

## OPEN

# Statewide Real-Time Tracking of Beds and Ventilators During Coronavirus Disease 2019 and Beyond

Matthias Johannes Merkel, MD, PhD<sup>1,2</sup>; Renee Edwards, MD, MBA<sup>3</sup>; Joe Ness, MHA, BSPHarm<sup>3</sup>; Carl Eriksson, MD, MPH<sup>1,4</sup>; Susan Yoder, RN<sup>1</sup>; Stephanie Gilliam, MN, RN, NE-BC<sup>1</sup>; Katie Ellero, MHSA<sup>1</sup>; Coral Barreto-Costa, BA<sup>1</sup>; Peter Graven, PhD<sup>5</sup>; Jeffrey R. Terry, MBA<sup>6</sup>; James Heilman, MD, MBA<sup>1,7</sup>

**Abstract:** This brief report describes the rapid deployment of a real-time electronic tracking board for all hospitals in the state of Oregon. In preparation for the coronavirus disease 2019 surge on hospital resources, and in collaboration across health systems, with health authorities and an industry partner, we combined existing infrastructures to create the first automated tracking board for our entire state, including bed types by health system and geographic area, and with granularity to the individual unit level for each participating hospital. At the time of submission, we have a live snapshot of 87% of beds in the state, including real-time ventilator data across eight health systems. The tracking board allows for rapid assessment of available bed and ventilator resources and pulls electronic health record data that is created through normal care processes rather than relying upon manual entry. It is updated every 5 minutes and is drillable from state to unit level. Together these factors make the data actionable, which is essential in a crisis. The new tracking system integrates seamlessly with our preexisting statewide, manually updated tracking board via bidirectional data sharing to ensure existing processes across the state can continue. This new tool allows any health system in our state to visualize occupancy by type and location in real time. Amid pandemic uncertainty, having a reliable tool for tracking critical hospital

resources will enhance our statewide ability to maintain healthcare functionality in a world with coronavirus disease 2019.

**Key Words:** census board; coronavirus disease 2019; hospital capacity; real time data; ventilator availability

## THE WHY

On February 28, 2020, the Oregon Health Authority (OHA) announced that the first preliminary coronavirus disease 2019 (COVID-19) patient had been admitted in the Portland metro area (1). With this case, most health systems in the state transitioned their emergency operations committees (EOCs) from theoretically preparing for COVID-19 in their hospital to being in active operation.

At Oregon Health & Science University (OHSU), this event in a neighboring metro-area hospital system triggered the start of daily EOC meetings to guide our health system's response to COVID-19. As the only quaternary academic medical center in the state of Oregon, OHSU took the lead in collaborating with the OHA and multiple hospital systems to develop a statewide hospital-capacity response to the pandemic. In 2017, OHSU had already established a Mission Control command center to manage statewide patient access and throughput across the four hospitals in our health system using a centralized, team-based approach (2). Our response to the pandemic was based on this preexisting Mission Control structure, which had already successfully increased access to inpatient beds by creating the equivalent of 18 more hospital beds/day across our health system through the use of real-time information tools and associated procedures and decision rights (3, 4).

Prediction models for the COVID-19 surge in Oregon in late February and early March showed a high possibility of exceeding critical resources, such as critical care beds, ventilators, and access to extracorporeal life support (ECLS) only offered at three health systems in the state (5). This grim prospect was further supported by reports from epicenters across the world (6–10).

<sup>1</sup>OHSU Health, Mission Control, Portland, OR.

<sup>2</sup>Department of Anesthesiology and Perioperative Medicine, OHSU Health, Portland, OR.

<sup>3</sup>OHSU Health, Hospital Administration, Portland, OR.

<sup>4</sup>Department of Pediatrics, OHSU Health, Portland, OR.

<sup>5</sup>OHSU Health, ITG Business Intelligence & Advanced Analytics & School of Public Health, Portland, OR.

<sup>6</sup>GE Healthcare Command Centers, Dallas, TX.

<sup>7</sup>Department of Emergency Medicine, OHSU Health, Portland, OR.

Copyright © 2020 The Authors. Published by Wolters Kluwer Health, Inc. on behalf of the Society of Critical Care Medicine. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

*Crit Care Expl* 2020; 2:e0142

DOI: 10.1097/CCE.0000000000000142

In order to ensure the highest possible utilization of critical resources to best meet this expected surge and to mitigate the risk of making decisions about resource allocation in silos, thus delaying access to the right level of care at any statewide facility, we collaborated to use the command center technology to track bed- and ventilator-capacity data across all hospitals in the entire state.

This approach builds on Oregon's preexisting hospital capacity system (HOSCAPS) which tracks overall status (green or red) for emergency department (ED), acute care, and critical care through daily manual entries from participating hospitals, which is similar to systems in place in other states and countries (11, 12).

The Oregon Capacity System was created to provide at-a-glance visibility to timely and accurate critical resource information without depending on manual data entry that could fail under pressure. GE Healthcare created the design concept, at OHSU's request, based on the command center technology framework already in use in OHSU Mission Control (Fig. 1). The data are automatically updated every 5 minutes from each hospital's electronic medical record with specificity to the bed level for both census and ventilators. No patient-identifiable data are collected. Through philanthropy (OHSU Foundation), we secured the necessary funds to offer this technology to all hospitals in Oregon. Collaboration was reached with nearly all institutions in the state, representing 90% of Oregon's hospital beds on the standardized, automatically updated electronic tracking dashboard.

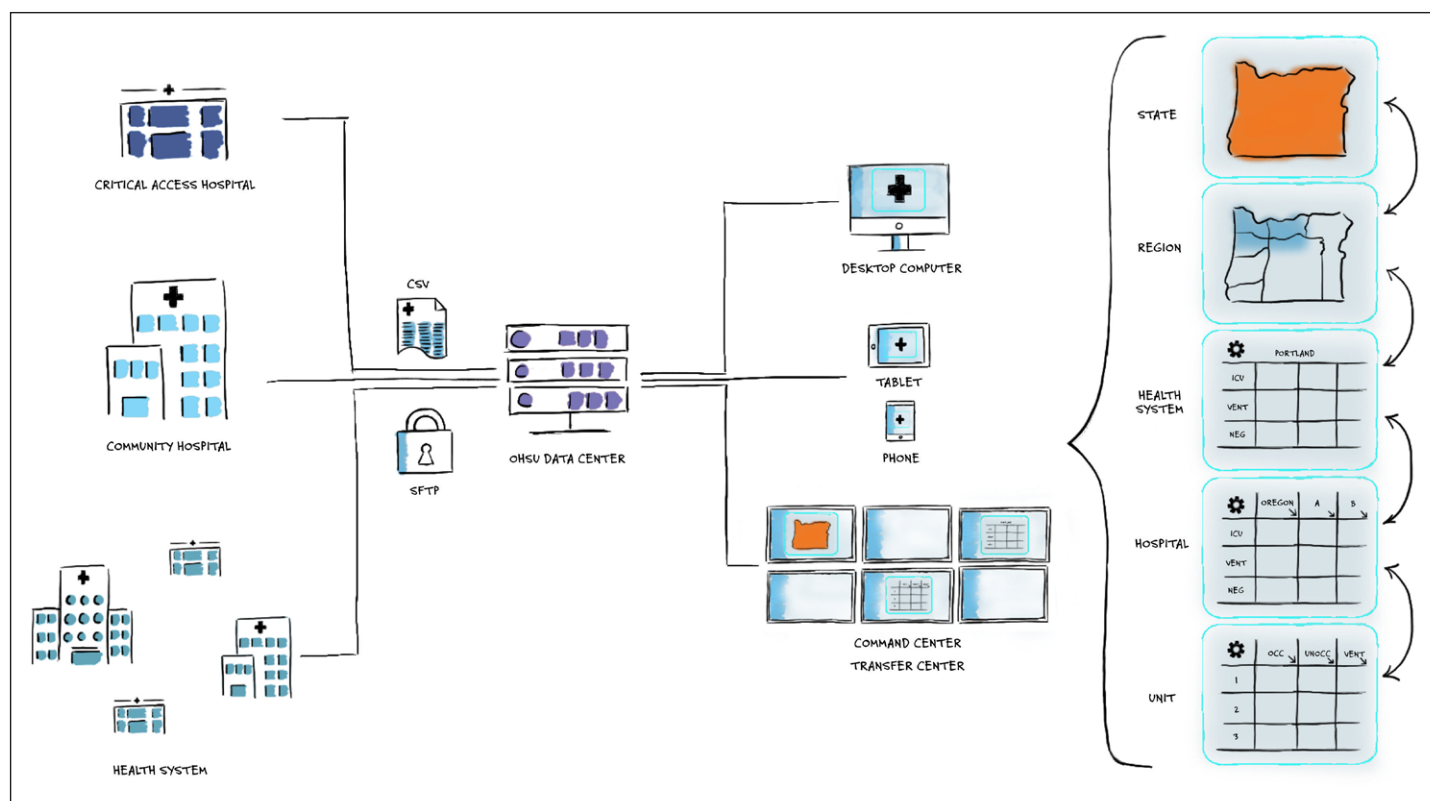
Our initial approach to all health systems was a personal communication by our health system chief operating officer and chief

medical officer to their respective counterparts about the intent and advantages of having linked capacity tracking. A critically important piece was the close connection with leadership in OHA to message the need for real-time data and a shared desire for unification to manage COVID-19 in our state. Recurrent concerns we encountered included the required information technology (IT) resources, so after initial participation agreement was reached, we connected the engineering teams from each hospital with our IT teams at OHSU and GE Healthcare. This quickly resolved concerns about the excess time required for completion. Key for success were a shared vision and the simplicity of the participation requirements. Oregon is the first U.S. state to have this specific system in place across an entire state.

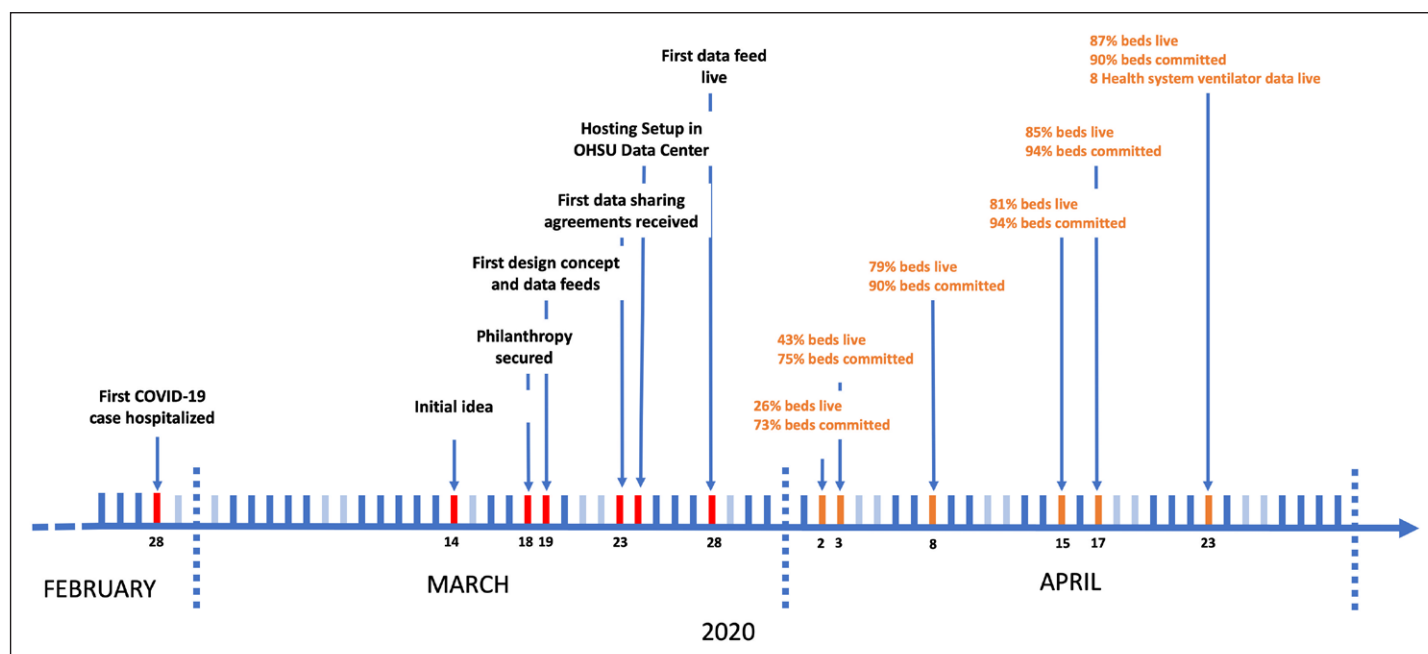
## DEVELOPING A ROADMAP-FROM IDEA TO REALITY

Figure 2 shows the timeline of the real-time data-tracking tool. This timeline exemplifies the speed at which an IT project can come together under urgent conditions. It took us 14 days from the initial idea to the first live dataset populating capacity in real time, and an additional 5 days to have it available in an online version.

Two weeks after the initial live version was published, 85% of Oregon's hospital beds were displayed with real-time data. First ventilator data (in-use vs available) was available within 4 weeks of initial release.



**Figure 1.** The sketch highlights the digital connection between various type of hospitals across the state to a central data center, via comma-separated-value (CSV) formatted flat files using a secure file transfer protocol (SFTP), which then can be displayed on different displays by state, region, health system, hospital, and down to the unit level showing occupied and available beds and ventilators (VENT). NEG = negative pressure room, OCC = percentage of occupied beds/total beds, OHSU = Oregon Health & Science University, UNOCC = unoccupied.



**Figure 2.** Timeline for real time hospital capacity dashboard. *Light blue* highlights weekends and *red* highlights development milestones; *orange* marks data-release dates. COVID-19 = coronavirus disease 2019, OHSU = Oregon Health & Science University.

## METHOD

We created a simple intake process for four required data elements from each participating hospital to simplify and synchronize the required data, independent of the data source (type of electronic health record [EHR]): 1) a “bed master” is provided once to describe the complement of beds and units at each hospital (**Table 1**), 2) a comma-separated-value (CSV) formatted flat file, which provides the census of every bed, is generated by each hospital’s EHR and sent every 5 minutes via secure file transfer protocol (SFTP) to GE Healthcare’s software housed in OHSU’s data center, 3) a CSV flat file is generated by each hospital’s EHR and sent every 5 minutes via SFTP to OHSU’s data center that provides the oxygen source of the patient in each bed (without identifying the patient), and 4) an application program interface provides the manually reported ventilator inventory in HOSCAPS from each hospital twice per day. The existing HOSCAPS system is being updated to provide the near-time bed-census data from this new Oregon Capacity System to complement the bed data available in HOSCAPS used by our Emergency Medical System and many hospital systems’ daily operations and transfer centers to create interoperability.

GE Healthcare streamlined the data requirements and the corresponding technical instructions such that the IT teams at participating health systems could each come online with items 1 and 2 within 3–4 days of signing the participation agreement with less than an hour of applied effort.

Each participating hospital can access the web-based tracking tool with a unique login and password, which ensures security and allows region-specific settings to be saved.

Critically important to this system is that the data in the flat files is created in each hospital’s electronic medical record through the normal processes of care rather than a separate effort to populate this Oregon Capacity System. This ensures the information is accurate. Furthermore, each hospital sends the new extracts every

**TABLE 1. Hospital Bed Master Template**

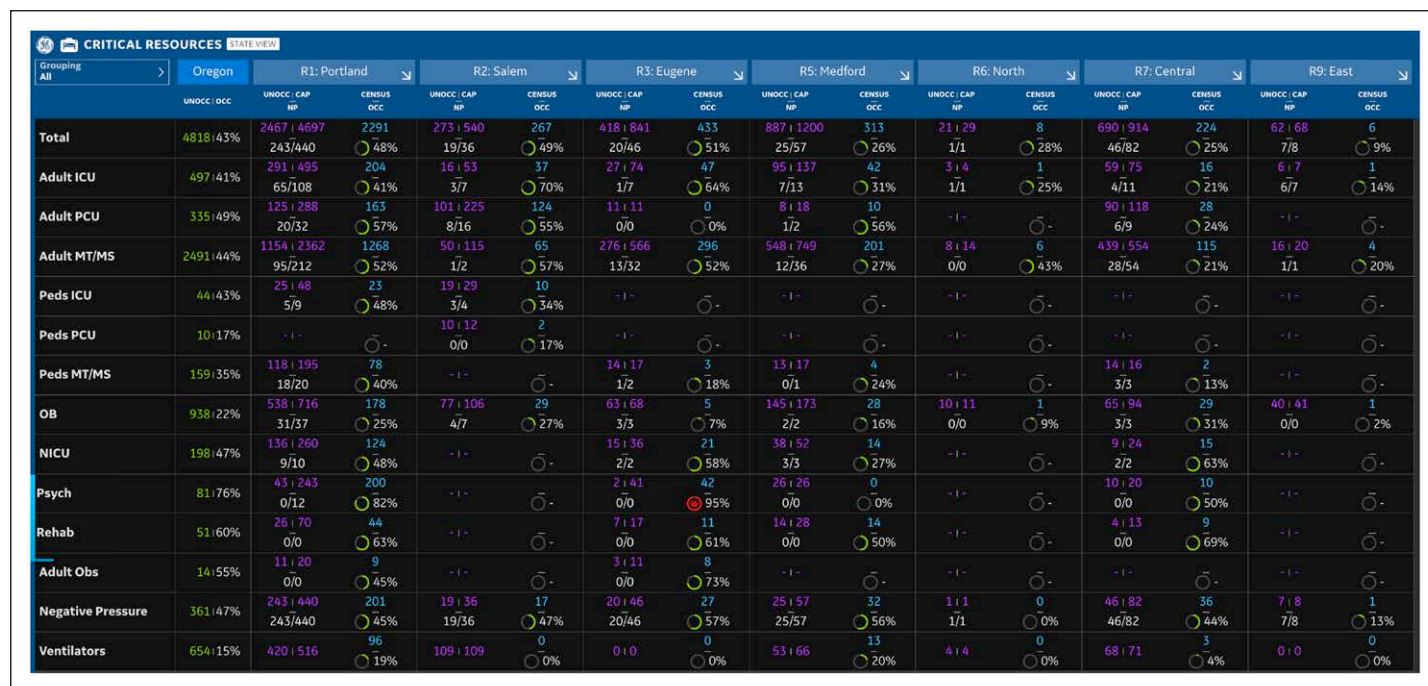
Item	Definition
Hospital ID	Name of facility
Unit ID	Unit ID in EHR
Unit name	e.g., Three West
Unit type	e.g., ICU, post-anesthesia care unit emergency department, inpatient
Room ID	Room name in EHR
Room name	e.g., 14
Bed ID	Bed ID in EHR
Bed name	e.g., 01
Level of care	e.g., ICU, progress care unit, medicine/surgery unit
Service	e.g., Cardiac, ortho
Attributes	Ventilator capable, negative pressure, positive, private room

EHR = electronic health record, ID = identifier.

5 minutes with no human in the loop, ensuring the information is timely and thus actionable. The system design allows surge areas to be captured automatically as long as they are tracked in the local EHR system. Each hospital indicates such changes to its bed configuration structure through the recurring flat files and will be displayed in the Oregon Capacity System in near real time.

## DISPLAY

The near-time data populates a web application (**Fig. 3**) independent of the electronic medical record used at the participating



**Figure 3.** Hospital capacity sorted by region and type of bed. Alert circle shows green for less than 90% percentage of occupied beds/total beds (OCC), orange for greater than 90 and less than 95%, and red for greater than 95% OCC. Timestamp: April 26, 2020, at 2:00 PM. CAP = bed capacity, CENSUS = currently admitted patients, MT/MS = medicine telemetry/medicine surgery acute care bed, NICU = neonatal ICU, NP = negative pressure beds, OB = obstetric beds, obs = observation bed, PCU = progressive care unit, UNOCC = unoccupied.

hospitals. It is designed to be easy to use, with intuitive bed groupings and a color scheme that allows the eye to easily track a particular piece of information (such as negative pressure beds) around the page. At the highest level, the webtool divides Oregon by the well-established regional trauma system (Fig. 4). Users can drill down to each trauma region and then to health system, hospital, and eventually unit level. In addition, filters are available to sort by type of beds (adult, pediatric, acute care, critical care, and specialty beds), health system, and within each health system (Fig. 5). We also have the ability to add room attributes (i.e., negative-pressure room) or scarce resources—especially useful in critical care—such as ventilators, continuous renal replacement, and ECLS capabilities. This allows our state to manage demand and supply on a regional and statewide level, and also add to each individual health system's capability to track their bed capacity in real time. When we started this concept 6 weeks earlier, we lacked the ability on a statewide level to understand available hospital-bed capacity and critical care beds, because licensed beds are different than staffed beds. Only the latter is readily available for immediate admissions.

Our major concern was that any one health system in our state would be overrun with an influx of patients “despite” having sufficient capacity within the state or region to care for these patients. Adding this statewide capacity overview to OHSU Mission Control and making it readily available for every health system in the state allowed us, in partnership with the OHA and all major health systems in the state, to overcome common barriers for effective collaboration. We now have the ability to rapidly react to increases in inpatient hospital-bed demands, even at the specialty-bed level through predefined threshold triggers. In the Portland metro area, there is an established protocol for regional

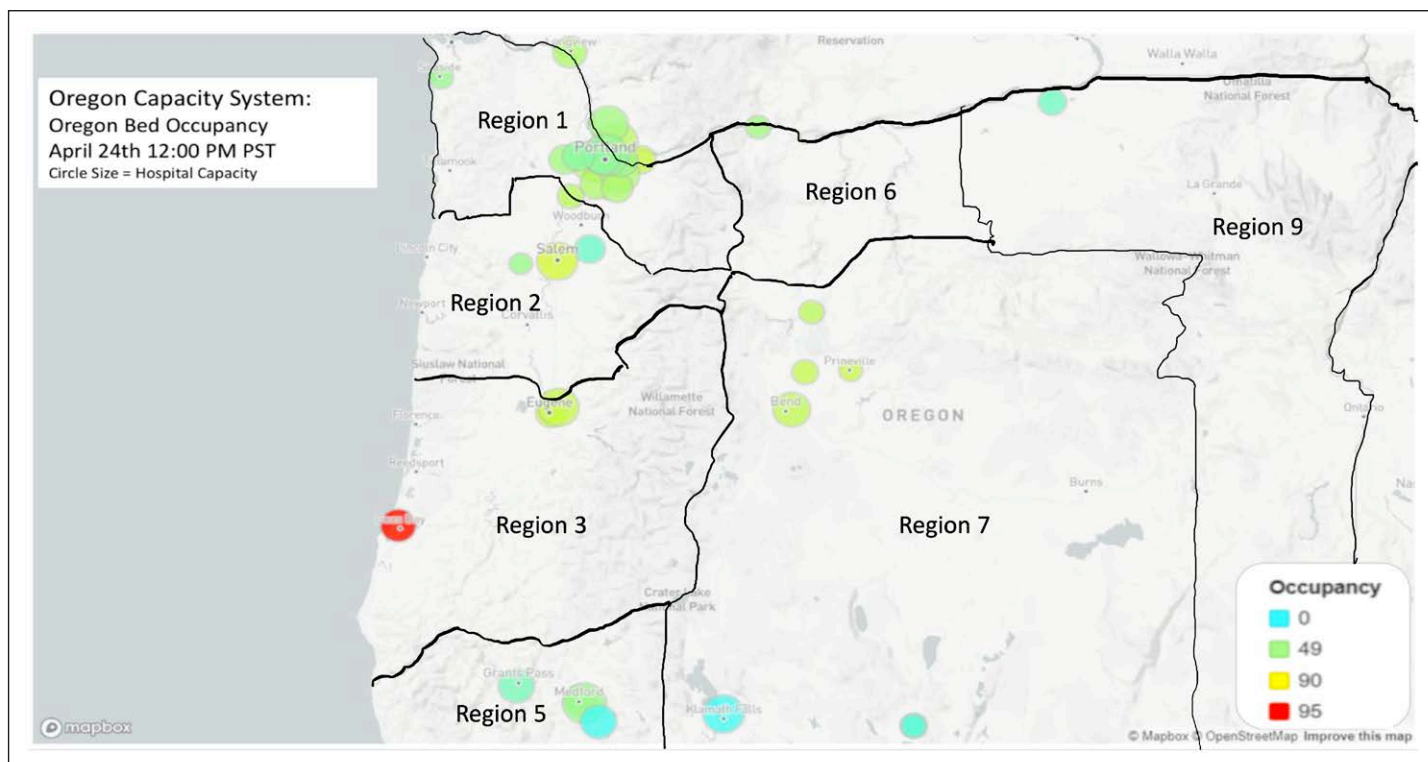
management of ED ambulance divert, so-called “zone management.” This protocol is based on manually reported ED divert status for region 1 of Oregon's HOSCAPS.

A regional zone management approach to our EMS ambulances is initiated if a majority of EDs in a zone of the Portland metro area declare divert status. OHSU Mission Control directs ambulances to alternating EDs, allowing for a more even distribution during high ED divert status situations. Our real-time data tracking for hospital beds adds additional versatility for more effective management in high-demand situations across the region and state. By avoiding delays in access to the needed hospital resources, we expect to be able to manage the needs of the state. The data exchange between HOSCAPS and Oregon Capacity System allows existing structures to be incorporated into future responses.

Furthermore, the Oregon Capacity System is capable of generating statewide capacity “snapshots” such as the one shown in Figure 4 of statewide ICU capacity. These are being published to all participating hospitals daily.

Our shared vision among physician and administrative leaders at Asante Health, Bay Area Hospital, Blue Mountain Hospital, Columbia Memorial Hospital, Kaiser Permanente, Lake Health District, Legacy Health System, Lower Umpqua Hospital, McKenzie Willamette Medical Center, Mid Columbia Medical Center, OHSU Health System, PeaceHealth System, Providence Health System, Salem Health, Sky Lakes Medical Center, St Anthony Hospital, St. Charles Health System, Portland VA Hospital, and OHA, combined with philanthropic support and a long-standing relationship between OHSU Health and a technology partner (GE Healthcare), allowed us to collectively and rapidly create a tool during this pandemic for the state of Oregon. The feasibility to quickly move from design to





**Figure 4.** Example snapshot visual from Oregon Capacity System of statewide bed utilization overlaid to the Oregon Trauma Regions Oregon Trauma Region System <https://www.oregon.gov/oha/PH/PROVIDERPARTNERRESOURCES/EMSTRAUMASYSTEMS/TRAUMASYSTEMS/Pages/atab.aspx>. Each region has a major hospital hub identified as regional hospital by the Oregon Health Authority. Regions 4 and 8 are incorporated into adjacent regions. PST = Pacific Standard Time.

CRITICAL RESOURCES <small>REGION VIEW</small>																		
Grouping All		R1: Portland		OHSU		Kaiser		PeaceHealth - R1		Legacy Health - R1		Providence - R1		Columbia Memorial		Womens Healthcare		
	UNOCC	OCC	UNOCC	CAP NP	OCC	CENSUS	OCC	UNOCC	CAP NP	OCC	CENSUS	OCC	UNOCC	CAP NP	OCC	CENSUS	OCC	
Total	2414	50%	446   923	38/85	52%	477	254   456	202	259   527	321	880   1572	692	535   1178	643	31   42	11	9   9	0
Adult ICU	265	46%	56   111	2/15	50%	55	36   60	24	33   65	32	66   132	66	65   118	53	9   9	0	-   -	-
Adult PCU	119	59%	9   23	2/9	61%	14	9   40	31	-   -	-	87   197	110	14   28	14	-   -	-	-	-
Adult MT/MS	1169	52%	253   525	24/47	52%	272	144   242	98	186   366	232	288   536	248	280   674	394	18   27	9	-   -	-
Peds ICU	26	46%	5   20	1/4	75%	15	-   -	-	-   -	-	17   24	7	4   4	0	-   -	-	-	-
Peds PCU	0	0%	-   -	-	-	-	-   -	-	-   -	-	-   -	-	-   -	-	-   -	-	-	-
Peds MT/MS	121	39%	45   84	5/6	46%	39	-   -	-	7   7	1	50   82	32	19   23	4	-   -	-	-	-
OB	492	31%	48   77	4/4	38%	29	53   88	35	15   49	34	289   376	87	74   111	37	4   6	2	9   9	0
NICU	137	47%	21   61	0/0	66%	40	12   26	14	14   26	12	49   77	28	41   70	29	0/0	33%	0/0	0
Psych	51	79%	9   22	0/0	59%	13	-   -	-	-   -	-	20   112	92	22   110	88	-   -	-	-	-
Rehab	26	63%	-   -	-	-	-	-   -	-	4   14	10	14   36	22	8   20	12	-   -	-	-	-
Adult Obs	8	60%	-   -	-	-	-	-   -	-	-   -	-	-   -	-	8   20	12	-   -	-	-	-
Negative Pressure	241	46%	38   85	38/85	55%	47	14   23	9	21   34	16	90   142	52	65   144	79	13   14	1	-   -	-
Ventilators	416	19%	121   154	33	21%	33	24   33	9	0   0	0	190   213	23	67   102	35	14   14	0	0   0	0

**Figure 5.** Oregon Capacity System showing bed and ventilator availability for region 1—Portland metro area. Timestamp: April 26, 2020, at 2:00 PM. CAP = bed capacity, CENSUS = currently admitted patients, MT/MS = medicine telemetry/medicine surgery acute care bed, NICU = neonatal ICU, NP = negative pressure beds, OB = obstetric bed, Obs = observation bed, OCC = percentage of occupied beds/total beds, PCU = progressive care unit, UNOCC = unoccupied.

implementation demonstrates a potential option for other states to transition from individual crisis management to a regional approach when supported by appropriate collaboration and technology. The state of Oregon has been able to flatten the COVID-19 curve by

implementing aggressive mitigation strategies, which, in combination with canceling elective surgeries, has resulted in a high percentage of unoccupied beds. Although each state makes choices about releasing mitigation strategies, this tool will help us identify Oregon regions

and health systems that will rapidly exceed their capacities, and it will allow for more active management at the local, regional, and state-wide level for the benefit of every patient in need of admission.

Our experience in using real-time data in our Mission Control command center at OHSU to manage inpatient capacity, across our four hospitals during high occupancy situations on a regular basis, was the foundation of our ability to rapidly build upon the existing technology platform and provide reassurance about why such a system would be critical across our state. Although we were able to use our existing infrastructure and quickly broaden the scope to the entire state, our approach highlights the relative simplicity of the data requirements to achieve visibility across a large geographic region, independent of the technology used. In times of uncertainty, having a reliable tool to track critical hospital resources will contribute to our statewide ability to regain health-care functionality in a world with COVID-19.

## ACKNOWLEDGMENTS

The Oregon Capacity System tracking board has been made possible by a philanthropic gift to the Oregon Health & Science University Foundation by Nike CEO John Donahoe and his wife, Eileen; Nike Chairman Mark Parker and his wife, Kathy; and Phil and Penny Knight. We are thankful for the ability to provide such a useful and unique tool to the state of Oregon. The technology for the tracking board is provided by GE Healthcare, and we thank the entire GE team for their dedication to setting up this tracking tool in such a short period of time.

---

Mr. Terry is employed by GE Healthcare and owns stock options. The remaining authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: merkelm@ohsu.edu

---

## REFERENCES

1. Oregon Health Authority: Oregon Announces First, Presumptive Case of Novel Coronavirus. 2020. Available at: <https://www.oregon.gov/oha/ERD/Pages/Oregon-First-Presumptive-Case-Novel-Coronavirus.aspx>. Accessed April 24, 2020
2. Kane EM, Scheulen JJ, Püttgen A, et al: Use of systems engineering to design a hospital command center. *Jt Comm J Qual Patient Saf* 2019; 45:370–379
3. Hayes E: How OHSU and GE Healthcare are solving a major headache: Patient logistics. *Portland Business Journal* 2019; 35:4–6
4. Wentz-Graff K: OHSU Mission Control Offers Modern, High-Tech Solution to Historic Challenge. 2019. Available at: <https://news.ohsu.edu/2019/10/31/ohsu-mission-control-offers-modern-high-tech-solution-to-historic-challenge>. Accessed April 24, 2020
5. Manning J, Sickinger T: Alarmed by Projections of Coronavirus Spread, Oregon Hospitals Team Up for Expanded Role. 2020. The Oregonian/OregonLive. Available at: <https://www.oregonlive.com/coronavirus/2020/03/oregon-hospitals-seek-larger-role-in-coronavirus-response.html>. Accessed April 24, 2020
6. Wu Z, McGoogan JM: Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: Summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *JAMA* 2020; 323:1239–1242
7. Rosenbaum L: Facing Covid-19 in Italy — ethics, logistics, and therapeutics on the epidemic's front line. *N Engl J Med* 2020; 382:1873–1875
8. Mannelli C: Whose life to save? Scarce resources allocation in the COVID-19 outbreak. *J Med Ethics* 2020; 46:364–366
9. Goyal P, Choi JJ, Pinheiro LC, et al: Clinical characteristics of Covid-19 in New York City. *N Engl J Med* 2020 Apr 17. [online ahead of print]
10. del Rio C, Malani PN: COVID-19—new insights on a rapidly changing epidemic. *JAMA* 2020; 323:1339–1340
11. CRISP: Organizations Sharing Data With CRISP. n.d. 2018. Available at: <https://www.crisphealth.org/connected-providers/>. Accessed March 24, 2020
12. Oregon Health Authority: Oregon Health Alert Network and HOSCAP. 2020. Available at: <https://www.oregon.gov/oha/PH/Preparedness/Partners/HealthAlertNetwork/Pages/index.aspx>. Accessed April 24, 2020