] Surgical blocks are the most energy demanding areas in a hospital and are renowned for having poor energy management. In this context, and as part of its Green Deal strategy, Vall d'Hebron University Hospital established a strategy to improve care throughout the surgical process while also saving energy. Using Internet of Things (IoT) technologies to manage both these things more effectively, a real-time location systems (RTLS) solution was implemented to streamline patient flows and to automatically adapt the climate conditions of each operating theatre (OT).

This article presents an innovation in the general surgery block that has reduced the greenhouse gases (GHG) emission by 1,227.27 tCO2e in the last 4 years, saving 5.78 GWh in electricity and €600,000 in public budgets.

Background

In high-income countries, the carbon footprint of healthcare systems is estimated to be 3–10% of the total national greenhouse gas (GHG) emissions.[2] A recent report revealed that the NHS produces 5.4% of the UK's GHG emissions.[3] Hospitals are the major GHG contributor in healthcare, contributing more than 50%, which is increased by other indirect factors such as patient and healthcare worker transport. In turn, the largest GHG contributor in hospitals is energy consumed by heating, ventilation, and air conditioning (HVAC) systems, which account for 57% according to some studies.[4] It is well known that these heavyweight infrastructures are poorly managed in hospitals, resulting in a chronic squandering of energy.[5] The surgical block is the most energy-demanding unit in a hospital, consuming around 20–40% of the total energy expenditure.[6] Strict temperature, air pressure and humidity control are required to contain microbial contamination, which results in significant energy expenditure for the hospital. However, fixation on maintaining over-optimal conditions to prevent air contamination leads to overspending, which current evidence suggests is unnecessary.[7]

Nowadays, most HVACs are operated manually by theatre staff to modify climate status. However, this is far from optimal, as it is rare that OTs are set to 'rest' while they are empty. Theatre managers will always prioritise surgical performance over any procedural cancellation due to suboptimal OT climate conditions.

The opportunity

Studies have concluded that shutting down OTs' HVAC during off-duty periods, especially at night, does not appear to result

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Table 1. Operating theatre climate variables

Theatre energy status	Mode of working	Activation
Active	Perimeter lighting: 100% Temperature: basal (21°C +/− 0.5°C) Ventilation flow: high	As soon as the RTLS system moves to status 'Theatre ready'
Active with low ventilation	Perimeter lighting: 60% Temperature: basal (21°C +/− 0.5°C) Ventilation flow: low	As soon as the RTLS system moves to status 'Theatre dirty'
Sleep	Perimeter lighting: 10% Temperature: basal (21°C +/−4°C) Ventilation flow: low	As soon as the RTLS system moves to status 'Theatre dirty' and there are no more patients on the list

in a significant particle count or microbial contamination. It has been shown that if HVACs are restarted 30 minutes before the scheduled operation, a high level of air quality is maintained.[8] That is why Vall d'Hebron hospital aimed to demonstrate how its new real-time locating system (RTLS) patient flow solution installed in the general hospital block could help to automate the adjustment of temperature, pressure and humidity in OTs based on surgical planning and real-time patient occupancy, representing a huge opportunity for saving energy in surgery units.[9]

Methods

Main objective

The main objective of this work has been to assess the impact on energy key performance indicators with the implementation of the new green RTLS solution that dynamically adjusts the right climate conditions of each OT as interventions move along surgical sessions.

The setting

The new solution was implemented in the new surgical block of the general hospital, which has adopted the latest technologies designed to carry out highly complex operations. The new surgical block required an investment of €21 million in construction and €16 million more in equipment. In 10,000 square metres of hospital space, there are 700 professionals serving 19 OTs, carrying out more than 9,000 interventions every year.

The solution

The novel digital approach was built in collaboration with MYSPHERA SL, which developed a bespoke RTLS solution for the surgical process. While this innovation was originally intended to optimise OT utilisation and increase the block performance, eventually it was also used to enable the smart energy control of the OTs.

The technological solution has two main elements. First, it automatically adjusts the climate level of the OTs according to different states generated by the real-time location system (RTLS) (Table 1). Thus, the HVAC is activated in theatre when the solution detects that a patient has been transferred to the preparation area and is ready for their operation (ie activation occurs at least 30 minutes before use). Whenever there is a patient transfer out of the OT, the solution sets the climate to rest, consuming far less energy, until the next patient to be operated on is in the preparation area. As soon as the last patient on the daily schedule leaves the OT, regardless of the time, the HVAC is turned off. Likewise, at the weekends, the HVACs are shut down. All this is possible because patients are localised in real time by means of Bluetooth tags. In specific cases such as professional training sessions, this approach is not used unless a real patient with a tag is part of the session (Fig 1).

Second, in order to improve the experience of theatre staff, the new RTLS patient flow solution provided a theatre screen that, as well as showing patient flow and theatre status to optimise process management, also provided information on and direct control of the following climate parameters (Fig 2):

- perimeter light control in 20% steps
- temperature control between 19–23°C
- humidity display
- air pressure display
- OT status control (ie active, active in low ventilation, sleep)
- OT timer control.

Solution deployment

The new RTLS patient flow solution was first implemented to monitor and automate surgical clinical pathways in 2017. As soon as this new approach was consolidated, the same solution was

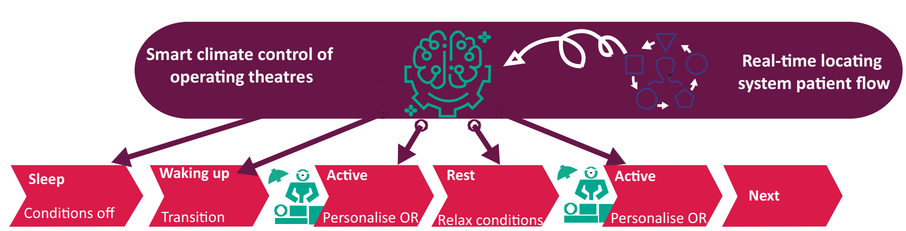

Fig 1. Automatic climate control of OTs.

Fig 2. Dashboard dedicated to improving OT climate control staff experience.

integrated with OTs' energy control system (ECS), based on a solution from Controlli Delta.

Endpoint monitoring

To assess the surgical block energy performance, five endpoints were monitored:

1. Surgical block consumption per year (SBC)
2. OT consumption per year (OTC)
3. Waste per surgical block year (WSB)
4. Waste per theatre year (WOT)
5. Economic savings (ES)

Results

By connecting the HVAC systems to MYSPHERA's solution, the hospital was able to obtain a staggering saving of 1,445 MWh in 2018, moving from a baseline spending of 4,817 MWh in 2017 to a final consumption of 3,372 MWh in 2018, representing a cost reduction of €150,000 per year. This is a reduction of about 30% of the total energy spending in that surgery unit alone and a waste per OT of 76 MWh/year (Table 2).

Overall, the whole hospital campus employs more than 9,000 professionals and comprises 22 buildings in an area of 132,695 m^2 including the general, maternity and trauma hospitals. This campus generated a total consumption of electricity of 22,431.6 MWh by the end of 2016 with a total cost of €2.33 million. The new surgical area in the general hospital covers 10,000 m^2 of that, representing only 7.5% of the total area of the hospital campus, but it before the innovation was implemented it consumed 21.46% of the campus electricity. After the implementation of the innovation, the contribution of this surgical block was reduced to about 15%.

Taking into account the years 2018, 2019, 2020 and 2021, the total accumulated eliminated waste was 5.78 GWh/year, with savings of €600,000 and a reduction on GHG of 1,227.27 tCO_2e.

Discussion

Optimising the use of HVAC is relatively straightforward and has a significant impact on energy savings in secondary hospitals in areas with demanding climate conditions. Usually, surgical units tend to be the areas with the highest consumption in a hospital. However, ITU and A&E are also high energy spenders, and opportunities should be investigated here too.[6]

Importantly, the real-time factor, with the OT logic being connected with each patient journey in real time, was key for the fine adjustment of climate conditions. As these RTLS solutions are increasingly adopted by hospitals, it appears plausible that these kinds of strategies will be implemented more widely in the coming years. Likewise, as RTLS solutions are also expanded to other areas of the hospitals, such as A&E, outpatients, ITU and more, the same concept could also be implemented in these areas to have a greater impact in the hospital.

Cost assessment

The freed waste achieved by the innovation has led to savings of €150,000 euros per year in that surgery unit with 19 OTs, which represents €7,895 euros per year per OT. On the other hand, according to MYSPHERA and taking into consideration the scope of this solution, which was originally designed to optimise surgical performance (ie area, number of theatres and other rooms, integrations, and application adaptations), the market price of this project is about €425,000 euros, which gives a return of investment (ROI) of 64.7% in the very first year of implementation. However, it is important to note that the original purpose of the RTLS patient flow solution was to increase surgical performance, and this was achieved with a ROI of 342%.[10] Therefore, the combined ROI, including increase of surgical and energy performance, would correspond to a total ROI of 406.7%.

Conclusions

A total saving of 6.44% of the total electricity consumed in the whole hospital campus was obtained by this innovation, which is remarkable considering that this space only accounts for 7.5% of the total area of the hospital campus. Therefore, it can be concluded that this simple-to-implement solution has a significant impact on mitigating energy squandering. Since Vall d'Hebron Hospital implemented this solution, several more hospitals have opted to do the same in Spain. This shows how an IoT application in the medical domain could have a significant impact in reducing GHG, thus signposting the direction smart hospitals could take in the future.[11] ■

Table 2. Results

	Endpoint	2017	2018
1	Surgical block consumption per year (SBC)	4,817 MWh/year	3,372 MWh/year
2	Operating theatre consumption per year (OTC)	253.52 MWh/year	177.47 MWh/year
3	Waste per surgical block year (WSB)	-	1,445.08 MWh/year
4	Waste per theatre year (WOT)	-	76 MWh/year
5	Economic savings (ES)	-	€150,000/year

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