Literature Review : Introduction

I have done my research on Ventilator Pressure Prediction connected to a sedated patient's lung. The ground work includes, checking for the best predictive model available for pressure prediction and enhance it further, so that the system will adapt itself and automatically predict the right level of pressure through respiratory circuit.

Research Question:

What is the predicted pressure to pass through the respiratory circuit so that the patient can survive on the ventilator?

Why I chose this research question?

> It will increase the chance of patients to survive who are on ventilator during Covid-19 pandemic situation.
> Expand my knowledge of enhancing the performance of model and use this expertise in various domain.

Literature Review : Why is this an Important Topic?

> Covid-19 inflames airways and essentially drown your lungs in fluid.

> The ventilator helps in breathing depending on patient's condition by blowing air and oxygen into the lungs..

> Due to Covid-19 pandemic situation the demand for ventilators has risen substantially and hence the pressure readings must be accurate.

> To increase the chance of patients survival the pressure has to be controlled and if not controlled then that may lead to hypoventilation (breathing abnormally in a slow rate and result in increase amount of carbon dioxide in blood)

> The pressure and the flow rate delivered by ventilators is critical to the well-being of the patient.

Literature Review : Paper 1

Research Process: I have taken the reference of this research paper published in 2021 which is associated for prediction of Mechanical Ventilation(MV) for patients in emergency room during Covid-19 pandemic.

Reference to the Paper: Yu L, Halalau A, Dalal B, Abbas AE, Ivascu F, Amin M, et al. (2021) Machine learning methods to predict mechanical ventilation and mortality in patients with COVID-19. PLoS ONE 16(4): e0249285. https://doi.org/10.1371/journal.pone.0249285

Research Findings and Methods: Based on the paper published, the prediction is done on both Mechanical Ventilation and the mortality rate of Covid-19 patients. There are several features associated with the risk of admitting patients including older age, male sex, obesity, oxygen saturation less than 88% , some conditions of patients like hypertension, diabetes and lab values like elevated troponin level, C reactive protein level > 200

Model Used: For predicting the Mechanical Ventilation authors have used Machine Learning Model (XGBoost) and for predicting mortality rate (catBoost) is used

Optimization Method: K-fold cross validation is used for optimizing the model and ensuring that the model is not overfitted.

Results: Accuracy score and **Area Under Curve (AUC)** are the metrics used for model prediction.

Prediction/Score	Accuracy Score	AUC
Mechanical Ventilation	86.2%	68%
Mortality Rate	80.3%	85%

Literature Review : Paper 2

Research Process: The research paper published in 2019 determines the study of Machine Learning Model to predict the existing, applied or measured hemoglobin oxygen saturation (5min SpO2) after a ventilator setting is changed.

Reference to the Paper: Ghazal, Sam & Sauthier, Michaël & Brossier, David & Bouachir, Wassim & Jouvet, Philippe & Noumeir, Rita. (2019). Using machine learning models to predict oxygen saturation following ventilator support adjustment in critically ill children: A single center pilot study. PLOS ONE. 14. e0198921. 10.1371/journal.pone.0198921. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0198921

Research Findings and Methods: Based on the research paper the authors check for the impact of the adjustment on gas exchange by adjusting the ventilation settings at patient's bedside. Vital parameter is SpO2 i.e Oxygen saturation. When SpO2 is low then either FiO2 (Fraction of Oxygen) or ventilation pressures/volume are increased.

Model Used: Two classification models like artificial neural network and bootstrap aggregation of complex decision trees were used.

Optimization: K-fold cross validation is used for optimizing for both models considering the k values = 10

Results: ROC curves are used as the metrics for model prediction and the area under the curve for all class is below 0.75

Literature Review : Paper 3

Research Process: The research paper published in 2021 determines the study of Machine Learning Model to predict the mortality based on the analysis of ventilation parameters of critically ill patients.

Reference to the Paper: Mamandipoor, B., Frutos-Vivar, F., Peñuelas, O. et al. Machine learning predicts mortality based on analysis of ventilation parameters of critically ill patients: multi-centre validation. BMC Med Inform Decis Mak 21, 152 (2021). https://doi.org/10.1186/s12911-021-01506-w
https://bmcmedinformdecismak.biomedcentral.com/articles/10.1186/s12911-021-01506-w

Research Findings and Methods: Based on the research paper the authors carried out four different analysis:

- Original ventilation parameters - on overall cohort(group)
- Original ventilation parameters - on subgroup of patients
- Additional parameters related to function of other organs - on overall cohort(group)
- Additional parameters related to function of other organs - on subgroup of patients

Model Used: Three models were used to compare the result of prediction: Recurrent Neural Network of deep learning (RNN-LSTM Model), Random Forest and Linear Regression.

Optimization: 5-fold cross validation is used for optimizing models considering the k values = 5

Results: LSTM model gave more accuracy in prediction compared to Random Forest and Linear Regression.

LSTM (AUC)	RF (AUC)	LR (AUC)
0.79	0.76	0.72

Literature Review : Paper 4

Research Process: The research paper published in 2019 determines the study of Machine Learning Model to predict the extubation failure for Intensive Care Unit patients.

Reference to the Paper: T. Chen et al., "Prediction of Extubation Failure for Intensive Care Unit Patients Using Light Gradient Boosting Machine," in IEEE Access, vol. 7, pp. 150960-150968, 2019, doi: 10.1109/ACCESS.2019.2946980. https://www.researchgate.net/publication/336453098_Prediction_of_Extubation_Failure_for_Intensive_Care_Unit_Patients_Using_Light_Gradient_Boosting_Machine

Research Findings and Methods: Based on the research paper the authors check for the impact of the risk associated with re-intubation and is associated with increased mortalities.

Model Used: Light Gradient Boosting Machine(LightGBM) model

Optimization: Number of features used(68 and 36 features)

Results: As per research paper LightGBM model prediction outperform over other Machine Learning Models such as ANN, LR and SVM.

Features	LightGBM	XGBoost	LR	SVM	ANN
AUC for 68	0.8130	0.8114	0.5285	0.6221	0.6836
AUC for 36	0.8198	0.8168	0.5425	0.6712	0.7358

Literature Review : Paper 5

Research Process: The research paper published in 2021 determines the study using Supervised Machine Learning Model to predict the duration of mechanical ventilation in respiratory distress.

Reference to the Paper: Sayed, M.; Riaño, D.; Villar, J. Predicting Duration of Mechanical Ventilation in Acute Respiratory Distress Syndrome Using Supervised Machine Learning. J. Clin. Med. 2021, 10, 3824. https://doi.org/10.3390/jcm10173824

Research Findings and Methods: Based on the research paper the authors use Supervised Machine Learning model across 3 days. 6 features were used for prediction age, ventilator parameters including PEEP, blood gas parameters including FiO2, PaO2, PaO2/FiO2, and PaCO2

Model Used: Three models are used like LightGBM, Random Forest, eXtreme Gradient Boosting

Optimization: K-fold cross validation is used for optimizing all three models considering the k values = 10 (9 for training and 1 for testing)

Results: As per research document, LightGBM predicted better than Random Forest and XGBoost. RMSE is the metrics used as measure.

XGBoost : 6.81 RF : 6.79 **LightGBM : 6.41**

Literature Review : Paper 6

Research Process: The research paper published in 2021 described their aim to establish scores on mechanically ventilated patients based on the features available on the first day of patient's admission.

Reference to the Paper: Zhu Y, Zhang J, Wang G, Yao R, Ren C, Chen G, Jin X, Guo J, Liu S, Zheng H, Chen Y, Guo Q, Li L, Du B, Xi X, Li W, Huang H, Li Y and Yu Q (2021) Machine Learning Prediction Models for Mechanically Ventilated Patients: Analyses of the MIMIC-III Database. Front. Med. 8:662340. doi: 10.3389/fmed.2021.662340 https://doi.org/10.3389/fmed.2021.662340

Research Findings and Methods: Based on the research paper the authors use Supervised Machine Learning model across 3 days. 6 features were used for prediction age, ventilator parameters including PEEP, blood gas parameters including FiO2, PaO2, PaO2/FiO2, and PaCO2. Data cleansing was done as more than 30% had missing data.

Model Used: Comparison is done between the following models; KNN, Logistic regression, decision tree, random forest, neural network, bagging, and XGBoost

Optimization: 66 features were used with 70% training and 30% testing data.

Results: As per research document, XGBoost predicted better than KNN, Logistic regression, decision tree, random forest, neural network, bagging. RMSE is the metrics used as measure.

KNN: 0.806 Logistic regression: 0.818 decision tree: 0.743 random forest: 0.819 neural network: 0.780 bagging: 0.803 **XGBoost: 0.821**

Literature Review : Paper 7

Research Process: The research paper published in 2021 describe their study related to the derivation and validation of an ensemble model for the prediction of agitation in mechanically ventilated patients maintained under light sedation.

Reference to the Paper: Zhang, Zhongheng MD1; Liu, Jingtao MD2; Xi, Jingjing MD3; Gong, Yichun MD2; Zeng, Lin PhD4; Ma, Penglin MD2 Derivation and Validation of an Ensemble Model for the Prediction of Agitation in Mechanically Ventilated Patients Maintained Under Light Sedation, Critical Care Medicine: March 2021 - Volume 49 - Issue 3 - p e279-e290 doi: 10.1097/CCM.0000000000004821 https://pubmed.ncbi.nlm.nih.gov/33470778/

Research Findings and Methods: Based on the research paper the authors build a model to predict the agitation on patients who are kept on sedation 24 hours prior and continued till 24 hours later. Sample variables were collected from the patients early morning for building model.

Model Used: Four Machine Learning algorithm is used like support vector machine, C5.0, adaptive boosting, extreme gradient boosting

Optimization: None.

Results: As per research document, XGBoost predicted better than Support Vector Machine, C5.0 and adaptive boosting. Calibration was considered as the metric measure.

Literature Review : Paper 8

Research Process: The research paper published in 2020 described their prediction related to acute severity in infants who are hospitalized and in ventilator.

Reference to the Paper: Zhang, Z, Navarese, EP, Zheng, B, et al. Analytics with artificial intelligence to advance the treatment of acute respiratory distress syndrome. J Evid Based Med. 2020; 13: 301– 312. https://doi.org/10.1111/jebm.12418

Research Findings and Methods: In this research paper the authors use Machine Learning model to predict the need of positive pressure ventilators or Intensive Care unit in patients based on the severity and various conditions and settings like sepsis, asthma exacerbation, emergency department triage.

Model Used: Machine Learning model - Lasso regression, elastic net regression, random forest, and gradient boosted decision tree and referenced model

Optimization: Tested on random n samples (20%)

Results: As per research document, machine learning model outperformed over referenced model. AUC is used as a metric measure for prediction.

Gradient Boosted decision tree : 0.88 vs referenced model : 0.62

Elastic net regression : 0.89 vs referenced model : 0.62

Random Forest : 0.79 vs referenced model : 0.62

Summary of the Literature Review

In research papers published by authors we can see the Machine Learning models used are:

For Classification:

> Artificial Neural Network (ANN)
> Decision Trees (Bootstrap Aggregation)

For Regression:

> Ensemble Model : XGBoost, LightGBM
> Gradient Boosting : catBoost
> Recurrent Neural Network - LSTM Model
> Random Forest
> Linear Regression

Optimization:

The optimization used in the research paper is k-fold cross validation for enhancing the performance of model.

Observation of Model:

According to research papers, among all the above models for Machine Learning model Ensemble or Boosting is the best predictive model, in Artificial Intelligence model, LSTM (Long Short Term Memory networks) model predicts the best result and in Deep Learning Model, ANN is the best model which gives the highest accuracy rate. The dataset which I have to predict is a continuous variable and hence, the machine learning model that is to be used is Regression. Classification can be used when the prediction is to be done on a discrete variable as an output.

Literature Review : Possible Barriers and what can be done?

Possible Barriers

- Authors have published in their papers that the important factor which affects the accuracy is dataset itself
- Model selection based on the dataset
- Model Optimization
- Overfitting of models
- Time series data

What can be done

- Analyze and cleanse the data before fitting the model and predicting on output variable.
- Check the dataset type and decide the model whether the dataset is related to classification, regression, clustering, etc
- Along with parameters we can use hyper parameters for fine tuning the model.
- Overfitting of data can be avoided by using cross validation, increasing training data, using ensemble methods like bagging or boosting
- The dataset chosen is time series data and hence feature engineering to be done to do the prediction

Literature Review : References

- Yu L, Halalau A, Dalal B, Abbas AE, Ivascu F, Amin M, et al. (2021) Machine learning methods to predict mechanical ventilation and mortality in patients with COVID-19. PLoS ONE 16(4): e0249285. https://doi.org/10.1371/journal.pone.0249285
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