




# The hospital of the future: rethinking architectural design to enable new patient-centered treatment concepts

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## Abstract

**Purpose** Today's hospitals are designed as collections of individual departments, with limited communication and collaboration between medical sub-specialties. Patients are constantly being moved between different places, which is detrimental for patient experience, overall efficiency and capacity. Instead, we argue that care should be brought to the patient, not vice versa, and thus propose a novel hospital architecture concept that we refer to as *Patient Hub*. It envisions a truly patient-centered, department-less facility, in which all critical functions occur in the same building and on the same floor.

**Methods** To demonstrate the feasibility and benefits of our concept, we selected an exemplary patient scenario and used 3D software to simulate resulting workflows for both the Patient Hub and a traditional hospital based on a generic hospital template by Kaiser-Permanente.

**Results** According to our workflow simulations, the Patient Hub model effectively eliminates waiting and transfer times, drastically simplifies wayfinding, reduces overall traveling distances by 54%, reduces elevator runs by 78% and improves access to quality views from 67 to 100% for patient rooms, from 0 to 100% for exam rooms and from 0 to 38% for corridors. In addition, the interaction of related medical fields is improved while maintaining the quality of care and the relationship between patients and caregivers.

**Conclusion** With the Patient Hub concept, we aim at rethinking traditional hospital layouts. We were able to demonstrate, alas on a proof-of-concept basis, that it is indeed feasible to place the patient at the very center of operations, while increasing overall efficiency and capacity at the same time and maintaining the quality of care.

**Keywords** Patient-centered healthcare · Hospital of the future · Clinical workflow

## Purpose

Current healthcare systems around the world are characterized by the organizational principles of segmentation and separation of medical specialties. They are structured into departments and facilities which offer the best service in their respective field but are not properly coordinated or tightly

linked to the rest of the healthcare ecosystem. Consequently, today's hospitals seem more a collection of different “departments” and medical fields than a fully integrated cooperative and service-oriented facility. Each department uses its own workflow schemes or standard operative procedures (SOP), employs specially trained personnel, and runs its medical service in well-circumscribed and precisely defined structures and areas. Communication between disciplines is often limited to the absolute minimum necessary for coordination tasks, e.g., regarding forwarding of relevant patient information and time scheduling of examinations or interventions.

The current system requires patients to step from doctor to doctor and from department to department to collect the jigsaw puzzle pieces of their disease. It is a serious drawback of current hospital structures that patients often need to tell their medical history and symptoms over and over again to the medical staff of different disciplines and subspe-

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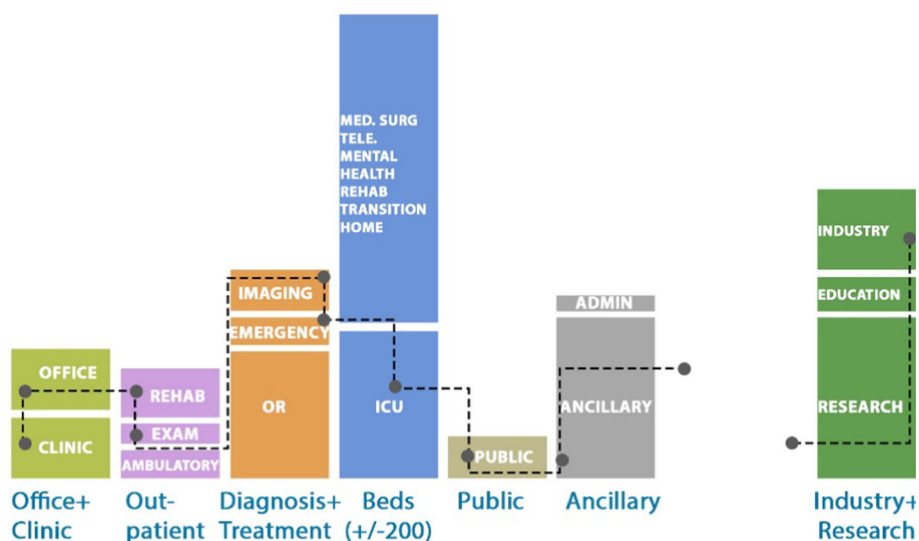
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**Fig. 1** Traditional Incremental “Patient to Care” flow: the patient is constantly being moved between departments, typically starting from clinical reception, followed by examinations, diagnostics, treatments, ward stays and other way stations. Due to the highly fragmented structure, a direct access of external parties, especially academia and industry, is aggravated



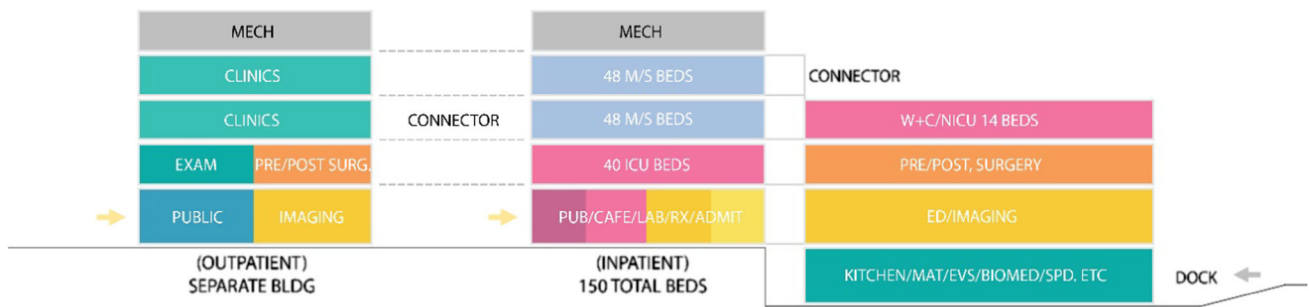
cialties. The request and scheduling of different diagnostic examinations across departments are often confined to a very succinct standard requisition, neglecting the exchange of any additional patient-specific information (e.g., the anatomical reconstruction after gastric surgery in case of a postoperative CT scan to rule out complications). This data that are essential for appropriate programming and interpretation of diagnostic procedures is often non-accessible to the physician performing the exams. We call this “incremental care” and in this traditional model, the patient is constantly moved around to receive care (Fig. 1 depicts an exemplary traditional patient’s pathway). While some of these issues could be addressed by optimizing the clinical communication and data storage infrastructure, we believe that by means of architectural choices it becomes possible to further benefit and simplify the necessary workflows and to reduce the amount of required technology.

Current hospitals are organized around well-separated specialized clinics and expert units, which all by themselves are perfectly tuned for economically optimized and efficient use of their dedicated infrastructure (e.g., the operating room in surgery or the MRI in radiology) and make efforts to reduce the cost of personnel wherever possible. Profit has become the main driver of healthcare and everything else including patient satisfaction and even quality of care often comes as a second priority. However, financial profit is generally not assessed on a global scale of patient management services but rather on the level of subsystems and specialized services, with a focus on separated profit centers which results in higher global costs rather than reducing them due to inefficient coordination and consolidation of clinical pathways. “Service-oriented” care units refer more to medical services (or equipment) and teams providing dedicated care, rather than to patient-centered care facilities. This often results in inefficient workflows such as excessive and unnecessary time

spent in waiting rooms, which is becoming prevalent in large facilities.

Although system optimization works well for a specialized and restricted field, e.g., a department or a single facility, the entire healthcare system has grown enormously toward becoming rigid, not-adaptive, and slow. It is not designed for the active prevention of disease, but for mere reaction in case an adverse health event or development arises. This approach entails that the patient suffers more overall, since diseases are allowed to develop and manifest themselves before they are finally diagnosed and treatment can be started. At the same time, the burden for clinical care facilities increases as well, since treatments become more complex and result in longer durations of stay. The preventive approach has been advocated for quite some time now [1] and its benefits have become very obvious during the recent Covid-19 pandemic [2].

Although “interdisciplinary care” and “overarching approach” represent typical buzzwords of modern treatment concepts, the integration of involved clinical disciplines remains on a low level. One notable exception is acute trauma or emergency management where any active action is focused on the patient and collaboration is crucial to handling critically vital situations. The growing field of emergency medicine could serve as a model for a more global paradigm shift, as an example of healthcare delivery that is, above all, patient-centered. In such a context, interdisciplinary communication is highly standardized involving all persons and services required for well-protocolled patient management scenarios. Services are brought to the patient, and not vice versa, and anything and everybody involved is geared to facilitate a fast and comprehensive treatment. It has been shown that the patient-centered multidisciplinary approach, at least for acute trauma, can save lives and is superior to traditional concepts [3]. So, one might ask whether such an approach



**Fig. 2** Functional stacking of (traditional) Template Hospital used for simulation comparison

could also be beneficial for other indications or even for general care? And if so, will this new concept maintain the current standard of care and the relationship between caregivers and patients?

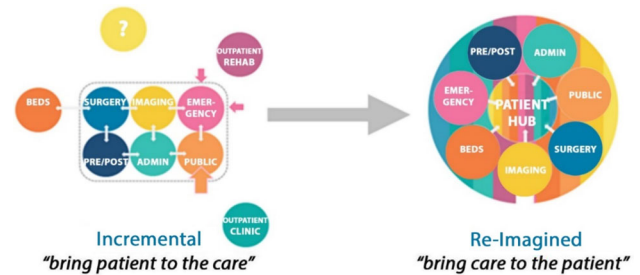
As a central building block for addressing the issues described in the previous we present our new hospital concept that we refer to as *Patient Hub*. It envisions a truly patient-centered, department-less facility, where all the critical functions occur on one floor. While our idea is not intended to solve all of today’s hospital design flaws (and we are fully aware that one solution will never fit all models), we aim at providing concepts and tools to help re-think traditional designs.

### Methods

We developed a novel, one-of-a-kind design concept for the hospital of the future. The envisioned facility is fully patient-centered and strives for a workflow-oriented design by clustering related functionalities and processes in defined hubs, all located on the same floor and in close proximity to each other. In order to demonstrate the effectiveness and added value of our proposed hospital architecture, we benchmarked this new concept against a traditional design. For that, we reconstructed both the Patient Hub and an exemplary traditional hospital layout using 3D simulation software and compared them with regard to workflow efficiency and patient satisfaction. For the initial analysis presented here, we chose a typical patient scenario based on a common real-world case.

### The patient hub concept

Today’s hospital buildings are often fancier versions of the 1960s bed-tower-on-diagnostic-and-treatment podium model, with a lot of newer technology crammed inside. In accordance with the principle of decentralization, which is prevalent in many healthcare systems around the world [4], such environments are characterized by being divided into

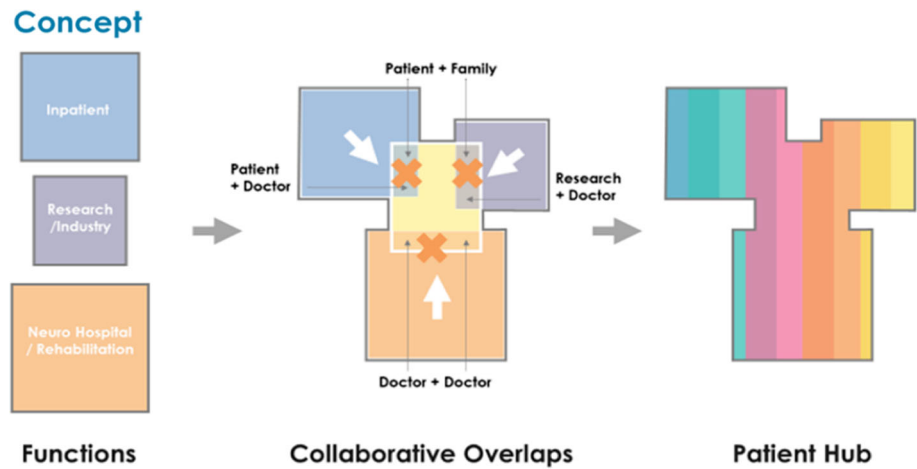


**Fig. 3** Re-imagined healthcare paradigm: changing from incremental “patient to care” approach toward a re-imagined “care to patient” approach

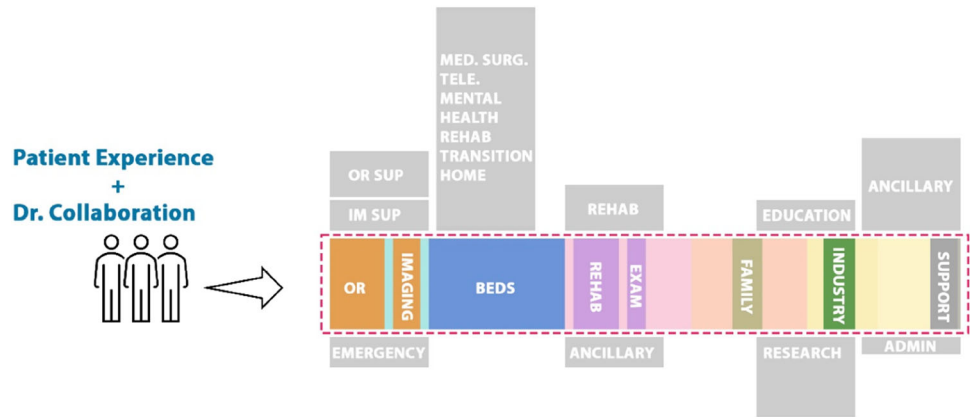
departments and individual silos, each possessing its own organizational structure (including permanent staff, assigned space and beds), optimized for operational and financial efficiency. The patient is moved around from place to place to receive care, instead of bringing the care and technology to the patient (e.g., infrastructure like CT or MRI is often inconveniently and remotely located in a different building, as illustrated by Fig. 2).

In contrast, our *Patient Hub* concept is a radical departure from the way traditional hospitals are designed. It envisions a transformative “one of a kind” and truly patient-centered, department-less facility. We propose a highly centralized clinical layout, where all relevant medical fields of expertise are available within the same space *surrounding the patient* (see Figs. 3 and 4). They form clusters which contain functionalities of equal classes, as for example *examination, out-patient care* or *administration*. For the patient, the whole system has a single-entry point to simplify wayfinding and is designed to minimize patient movement. The centralized clinical layout brings together staff from all specialties to encourage clinical collaboration and care coordination, thereby stimulating health care performance [5]. Instead of facilities being distributed along the hospital, and most often on different levels or even buildings, the new design concept aims at achieving a logical and self-explaining layout by bringing together what belongs together. However, the vision of the Patient Hub encompasses much more than a traditional

**Fig. 4** Concept diagram illustrating “all under one roof” collaborative Patient Hub concept



**Fig. 5** Re-imagined “Care to Patient” flow diagram indicating functional adjacency needed to deliver patient-centered care



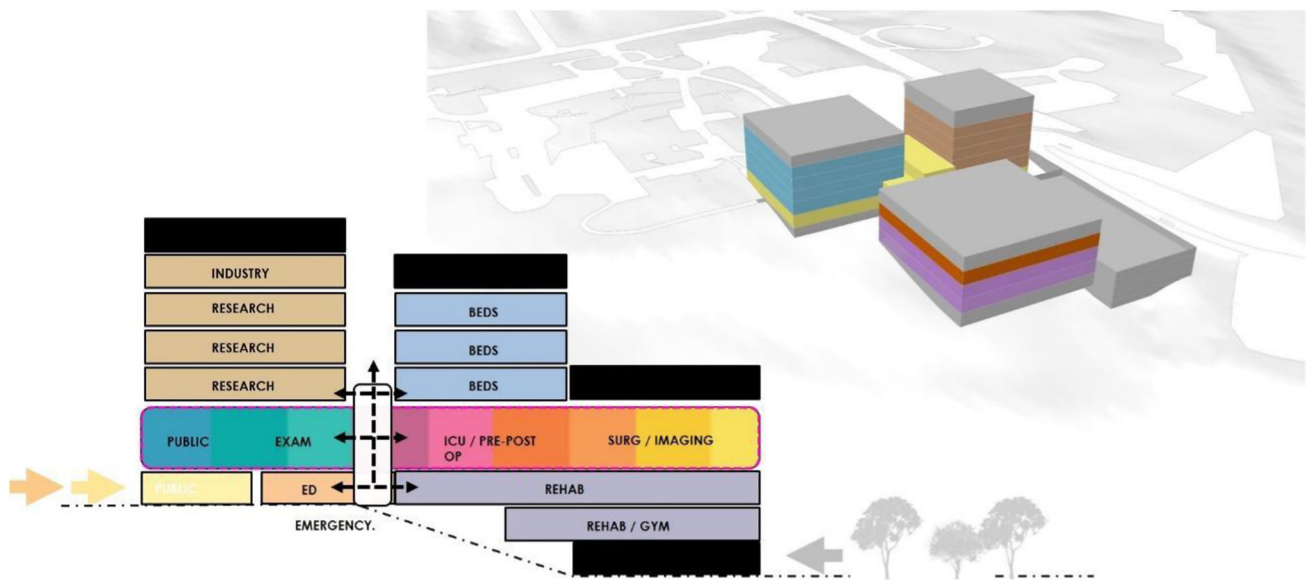
hospital: This new environment (or ecosystem) co-locates outpatient, inpatient, rehabilitation, wellness and prevention, ancillary support spaces, and industry (research and development) all under one roof. It is envisioned to be no longer just a site for the treatment of the sick but a health-oriented all-encompassing facility, which is achieved by implementing patient-centered structures and workflows as well as by an expansion of services to also incorporate prevention and wellness.

Instead of being department-oriented, the Patient Hub design follows a more functional approach. To avoid getting lost in the sub-channels of the system (different departments with specific ecosystems), the architecture is logically constructed and patient-centered. It features a single point of entry, and a central meet and commute “core” to which the relevant facilities (housing, examination, out-patient care, administration) are linked, just as the arms of a tree are joined to the trunk. For the reduction or even full avoidance of patient moves, the respective areas cluster the required functionalities on one site. This will be done irrespective of the affiliated department or responsibility. Instead of passing from the radiologic department in level A to cardiology in level D to complete the pre-operative check-up, the patient

will now move from one to the other door, as depicted in Fig. 5.

By avoiding duplicating functionalities which today are replicated in every department (e.g., waiting rooms, registration area, observation area) the Patient-hub concept aims at saving space, simplifying patient pathways, and facilitating implementation and adaptation of new treatment concepts. While keeping this functional patient-hub design with all required functionalities being logically distributed on one floor, we envision different levels of the building to be adaptable to different patient needs and specialties, like surgery, medical treatment, rehabilitation, etc. (see Fig. 6).

Due to its horizontal layout and resulting space demands, the Patient Hub layout in its most essential form is best suited for freestanding greenfield hospitals. The hub floor of our current design requires an 8,000–9,000 square meter floor plate but can be scaled up and down depending on the number of beds and procedure space needed. Since a further increase of the horizontal expansion would start to contradict the goal of having a compact centralized hub with streamlined workflows and short routes, we instead propose to stack multiple independent Patient Hub units vertically. Thereby, it becomes possible to retain the compact size of each hub and keep all movements of a given patient on the same floor, while mak-



**Fig. 6** Patient Hub functional stacking and 3D massing

ing more efficient use of the available building ground and increasing the overall capacity.

### Patient scenario

Our exemplary scenario revolves around a patient being diagnosed for rectal cancer. First, the patient receives general examination and diagnostics according to current guidelines [6], which include endoscopy, pelvic MRI and CT. After physical examination, which, due to his age and existing comorbidities includes cardiologic assessment, the case is discussed in multidisciplinary consultations such as tumor conferences and the patient is scheduled for surgery. Preparation measures for surgery include obtaining the patient's informed consent by the surgeon and anesthesia, as well as preoperative preparation such as bowel cleansing and blood tests. After the intervention, observation in the ICU is carried out for one day, before the patient is returned to the regular ward. In our scenario, an eventless postoperative course is observed, which is why only a chest x-ray is performed to examine the postoperative lung status. No other tests or assessment of anastomotic healing are undertaken. During the hospitalization, the patient has an interview with the surgeon, to discuss upon the results of surgery and eventually additional treatments, and another interview with the social worker to decide upon auxiliary measures. Finally, the patient is discharged from the clinic.

The case above describes a common situation that clinicians are dealing with regularly and is based on the organizational structure and standard operating procedures of a university hospital. We analyzed the necessary steps along this clinical pathway for a traditionally designed hospital.

Even though we chose a complication-free course for our scenario, the resulting list of necessary steps contains 95 entries, many of which are describing a change of the patient's location or time spent within various waiting rooms. Refer to Table 1 for an excerpt of this list.

### Workflow simulation

Using the 3D simulation software FlexSim Healthcare™ (FlexSim Software Products, Inc., Orem, Utah, USA), we developed dynamic models for comparing various quality measures between our two different hospital layouts. FlexSim Healthcare is a standalone healthcare simulation product aiming to model patient flows and other healthcare processes. It is designed to help healthcare organizations to evaluate different scenarios and validate them before they are implemented. For that, one or several architectural models can be created, followed by the definition of patient journeys. During execution of the simulation, FlexSim can monitor data contributing to patient satisfaction, including the total time spent, time spent for each treatment, time proportion of receiving care, travel distances, etc. It can also be used to analyze staff and equipment utilization rates and help to balance staff workload and amount of equipment.

### Modelling of architectural layout

We selected Kaiser Anaheim hospital, a traditional hospital with a similar size, to be compared to the Patient Hub. The construction of this hospital was based on a generic "template" hospital plan developed and used by Kaiser-Permanente, the US largest non-profit Health Management

**Table 1** Steps of exemplary patient scenario (excerpt). The typical duration at each step is given in minutes. The parameter range describes how much the duration can differ between cases by giving a lower and upper boundary

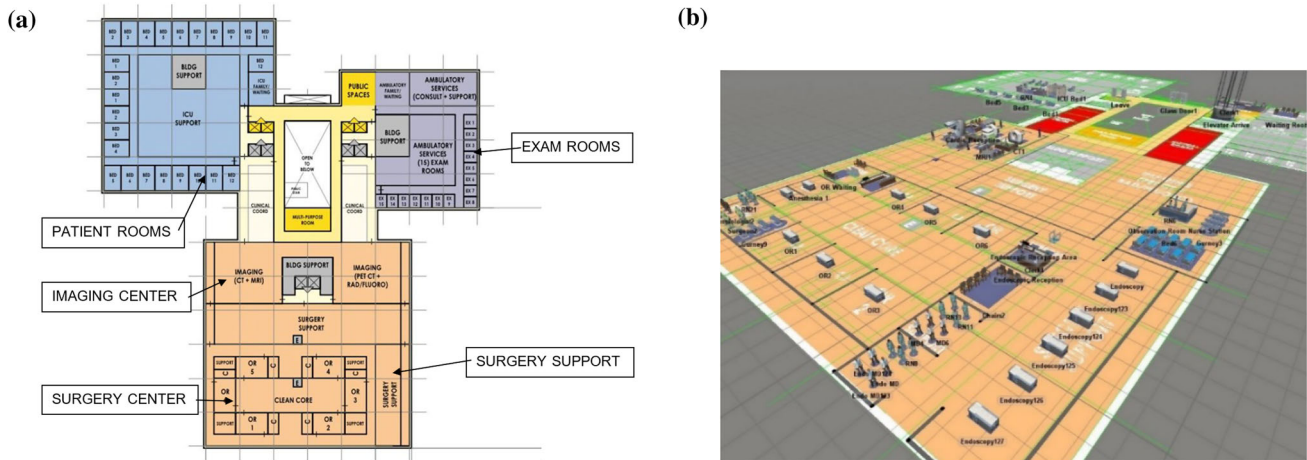
Step	Process	Purpose	Task	Duration [min]	Range [min]
1	Reception &		Enters Hospital	0	0
2	Admission to Ward	Reception and registration in clinic	Walks to Ward	5	3–10
3			Checks in	5	3–10
4			Enters Room	5	2–10
5			Returns to Reception	5	2–10
6			Walks to Administration	5	3–10
7			Waiting room of Administration	10	5–30
8			Registration to Clinic	15	10–20
9			Returns to Ward	5	3–10
10			Intake by Nurse	15	10–30
11			Return to Room	5	2–5
12	Intake interview and primary assessment	Assessment of existing data	Walks to Physician	5	2–5
13		Information on process/treatment	Intake/Interview by Physician	25	15–40
14		Blood test	Information on planned diagnostics	10	5–15
15			Blood Sampling	5	5
16			Return to Room	5	2–5
...	...	...	...	...	...
64	Transfer to OR/Operation	Operation	Transfer to Reception	10	5
65			Transfer to OR	10	5–15
...	...	...	...	...	...
71			Transfer to wake-up/observation room	15	5–20
72	Retransfer to ICU	Post OR observation	Transfer to ICU	10	5–15
73	Return to Ward		Transfer to ward	5	5–15
74			Transfer to Room	5	2–5
75	Check in Radiology	Examination of lung status	Transfer to Reception	5	2–5
76			Transfer to Radiology	5	3–10
77			Radiology Waiting Room	10	5–15
78			Chest X Ray	5	=
79			Transfer to Ward	5	3–10
80			Transfer to Room	5	2–5
...	...	...	...	...	...
95	Exit		Leaves Hospital	5	5–10

Organization (HMO) (Fig. 7). This plan was developed when the organization was required to replace half of its hospital beds in California due to new seismic regulations and resulted in a prototypical hospital “template” that can be built on virtually any site, with few modifications [7], with a minimum of effort, lead time, and government review [8]. The design aimed at incorporating the best known clinical practices and design success stories and was optimized for a fast and efficient construction process [7]. Due to these characteristics,

and a broad and successful implementation, we have selected this layout as the best comparison available today.

The second model (see Fig. 8) represents our Patient Hub, i.e., a hypothetical department-less hospital layout based on patient-centered care activities and concentrated on a single floor. Both buildings were modeled in FlexSim based on the floor plans. The model elements essential to this process were those affecting patient travel distance and waiting time, including vertical transportation, wall arrangement and the available medical equipment.





**Fig. 8** a 2D view of main Patient Hub floor showing diagnostic and treatment, outpatient, universal inpatient patient ward and patient experience / public / interdisciplinary coordination core blocks; **b** 3D rendering

of Patient Hub floor within FlexSim environment; showing simulation workflow study to determine and test ideal functional adjacencies

providing direct and indirect care including escorting and monitoring patients.

### Simulation

Using FlexSim we simulated the whole process from entering the hospital to exiting, and monitored key statistics including travel distance, major milestones, treatment times, waiting times, time proportion, utilization rate for both patient and staff. For both scenarios, we simulated the arrival of three patients every half hour between 8am and 9:30am, which amounts to a total of nine patients.

### Comparative parameters

For measuring the performance of the two models, we selected multiple parameters, with a high focus on improving the patient experience:

1. *Waiting and Transfer Time*
2. *Travel Distance*
3. *Wayfinding*
4. *Number of Elevator Runs*
5. *Access to Respite Spaces, Nature and Quality Views*

The first parameter *Waiting and Transfer Time* is arguably the most relevant for patient experience, staff workload and overall efficiency alike. By decreasing this parameter, the overall duration of the hospital stay can be shortened and resting/recovery time for the patient (i.e., time spent in the ward) can be maximized. Furthermore, staff members are less overburdened and can potentially use the gain in time for other tasks or patients, thus improving staff satisfaction

and economic interests of the hospital. Admittedly, reducing transfer times likewise can serve to increase the throughput of patients, however, we did not intend to improve on this measure.

The parameter *Travel Distance* refers to the length of the path that each single patient needs to travel during the hospital stay. We split this into the following three parts reflecting the different stages of the patient's pathway: *Endoscopy*, *CT + MRI + Cardiology* and *Anesthesia + OR + ICU*. Decreasing travel distance is desirable since long transfers between distant departments are a burden for patient and personnel alike and extend the duration of hospital stays.

*Wayfinding* refers to the complexity of the patient's traveling route within the hospital. A high number of turns, stop-and-go's, transfers paired with rather chaotic paths and destinations scattered across different buildings indicate a poor performance with respect to this parameter. Short and infrequent transfers paired with simple and uncomplicated routes within the same building and on the same floor indicate a good performance. For our initial assessment, we interpreted the patient's path as a graph and used the number of nodes and edges as an abstract measure of complexity. In addition, we considered the number of locations requiring signage as a more user-oriented parameter.

The *Number of Elevator Runs* is another measure for the complexity of patient transfers. Elevators often are bottlenecks within hospital buildings and contribute to elongated transfer times, which is disadvantageous from patient, staff and economic perspectives. Therefore, a low number of elevator runs indicates better performance. Furthermore, elevator operation typically accounts for 3 to 8% of the total energy consumption of a building [9]. Thus, a decrease can have a positive impact on the hospital's CO<sub>2</sub> footprint.



**Table 2** Results of workflow simulation for traditional and Patient hub models

Parameters		Kaiser-Permanente Model	Patient Hub Model
Waiting and Transfer Times	to different building	60 min	0 min <sup>a</sup>
	to different patient ward	15 min	0 min <sup>a</sup>
Travel Distance	Endo	891.26 ft	227.65 ft
	CT + MRI + Cardio	263.49 ft	188.24 ft
	Anesthesia + OR + ICU	319.44 ft	260.15 ft
Wayfinding	Path Nodes	6	3
	Path Edges	9	3
	Signage Locations	7 <sup>b</sup>	1 <sup>c</sup>
Number of Elevator Runs		9	2
Access to Respite Spaces, Nature and Quality Views	Patient rooms	67%	100%
	Exam rooms	0%	100%
	Corridors	0%	38%

<sup>a</sup>No transfer required

<sup>b</sup>Signage required at each path node and in hospital lobby

<sup>c</sup>Signage only required in hospital lobby

Hospital stays can be associated with high mental stress or anxiety for many reasons, such as individual ailments and separation from the outside world and everyday life. The bleak, functional and sterile look that hospital interiors tend to have, may further amplify this effect. However, there is overwhelming evidence and research indicating that having frequent *Access to Respite Spaces, Nature and Quality Views* influence our health outcomes and help mitigate this problem [10–12]. To evaluate the performance of our models with regard to this parameter, we analyzed the number of patient rooms, examination rooms and corridors providing quality views to gardens surrounding or located in between hospital buildings.

## Results

Numeric results of the workflow simulations for the parameters and models explained in the Methods section are given in Table 2.

## Discussion

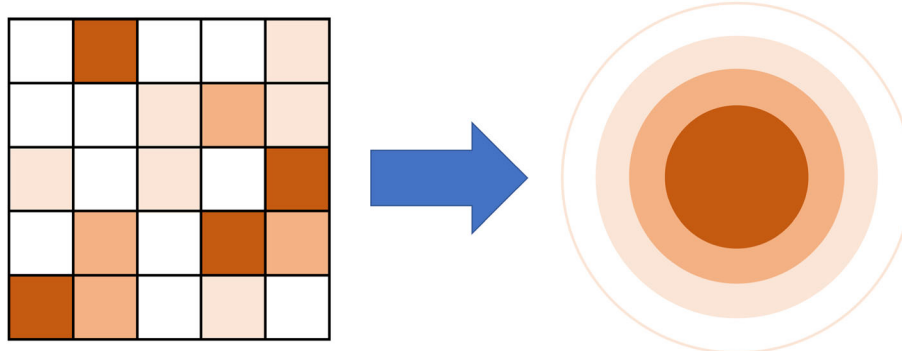
Our results presented in the previous section are promising, since a considerable improvement for every selected parameter can be observed. We see this as a proof-of-concept of our ideas. However, we want to stress that the investigated scenario is only a first step toward proving the feasibility of the Patient Hub concept. Other patient scenarios and combinations of them will lead to even more complicated situations and workflows, where we believe the benefits of the new patient-centered layout will become even more obvious—due to the reduction of bottlenecks and result-

ing improvements of target parameters relevant for patient experience. Generally, we interpret the simulation results as evidence for the postulation that, as healthcare strategies are expected to evolve toward more ambulatory and short-term hospitalization, facilities should focus more on optimizing their workflows rather than maintaining the priority of traditional inpatient procedures of hospitalized patients. Our study also concludes that a *patient experience measurement or scoring system* should be formally included in all hospital design simulations, although the construction of such an integrated index is still pending and requires the involvement of experts from different fields.

Clearly, the proposed layout has not yet been fully implemented in the real world and thus may be prone to problems that cannot be identified using the proof-of-concept approach presented in the manuscript. As of now, a test pilot project with limited scale is under construction in Philadelphia, which will accommodate 150 beds. This test project will be a valuable source of insights regarding problems and limitations of the Patient Hub concept.

Still, there are limitations that we are already aware of, especially regarding the size of the Patient Hub. It is neither reasonable nor feasible to scale up a single floor facility indefinitely to accommodate for more and more patients. The strengths of the centralized layout would be mitigated by the huge size and the whole system would presumably become sluggish and less efficient. Also, the available building ground would not be used very efficiently, as compared to a multi-level building. A possible solution to this is the stacking of multiple patient hubs (e.g., with different specializations) on top of each other. However, this would mean that diagnosis and treatment services need to be duplicated, which has been done in the past, but is not preferred by most hospital operators due to financial concerns.

**Fig. 9** Functional design changes from a distributed pattern to an expanding core concept



A further limitation is that an integration of the Patient Hub concept into existing facilities is not possible. Thus, it is exclusively applicable to new building projects.

As of now, the proposed concepts mainly focus on *architectural design* and a translation to the real world will certainly require many more building blocks, such as *AI* (notably workflow scheduling/optimization), *big data* (collection and processing of health data) and *robotics* (e.g., self-driving assistance systems). In particular, we envision the entire infrastructure, including technical devices, spaces and functional units to become adaptive and mobile. For example, a medical/surgical patient room could be utilized as an ICU site (Universal Room). Intervention rooms could be suitable for surgery, interventional radiology or cardiologic manipulations. CT scanners and other assistance systems could be designed as self-navigating systems, to move independently to desired locations.

While we plan to incorporate such considerations into future work, we advocate a very *deliberate* use of technology, governed by the paradigm of bringing care to the patient and not solely by economic interests. As argued before, the new patient-centered approach is expected to increase patient satisfaction, to reduce overall procedure times (if combined with an intelligent real-time scheduling and organization system) and to even be superior regarding infection prevention. Moreover, such an adaptive environment will most likely contribute to the physicians' satisfaction as well as foster collaborative and interdisciplinary work. At the same time, it will allow for fast and easy adjustment of the entire system according to the current number of patients and the prevailing diseases they are suffering from (e.g., in case of a pandemic). As shown in Fig. 9, we envision the Patient-Hub to behave according to an expanding core model, where all activities can be centralized during times of low demand (e.g., at night) and expanded by reactivating auxiliary areas from hibernation to deal with higher workloads. A centralized layout would facilitate such an expansion and retraction as opposed to a traditional layout where all core functionalities are distributed throughout the hospital.

The Patient Hub Design maintains the patient–caregiver relationship and the principle of patient-centered care delivery by preserving core aspects of current hospitals such as wards and operating theaters, which, however, are functionally rearranged and smartly repositioned within the Patient Hub. This rearrangement not only improves patient experience but also the patient-related communication and collaboration of physicians, further improving workflow and information exchange.

We believe “departments” will no longer define the basic structure of a hospital. Instead, patient requirements and functionalities, such as “operative care,” “infectious disease recovery”, “conservative oncology” or “preventive care” will be brought into focus. By using this revised interpretation of interdisciplinary patient-centered care for our Patient Hub concept, we are able to improve patient and healthcare workers experience and satisfaction while maintaining the current standard of care.

Lastly, we do not believe that economic parameters are deteriorated by the patient-centered approach. On the contrary, our simulation results show significant increases in efficiency throughout the facility, with less required staff members and less time required per patient. Therefore, we expect our approach to not only be beneficial for patients and employees, but to be cost effective and economically reasonable at the same time.

## Conclusion

We have presented our vision of a novel patient-centered department-less hospital design referred to as the Patient Hub. While the realization of this vision clearly requires disruptive change regarding many aspects (such as clinical workflows, application of technology, functioning of the healthcare system in general), our main aim herein was to focus on re-inventing the architectural layout. For benchmarking the performance of our concept with regard to patient experience, we have defined a patient scenario and created simulation models for both the Patient Hub lay-

out and a standard hospital template by Kaiser-Permanente. The simulation results were highly promising, showing clear advantages of the Patient Hub layout throughout all benchmark parameters. We see this as a proof-of-concept of our ideas and as an important validation before implementing the Patient Hub in the real-world.

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## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This article does not contain any studies with human participants or living animals performed by any of the authors.

**Informed consent** This article does not contain patient data.

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