Patient-Human Digital Twin (P-HDT) Platform

AI-Supported Risk Mitigation for ICU/NICU Patients

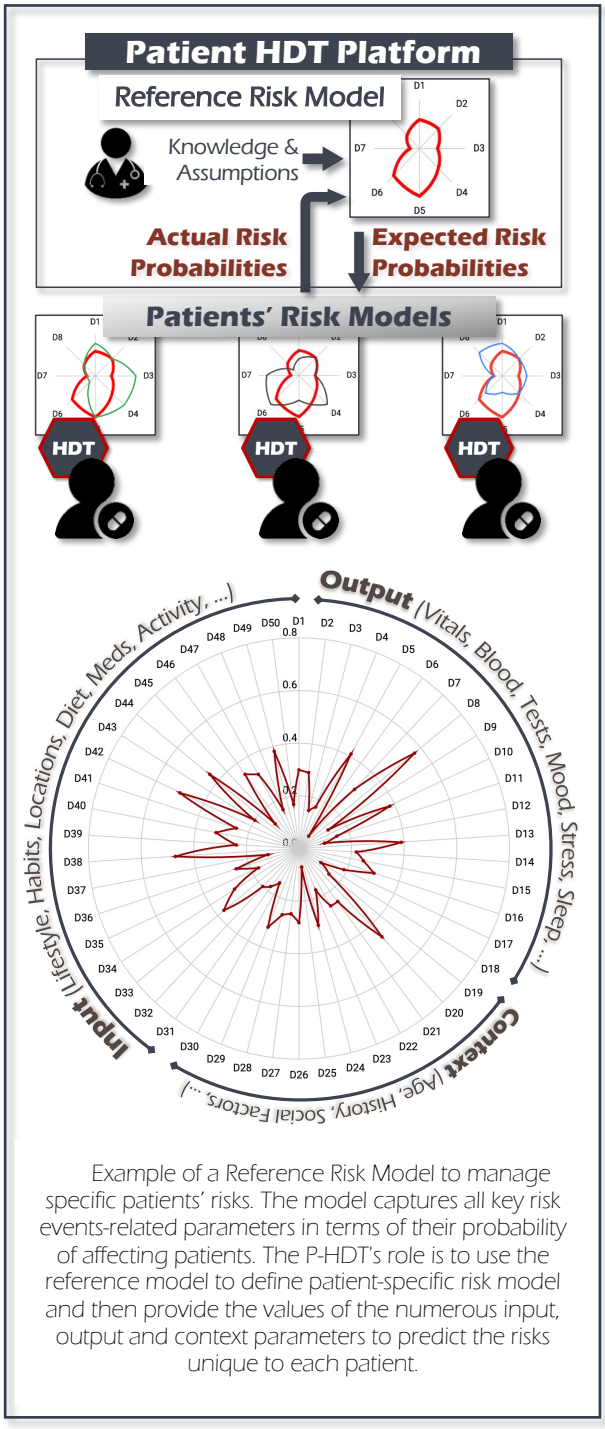
Wael Hafez | Semarx Research USA | w.hafez@semarx.com

What is the P-HDT Platform?

The P-HDT Platform is an AI-based solution that provides NICU physicians with patient-centric predictions, recommendations, and insights regarding critical events, allowing them to proactively implement timely and effective treatment strategies. The P-HDT Platform thus enables hospitals to reduce patients' risks, improve ICU performance, lower treatment costs, integrate and standardize medical knowledge and reduce the expertise gap among medical personnel.

Early Detection of Critical Events

Using the P-HDT Platform, experienced physicians define a Reference Risk Model that depicts the probabilities of critical events for a specific group of patients. The Reference Risk Model is based on patients' medical records, environment (e.g., ambient temperature or noise), and clinicians' assumptions about how critical conditions evolve (See Fig., the red lines indicate a specific risk event profile.) Using the Reference Risk Model and actual patient data, a patient-specific smart app, the Patient Human Digital Twin, P-HDT, generates a risk model specific to its patient. The P-HDT uses the patient risk model to continually monitor the patient's condition, predict the onset of critical condition, and notify the medical team as necessary. With more data, the P-HDT can also suggest mitigation actions. In its most advanced version, the P-HDT will enable clinicians to simulate various therapies and generate what-if treatment scenarios for a particular patient. On the physician's side, the Reference Risk Model is automatically updated and refined over time based on the observations and data collected from patients' P-HDTs. The Reference Risk Model thus reflects the risk level across all patients and can be centrally analyzed, validated, and deployed across departments within a hospital or across multiple hospitals. Hospitals can use the Reference Risk Model to enhance medical team knowledge, standardize treatments across multiple hospitals, eliminate staff competency variations, and provide consistent data sets for analysis, learning, and research. Ultimately, the solution will improve patient care and reduce treatment costs.



Example of a Reference Risk Model to manage specific patients' risks. The model captures all key risk events-related parameters in terms of their probability of affecting patients. The P-HDT's role is to use the reference model to define patient-specific risk model and then provide the values of the numerous input, output and context parameters to predict the risks unique to each patient.

Time-Critical Decisions

Even tiny changes in patient vital signs and measured values, especially in neonatology, can signal a developing problem. Time is of the essence when it comes to recording these deviations, placing them in context, understanding them, and reacting to them with a therapeutic change. These tasks are especially demanding for physicians who have little experience with the patient group. Thus, the P-HDT Platform provides a knowledge baseline for patient critical conditions upon which various physicians can assess patient-specific risks, enabling them to anticipate and mitigate risk in real-time, significantly reducing morbidity and mortality and improving patient prognosis and outcome.

P-HDT Platform in Action

Before leaving the station and handing over the NICU patients to the young assistant doctor for the night, the senior physician consults the P-HDT Platform to double-check pertinent risk profiles for the individual NICU patients. The risk profiles for the patients in question define the likelihood ranges for various critical situations. A few hours later, one of the children's P-HDT detects slight changes in the probabilities of some of the many factors it monitors. While the estimated probability values remained within the age-specific standard range, the overall likelihood trajectory grew closer to one of the designated risk events. The assistant doctor is then notified by the P-HDT and accordingly extensively examines the child and discovers that they have minor, unanticipated conditions. The assistant and the senior physician confer and agree on the best course of action to limit the risk of a severe condition. Currently, various patient parameters are assessed at predetermined intervals or at the doctor's request. As a result, some changes in these parameters might go unnoticed. If the P-HDT had not estimated the implications of such unnoticed changes, then the infant would have been clinically identified considerably later and most likely in serious condition. Delaying the start of appropriate therapy significantly raises the risk of long-term morbidity and mortality. Deviations indicating a serious condition were predicted and reported early, thanks to the P-HDT real-time monitoring. Clinicians can then provide appropriate diagnosis and therapy much earlier than they would have under current standard practice.

How is the P-HDT Platform Unique?

The P-HDT Platform is enabled by the proprietary Bayesian-based algorithm called the Semantic Algorithm. Using historical treatment data, the Semantic Algorithm computes, assigns, tracks, and updates probabilities for hundreds of parameters and health-related events in near real-time. However, the Reference Risk Model, which captures the risk probabilities associated with specific outcomes for all patients who have ever been linked to the model, is the unique feature of the P-HDT Platform. The Semantic Algorithm enables the Reference Risk Model to maintain what might be called the “patient Risk-DNA" in the form of probability values for various risk-related parameters. Accordingly, the risk assessment by a P-HDT at a Berlin NICU station can automatically help improve the risk assessment of another child's P-HDT in Stuttgart (or Tokyo!), as long as both P-HDTs rely on the same Reference Risk Model. That is, the P-HDT Platform enables adaptive crowd intelligence, where—If desired—risks experienced by one member of a population can be used to help other members update their events’ risk assessment and following decisions. Additionally, physicians can incorporate new knowledge and assumptions directly into the Reference Risk Model and reflect them to all relevant P-HDTs, enhancing the risk forecasting accuracy in the entire patients' population.

Long-Term Vision

The proposed P-HDT Platform is based on developing and maturing Reference Risk Models encompassing many disease characteristics. The risk models can be defined for children in the NICU, patients in normal ICUs, or a specific disease in a population. To put it another way, the P-HDT Platform can assist clinicians in managing the risks of ICU patients or support health organizations in managing specific disease risks across a population. In either scenario, the risk models are created centrally. Patients or citizens can then utilize their own P-HDT to connect to the relevant Reference Risk Model to define their own risk profile and manage it according to their own specifics. The solution's long-term goal is to broaden the P-HDT Platform scope to manage patients' risks in various aspects of their lives and integrate lifestyle data to enable even earlier risk assessment, risk mitigation, and individualized guidance for a balanced lifestyle.

How To Start?

We propose investigating the concept by developing Reference Risk Models for certain risk events in an ICU. Based on historical data from that ICU, the models will link the therapies data, context, and background information about the patients to the patients' conditions as collected by various monitoring devices and tests. The Reference Risk Models are then assessed for their capability to predict the critical events in scope and the potential impact of the P-HDT Platform on lowering patient risks. The Reference Risk Models definition would also indicate the effort required to scale up the solution and develop the P-HDTs to automate the risks prediction task.

Our Role

We are information and solution architects. Our role is to define the informaiton architecture of the P-HDT Platform, ensure the various risk models are designed according to the P-HDT data structures and provide the algorithms required to predict the various risks. We have pending patents for the methods and algorithms underlying the P-HDT solution: the Human Digital Twin (HDT), which is also described in various research papers (www.orcid.org/0000-0002-2775-6946).

Contributions

Dr. Rokya. Camara, MD, Germany | Dr. Marianne Miller, MD, Germany.