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A disruptive Big data approach to leverage the efficiency in management and clinical decision support in a Hospital

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ABSTRACT

There is an urgent need to potentiate evidence-based clinical-decision-making with a holistic, patient-centered approach to value, one that focuses both on health-care spending and treatment outcomes.[1] On the other hand, in the era of self-driven vehicles, computer systems in healthcare need also to become proactive and to identify relevant clinical patterns in a much faster and automated way than currently used solutions enable. Although this is the state-of-the-art paradigm, in fact, technical constraints block further developments in these areas as hospitals lack the skills to really manage and take value from the big amount of Data about their patients that is stored in dozens of heterogeneous information systems, from lab results to imaging studies, from pharmacy to the Electronic Medical Record (EMR). At São João Hospital Center (São João), a novel analytics platform was conceived, a new approach that is able to leverage all the Big Data that is stored about hospital patients in seconds and to apply some of the most advanced and lightening speed analytics on top of this information in order to empower clinicians and to give them a new decision support tool. This sets the road towards a data-driven hospital of the future, where Data Analytics and Data Science can become as important as the most recent Harrison's edition.

With this analytics platform, São João was able to be the first Non-Us institution to ever win the Microsoft U.S Worldwide Innovation Award (HIMSS - Florida, 2014) and the European Big Data & Analytics solution of the year (IT EUROPA - London, 2014).

This solution is called HVITAL (Hospital surVeillance, moniToring and ALert) and is working 24/7 at São João Hospital since 2012.

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What is HVITAL?

HVITAL is a unique data analysis software platform, capable of achieving an integrated and immediate view of all the relevant clinical and business information electronically stored every minute in several hospital information systems. This data comes in different formats (tables, written text, coding, analytical results, data streams…), at different periods in time and is registered by hundreds of different users. HVITAL is able to automatically collect and analyse all this data to produce more than 600 KPIs every second, from the clinical and management perspectives. Data that used to take weeks or months to obtain is now available within seconds, by means of a system capable of exploring millions of records per second, speeding up the decision making and the correction of less efficient processes. HVITAL indicators are available at all levels of the organization, from top executives to operational levels, through online dashboards published on each of the organization department's television screens, popping up alerts of several types with red, yellow and green icons attached. Nowadays, HVITAL goes even further by constantly monitoring a series of physiological signs from every patient since their day 1 at São João and it is programmed to automatically identify and promptly alert regarding patients at risk for clinical deterioration. By providing a more systematic and intelligent approach to the early identification of patients at risk, aided by advanced computer power which works automatically, in real time, 24 hours a day, 7 days a week, independently from any physiological or psychological stressors, HVITAL has become a valuable tool to monitor every patient that is in a São João inpatient ward.

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What makes HVITAL so differentiating?

The speed of analysis and access to information that is critical from a decision support point of view. HVITAL can analyse 300 million records that are spread out in dozens of information systems in just a few seconds and to identify where the clinical and operational problems are, thus shortening the "time to act" to just hours or seconds. Before HVITAL, only 30% of the decisions were taken based on sustained information, whereas nowadays decision makers are able to base their decisions on information coming from HVITAL in 95% of the cases. Decision makers are not only the CEO and the board of executives, in a hospital scenario those who most need to take decisions are doctors and nurses, it's for them that HVITAL ultimately exists.

Nationally this platform is unique. There is no hospital, both in the public and private sectors, with anything alike. Also at the European level we are not aware of any hospital with this type of solution. HIMSS Europe, the most recognized organization that evaluates maturity and innovation systems health information in hospitals, recently invited HVITAL to be shown in the Keynote session of its annual event, which demonstrates the impact in terms of disruptive innovation that this solution represents.

There is also a key aspect that is worth mentioning to explain HVITAL's success. Instead of being developed away from its primary users. HVITAL was developed and tuned in the field with the contribution of a large multidisciplinary team of managers, doctors, nurses, epidemiologists and analytics experts. Software solutions cannot continue to be developed outside the organizations. They need to be born and grow inside them and this makes a huge difference in terms of the impact a solution can have for users.

What kind of impact can doctors and nurses expect from HVITAL? What about patients?

HVITAL provides more than descriptive analytics (production of indicators). From the beginning, in 2013, HVITAL is being tailored to become a state-of-the-art instrument from a clinical decision support perspective. Its highly advanced predictive analytics technology started to analyse the evolution of hundreds of physiological parameters about each patient coming from their lab results, vital signs, level of consciousness, clinical notes and so forth, in order to alert physicians about potentially life-threatening conditions that only a highly advanced computer that can make thousands of calculus in seconds can detect in such a short time. The idea is to evaluate each patient's information every second, and trigger an "action algorithm" for additional assessment and/or immediate treatment when a problem is detected, sending an immediate alert message to the doctor and nurse in charge of the patient (Fig. 1). This novel technology has already helped save lives at São João by early warning physicians about unnoticeable clinical factors that would lead to a fast and irreversible clinical deterioration situation.[2] The prediction power of this tool now helps to anticipate 30% of intensive care unit (ICU) admissions and 50% of non-intensive care unit (non-ICU) inpatient deaths within seven days before the event occurs.

HVITAL is also a valuable instrument for the surveillance and operational control of multidrug resistant infections. It has a complex algorithm that detects whether a patient has a multi-drug resistant infection, locates the infection areas and automatically produces an alert that leads to the adoption of additional infection control precautions as well as optimising antimicrobial treatment (Fig. 2). More than being able to do this, HVITAL can do it on real time. Some critical indicators that might take weeks to collect and analyse are now available within seconds and this boosts all the subsequent actions that need to be taken in the field, drastically reducing the "time to act".

In the Antibiotics Area, HVITAL also plays a key role by performing an automatic and targeted surveillance of all patients receiving anti-biotics throughout the hospital. Pharmacists and Antibiotic Stewardship Teams see in HVITAL a valuable asset to help them monitor antibiotics use in real-time, either from an institutional or individual perspective, and to immediately perform targeted interventions that lead to more adequate antibiotic use.

From a Management and Research point of view, it is now possible to explore all the hospital's activity in depth and find patterns in data which enhance the cost-benefit analysis for the identification of more effective treatments against the consumption of resources, allowing questions like "Why is that patients with pathology 'X', that are more than 35 years old, who take drugs 'A' and 'B', live outside Oporto, and have blood results 'C' and 'D', normally catch 20% more nosocomial infection when they have a 'gastric bypass' procedure in surgical room '4'?" to be posed to the system. In a healthcare organization, to gain the ability to detect the occurrence of these patterns and their causes is essential for a more accurate and informed clinical and financial management.[1]

All this search and exploration capabilities are surrounded by strict authentication, confidentiality and other security mechanisms in order to assure that sensitive data is only accessed by those who already have the permission to see this data accordingly to the Hospital's information access guidelines and procedures.

Looking at the Future, where is HVITAL heading to?

Every day in a hospital scenario there is a huge knowledge based system that is being enriched at each second as clinicians evaluate their patients through their clinical notes, order blood tests, alter the patient's medication or request a new imaging study. Besides some outstanding initiatives that are happening at major institutes like the Mount Sinai New York hospital, nobody is really leveraging this information at scale [6]. As the clinician is passing new ideas and sources of information about his patient to the electronic medical record (EMR), HVITAL will be able to analyse this information in the background, run a series of very complex algorithms on the fly and produce risk scores and probabilities about each specific patient, pathology and adequate treatment, providing the output and suggestion of these algorithms at the point of care, when the doctor or nurse are at the bedside. In order to accomplish that, HVITAL needs to become more clinically intelligent, i.e, to deeply understand what is the clinical practice and the specificity of each clinical treatment and to be able to apply highly sophisticated Machine Learning techniques on top of these data in an automated and systematic way, dynamically weighting all the probabilities and contribution of each variable every second. Then, based on this Clinical Intelligence engine, the challenge is to deliver new insights to clinicians that can prove to make a clear difference when compared with current clinical practice and with the clinician's unique evaluation and judgment. This road has already started as HVITAL currently evaluates every single patient that enters São João and stratifies the patient in terms of clinical deterioration risk, being able to predict ICU admissions and non-ICU deaths. But this kind of approach needs to be pursued even further and HVITAL needs to become more pervasive in a "good sense" and to become even more helpful for clinicians. HVITAL needs to be an active and intelligent component inside the EMR that proactively assists clinicians by providing insights that can guide them to better match the right treatment for the right person at the right time. This road towards precision medicine involves the analysis and correlation at the scale of thousands of clinical variables in seconds, coming not only from the typical EMRs but also from unstructured sources of information such as clinical diaries, imaging exams and, obviously, from biological sources like the genomics databases that will become the new gold standard to evaluate each patient with the fast decreasing cost of Next Generation Sequencing that will enable, sooner or later, to apply a whole genome sequencing analysis to each patient and to enrich the EMR with that information.[3,4] The approach to deal with such an unimaginable dimensionality, that no

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human can ever manage and correlate, is to use powerful Machine Learning algorithms combined with Big Data techniques that are able to infer new hypotheses about the patterns that these thousands of patient variables could be expressing and that nobody has yet noticed.[5,6] These kinds of technologies are nowadays the cornerstone used to support autonomous vehicles, to help Google find the best search result for a user's search query or even to boost Amazon's sales by intelligently suggesting the user a series of items that he will probably want to buy next. It has been proven that these algorithms can provide outstanding results.[7,8] Why not to use them to timely and precisely judge each patient's risk, evolution and outcome?

I envision a future where the computer will be able to anticipate and precisely assess the risk of each patient and to suggest the doctors the actual effectiveness of certain treatment approaches in comparison with others, helping them to decide the best therapeutic path for a patient, carefully weighting thousands probabilities which no human could ever compute in a timely manner. This is my vision as the Project Manager of HVITAL.

Acknowledgments

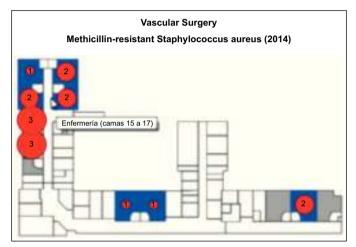**Fig. 1.** HVITAL – Emergent Parameters being shown inside each patient's EMR card (some text in Portuguese).

Fig. 2. HVITAL – Signalling MRSA events in the Hospital's floor plant (some text in Portuguese).

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