

## AI, Machine Learning and Data Analytics solutions for ICU and Hospitals

### Overview

In times of an extraordinary event like an epidemic, pandemic or natural disaster, Intensive Care Unit and Emergency departments in a hospital operate at full or excess capacity. Hospital resources are overworked and stressed in these situations. Healthcare workers will be exposed to the epidemic. There is an immediate need to assist hospital operations with technology that helps to keep healthcare workers safer and help minimize errors in treating patients. The focus of this project will be to assist healthcare workers in ICU and emergency departments through technology to perform their jobs better.

### Goals

This project proposes to create a web based user interface to assist healthcare professionals in a hospital with the following:

- The ability to check if they are at risk for a prevalent epidemic/pandemic based on symptoms
- Determine if they are at risk for job related issues like stress, burnout
- Ability to report problems in their work area anonymously
- Analytics and prediction dashboards for hospital management
- Notifications and broadcast messages to phones

### Symptom checker

The purpose of this application is to provide a risk score based on symptoms and advice further lab testing for an epidemic or illness. Initial implementation of this predictive application can be through heuristic methods but will need to be upgraded to a machine learning model when enough data is available.

A simple interactive form with YES/NO answers and scale from 1 to 10 will be typically used. An example form for SARS-Cov-2 is shown below.

Fever over 100.5 deg.  YES  NO

Persistent dry cough  YES  NO

Trouble breathing  YES  NO

Persistent pain or pressure in chest. Choose 1 for No pain and 10 for extreme pain  1           10

Can you hold your breath for 10 seconds?  YES  NO

Have you had an organ transplant?  YES  NO

Are you undergoing any cancer treatment  YES  NO

Have blood or bone marrow cancer?  YES  NO

Chronic lung issues like COPD, cystic fibrosis, asthma  YES  NO

Do you take any medication that weakens your immune system?  Yes  No  I don't know

Are you pregnant and have a serious heart condition?  YES  NO

Do you have diabetes?  YES  NO

Are you over 65 yrs of age?  YES  NO

Each symptom is assigned a weight and a risk score is calculated. If the patient exhibits a risk score of greater than a threshold (0.75), then they are directed to get further lab tests. If their risk score is above a particular threshold (0.5), they may need to track their symptoms closely. Precautionary instructions should be given to them to enable them to avoid getting worse. In the survey, if a worker enters 10 for pain, then they need to be directed to emergency immediately and a notification sent to their supervisor.

The method of assigning weights to the questions may need a few iterations. When a machine learning model is deployed, these weights get adjusted automatically based on data available. Machine learning models can be constantly updated when more data is available.

## Stress checker

Preliminary data from the hospital schedule needs to be available to understand the number of hours worked, days worked and shifts worked. A score is generated to indicate if someone is overworked and by how much. EHR data with entries from workers that can input events is another measure to understand how much work was done. It could be the number of entries in the database, number of words in textual notes or other quantities. A time series spread of these events gives an idea of how much continued work was done.

In addition, a survey application to identify stress and burnout can be provided. A sample questionnaire is shown below.

15 Statements to Answer	Not at All	Rarely	Sometimes	Often	Very Often
1 I feel run down and drained of physical or emotional energy.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2 I have negative thoughts about my job.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3 I am harder and less sympathetic with people than perhaps they deserve.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4 I am easily irritated by small problems, or by my co-workers and team.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5 I feel misunderstood or unappreciated by my co-workers.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6 I feel that I have no one to talk to.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7 I feel that I am achieving less than I should.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8 I feel under an unpleasant level of pressure to succeed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9 I feel that I am not getting what I want out of my job.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10 I feel that I am in the wrong organization or the wrong profession.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11 I am frustrated with parts of my job.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12 I feel that organizational politics or bureaucracy frustrate my ability to do a good job.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13 I feel that there is more work to do than I practically have the ability to do.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14 I feel that I do not have time to do many of the things that are important to doing a good quality job.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15 I find that I do not have time to plan as much as I would like to.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Another sample questionnaire from squarespace can be found here - <http://static1.squarespace.com/static/58e2d54de3df28e295f6709c/59233c6b890b27a16b2b765e/59233c79890b27a16b2b77a0/1495481465681/Stress-and-Burnout-Questionnaire.pdf?format=original>

Additional questions specifically about the nature of work can also be added. It is important for employees to fill this out periodically to understand their engagement and progress.

## Anonymous reporting

In order to maintain a transparent workplace, it is necessary for employees to be able to speak up freely with their supervisors. In cases, where supervisors are less forthcoming or don't engage their employees properly, other channels need to be in place to ensure flow of communication. In a typical workplace, this is through human resources and may be as a "last resort".

Anonymous reporting with a guarantee of no quid pro quo will encourage many employees to speak up. You can find numerous examples of applications like Blind, thelayoff.com, where employees speak up more freely.

A simple form should be provided to gather textual input. Fingerprint of the infrastructure or any identifying information cannot be stored. The department where this incident or event occurred needs to be input. The information on this form can only be read by human resources or an administration personnel outside of the department (COO, legal). When a report is entered, the employee should be provided with a long random string (e.g: 123e4567-e89b-12d3-a456-426655440000). This string can be used by the employee to check on a response.

The action on a report needs to be investigated and a response provided. The investigator can recommend further action with a meeting of the employee and appropriate personal (HR, legal).

## Xen.AI Medical - ICU Data Analytics Solution

An analytic dashboard is an important tool to capture the health of operations of an organization or department. It is also a tool that can be used to communicate the health of operations to employees. Aggregated data from surveys for burnout can be published so that all employees are aware. Crucial metrics for a department like intensive care unit is necessary to monitor progress as well as identify errors, outliers and any interventions that may be necessary. At [Xen.AI](http://Xen.AI), we have developed an Artificial Intelligence, Machine Learning based, predictive ICU data analytics application called [Xen.AI Medical - Imaging](#) using the [MIMIC3 dataset](#). This dataset contains information on ICU admissions at the Beth Israel Medical Center in Boston over a period of 12 years. The following metrics provide information on operational metrics and predictions. The data has been de-identified and the time period scrambled to protect privacy.

## I. Length of stay in ICU

The table below shows the average number of days that a person spent in ICU on a quarterly basis.

Length of stay in ICU quarterly average

Year	Quarter	LOS
2100	2	3.9
2100	3	3.1
2100	4	2.9
2101	1	2.9
2101	2	3.2
2101	3	3
2101	4	3.1
2102	1	2.8
2102	2	2.7
2102	3	3
2102	4	2.7



## II. Number of readmissions

The table below shows the average number of days that a person spent in ICU on a quarterly basis. A readmission is said to have occurred if a patient was discharged from ICU and then admitted again within 48 hours. This metric can also be calculated for a longer duration like a week.

### Readmissions in ICU per quarter

Year	Quarter	Readmissions
2146	1	1
2146	2	0
2146	3	0
2146	4	0
2147	1	0
2147	2	0
2147	3	2
2147	4	1
2148	1	1
2148	2	0
2148	3	0
2148	4	1



### III. Number of infections from ICU procedures

The following complications from ICU procedures are determined to be part of the infections metric:

- Urinary Tract Infection due to an ICU procedure
- Infection or inflammation due to a device, implant or graft in ICU
- Bloodstream infections
- Infections due to MERS, C-diff

### Infections in ICU per quarter

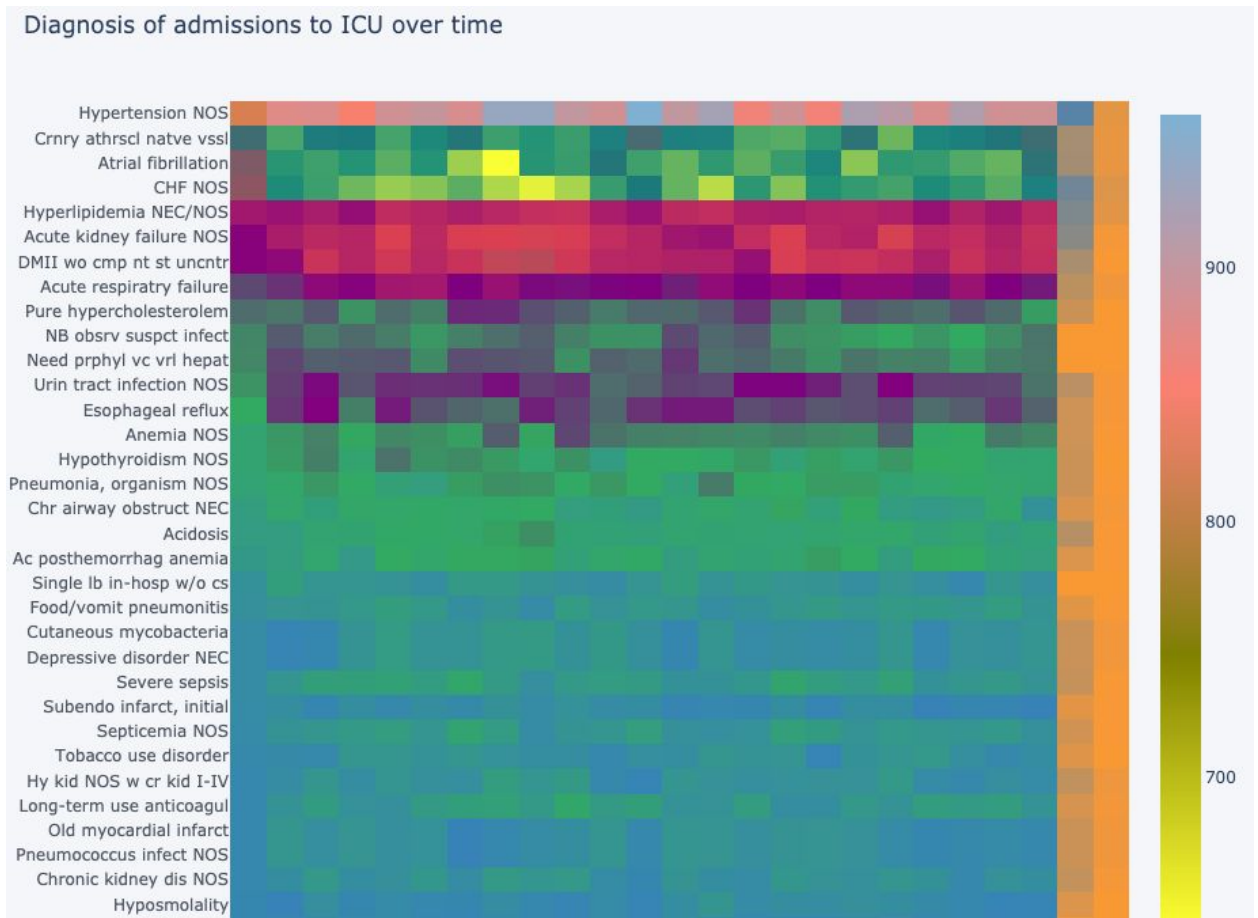
Year	Quarter	Infections
2100	1	0
2100	2	4
2100	3	17
2100	4	22
2101	1	17
2101	2	23
2101	3	24
2101	4	21
2102	1	27
2102	2	12
2102	3	18
2102	4	13



#### IV. Cause of admission to ICU

A heatmap of the most common admission cases to ICU over time gives a quick glimpse of the prevalent illnesses. The causes may vary depending on season and when there is an epidemic. It does give a good insight in the types of resources necessary to combat the major causes in ICU.





## V. Most used drugs in ICU

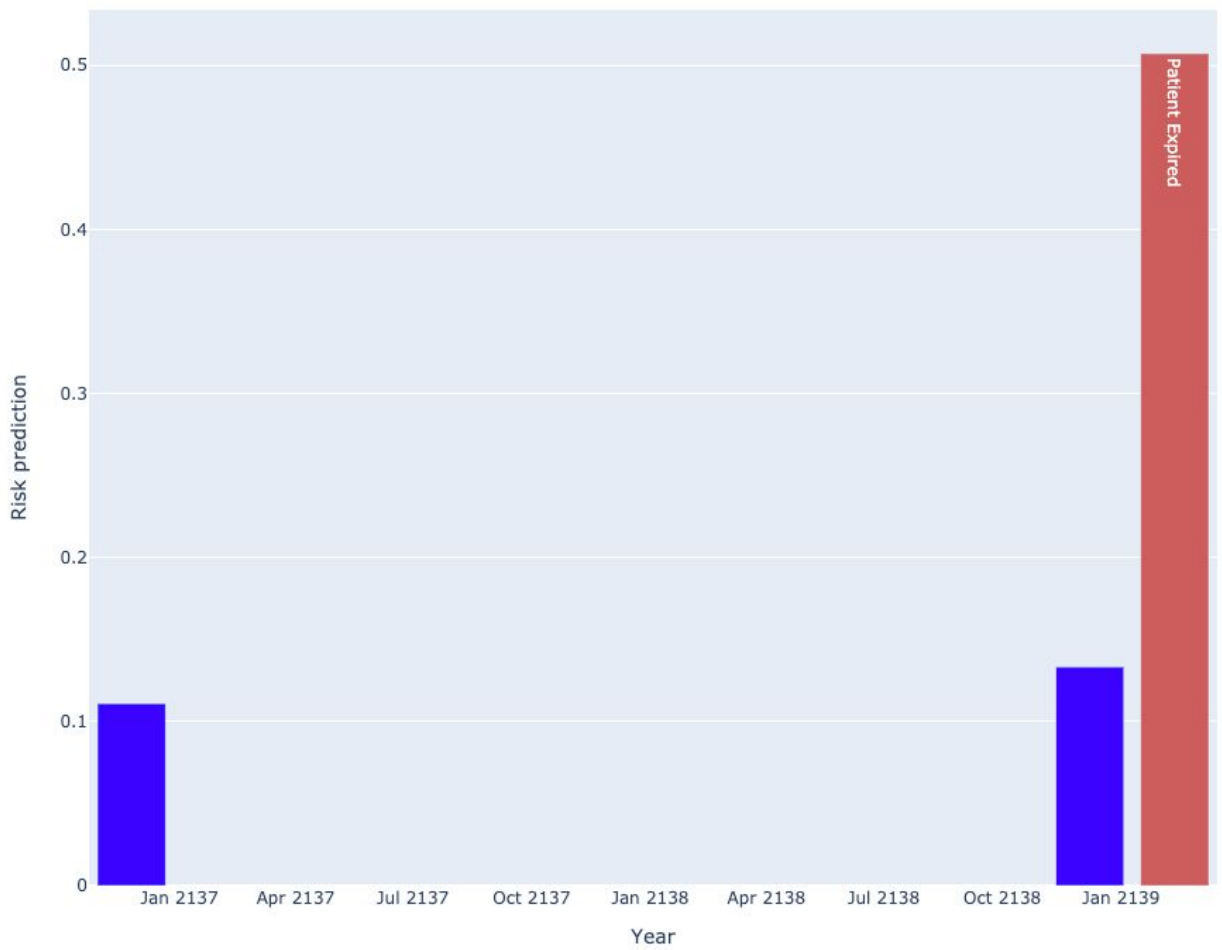
A treemap of the most frequently used drugs in the ICU is shown below. Hospital administration can use this information to ensure they are well stocked with most needed drugs.



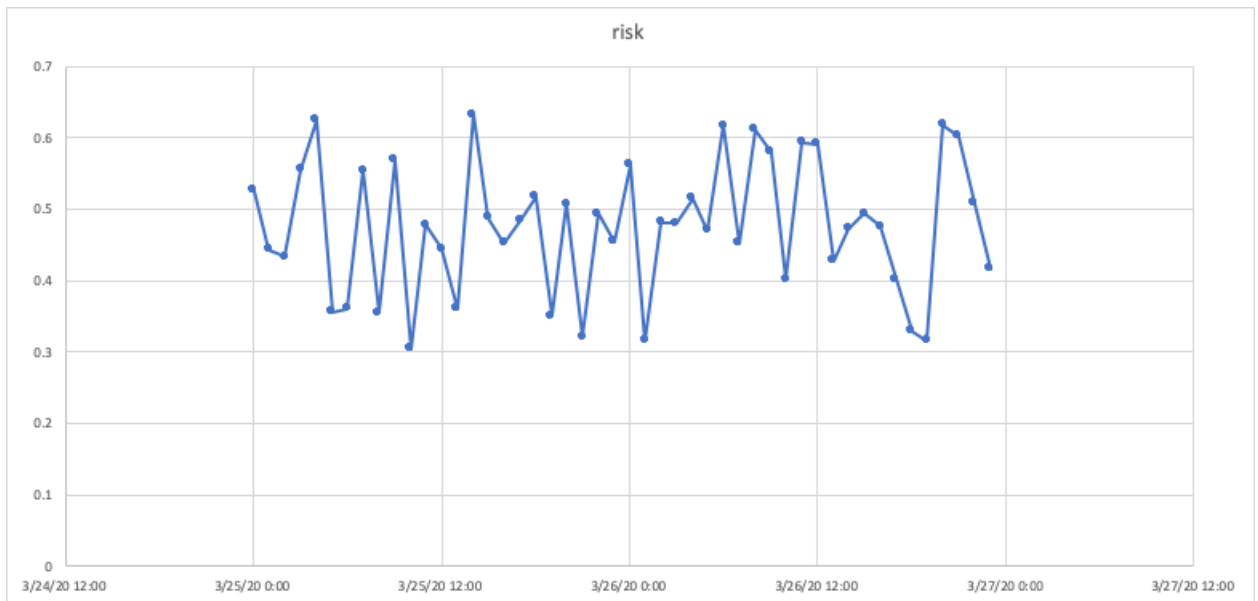
## VI. Patient mortality prediction

This is a predictive machine learning application that uses diagnosis, lab events, microbiology events and notes to provide a risk score of patient mortality. In the chart shown below, a patient was admitted thrice to ICU in different years. The risk score during each event is shown and during the last admission, the patient expired.

### Patient Mortality Prediction



The above chart is from historical data. It is envisioned to provide a risk chart for real time data as shown below.



In addition to these charts, other types of patient specific charts can also be shown as a time series - lab events, diagnosis, vital signs, abnormal events.

## Notifications

Hospital operations may need to send urgent notifications and messages to staff. It is necessary to have the ability to send SMS messages to mobile phones of staff for any critical notifications that require their action. A simple user interface as a web application can be provided to pertinent staff to send such notifications. If an existing infrastructure solution exists for notifications, it can be used for the purposes of events generated from above applications.

## About Xen.AI

[Xen.AI](http://Xen.AI), is an Artificial Intelligence (AI) Research and Development (R&D) organization. We help our customers to build innovative solutions and applications using Artificial Intelligence, Machine Learning, Deep Learning, Data Science & Open Source technologies. Currently [Xen.AI team](#) is implementing the [Medical360.AI](#) ICU data analytics solution at two Hospitals in Los Angeles, California. We have a [passionate group of PhDs](#) from all over the world building Machine Learning applications in various domains. With this dedicated team of experts we can ensure that the solutions we provide are outstanding. We build our AI solutions on top of open source innovations providing transparency to clients.

## Opportunities

In addition to the above stated goals, Xen.AI will be delighted to help the ICU and emergency departments with the following technologies:

- Chatbots to assist healthcare workers with their needs. Chatbots are especially useful to make the surveys or questionnaires dynamic. It is intended to use machine learning to structure the questions so that only information relevant to the current context is collected. For e.g: If a patient answers yes for over 65 yrs, then additional questions relevant to typical conditions over 65 are asked and if not, they are skipped.
- Machine learning imaging applications to detect and diagnose abnormalities. With SARS-Cov-2 virus, the primary infections are in the lung. You could classify the condition as early or progressed depending on whether the upper or lower respiratory tract is infected. If lung scans are available, this process can be automated to get results quickly.

## Next steps

Xen.AI team would be happy to discuss and help develop customized Artificial Intelligence, Machine Learning based predictive data analytics solutions to assist the Hospitals and healthcare workers to navigate the current crisis as well as future events. Please feel free to email at [support@xen.ai](mailto:support@xen.ai) or visit [Xen.AI](http://Xen.AI) to know more about us.

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