**Creation of a Robust and Generalizable Machine Learning Classifier for Patient Ventilator Asynchrony**

Gregory B. Rehm1, Jinyoung Han2, Brooks T. Kuhn3, Jean-Pierre Delplanque4, Nicholas R Anderson5, Jason Y. Adams3\*, Chen-Nee Chuah6\*

\*these authors contributed equally to this work

# Online Supplement

|  |  |  |
| --- | --- | --- |
| Variable Name | Units | Description |
| TVi | Milliliters/second | inspiratory tidal volume, defined as the integral of the flow-time curve values from breath start (BS) to point where flow crosses 0 (x0). |
| TVe | Milliliters/second | expiratory tidal volume, defined as the integral of the flow-time curve values from x0 to breath end (BE) |
| TVe/TVi | Unitless | the ratio of expiratory tidal volume to inspiratory tidal volume |
| I-time | Seconds | the time from BS to [x0 minus 1 time point] |
| E-time | Seconds | the time from x0 to BE |
| I:E ratio | Unitless | the ratio of the I-time to the E-time |
| RR | Unitless | instantaneous respiratory rate, defined as 60/breath time |
| PIF | Liters/minute | peak inspiratory flow, defined as the maximum positive flow recorded from BS to [x0 minus 1 time point] |
| PEF | Liters/minute | peak expiratory flow, defined as the most negative flow recorded from x0 to BE |
| PIP | cm H2O | peak inspiratory pressure, defined as the maximum recorded pressure from BS to [x0 minus 1 time point] |
| Mean flow from PEF | Milliliters | The mean flow observation from the point in time PEF occurred to the point where the breath terminated and a new one begins |
| ipAUC | cm H2O | the inspiratory pressure area under the curve, defined as the integral of the pressure-time curve from BS to [x0 minus 1 time point] |
| epAUC | cm H2O | the expiratory pressure area under the curve, defined as the integral of the pressure-time curve from x0 to BE |
| PEEP | cm H2O | positive end-expiratory pressure, defined as the average of the last 5 data points from the pressure-time curve of each breath |
| Paw | cm H2O | mean airway pressure |
| Dynamic Compliance | Unitless | The pulmonary compliance of the lung at any given point during a breath. This measure is derived via : |

Table S1: List of all metadata variables along with a description. These variables were all processed from raw ventilator waveform data and were evaluated as independent features to add to our PVA detection model.

Figure S: Binary DTA detection using metadata features without SMOTE.DTA: double trigger asynchrony;SMOTE: synthetic minority over-sampling technique.

Figure S: Binary DTA detection using expert feature without SMOTE.DTA: double trigger asynchrony;SMOTE: synthetic minority over-sampling technique.

Figure S: Binary DTA detection using retrospective and metadata feature without SMOTE. DTA: double trigger asynchrony;SMOTE: synthetic minority over-sampling technique.

Figure S:Binary DTA detection with expert retrospective features and run without SMOTE.DTA: double trigger asynchrony;SMOTE: synthetic minority over-sampling technique.

Figure S: Chi-square sensitivity analysis for binary BSA detection using all retrospective and metadata features. We found 21 features was the optimal number of features here for a subset of DTA features derived from the retrospective and metadata features. BSA: breath stacking asynchrony; DTA: double trigger asynchrony.

Figure S: Chi-square sensitivity analysis for binary BSA detection using all retrospective and metadata features. Here we found the optimal number of features was 32, which is all possible features. BSA: breath stacking asynchrony.

Figure S: Binary BSA detection using all retrospective and metadata features. From this experiment we found the addition of the retrospective features did not improve our model above baseline performance of using all metadata. BSA: breath stacking asynchrony.

Figure S: Figure details the results of running our final model without SMOTE. Most classifiers with exception of GBC suffer from poor DTA sensitivity, while BSA is relatively unaffected by lack of SMOTE. SMOTE: synthetic minority over-sampling technique; PVA: patient ventilator asynchrony; BSA: breath stacking asynchrony; DTA: double trigger asynchrony; ERTC: extremely randomized trees classifier; GBC: gradient boosted classifier; MLP: multi-layer perceptron

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Algorithm | Class | Accuracy | Sensitivity | Specificity |
| **Ensemble** | **Non-PVA** | 0.9473 | 0.9315 | 0.9888 |
|  | **DTA** | 0.9467 | 0.9801 | 0.9439 |
|  | **BSA** | 0.9679 | 0.9098 | 0.9823 |
| **ERTC** | **Non-PVA** | 0.7603 | 0.7323 | 0.8336 |
|  | **DTA** | 0.8743 | 0.9973 | 0.8639 |
|  | **BSA** | 0.8062 | 0.5685 | 0.865 |
| **GBC** | **Non-PVA** | 0.9519 | 0.9382 | 0.9881 |
|  | **DTA** | 0.9534 | 0.9761 | 0.9515 |
|  | **BSA** | 0.9726 | 0.9274 | 0.9838 |
| **MLP** | **Non-PVA** | 0.9315 | 0.9162 | 0.9716 |
|  | **DTA** | 0.9391 | 0.9721 | 0.9363 |
|  | **BSA** | 0.9518 | 0.8693 | 0.9723 |

Table S2: **Descriptive statistics for the all classifiers run on the multiclass classification problem using RUS. ERTC: Extremely Randomized Trees classifier. GBC: Gradient Boosting classifier. MLP; Multi-layer Perceptron. RUS; Random Under-Sampling. DTA; Double-Trigger Asynchrony. BSA; Breath Stacking Asynchrony**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SMOTE Ratio | Class | Accuracy | Sensitivity | Specificity |
| **0.1** | **Non-PVA** | 0.9738 | 0.9763 | 0.9672 |
|  | **DTA** | 0.9798 | 0.9069 | 0.9859 |
|  | **BSA** | 0.9783 | 0.9512 | 0.985 |
| **0.2** | **Non-PVA** | 0.9731 | 0.9747 | 0.969 |
|  | **DTA** | 0.9794 | 0.9229 | 0.9842 |
|  | **BSA** | 0.9781 | 0.9476 | 0.9856 |
| **0.3** | **Non-PVA** | 0.9719 | 0.9724 | 0.9705 |
|  | **DTA** | 0.9774 | 0.9362 | 0.9808 |
|  | **BSA** | 0.9785 | 0.9435 | 0.9872 |
| **0.4** | **Non-PVA** | 0.9716 | 0.9707 | 0.9739 |
|  | **DTA** | 0.9753 | 0.9415 | 0.9781 |
|  | **BSA** | 0.9784 | 0.9414 | 0.9875 |
| **0.5** | **Non-PVA** | 0.9713 | 0.9699 | 0.975 |
|  | **DTA** | 0.9753 | 0.9415 | 0.9781 |
|  | **BSA** | 0.9787 | 0.9445 | 0.9872 |
| **0.6** | **Non-PVA** | 0.9708 | 0.969 | 0.9754 |
|  | **DTA** | 0.9747 | 0.9388 | 0.9777 |
|  | **BSA** | 0.9786 | 0.9455 | 0.9868 |
| **0.7** | **Non-PVA** | 0.97 | 0.9678 | 0.9757 |
|  | **DTA** | 0.9732 | 0.9521 | 0.975 |
|  | **BSA** | 0.9782 | 0.9383 | 0.9881 |
| **0.8** | **Non-PVA** | 0.9704 | 0.9676 | 0.9776 |
|  | **DTA** | 0.9736 | 0.9495 | 0.9756 |
|  | **BSA** | 0.9787 | 0.9429 | 0.9875 |
| **0.9** | **Non-PVA** | 0.9705 | 0.9676 | 0.978 |
|  | **DTA** | 0.9742 | 0.9521 | 0.976 |
|  | **BSA** | 0.9786 | 0.9435 | 0.9873 |
| **1.0** | **Non-PVA** | 0.971 | 0.9673 | 0.9806 |
|  | **DTA** | 0.9742 | 0.9601 | 0.9754 |
|  | **BSA** | 0.9793 | 0.9445 | 0.9879 |

Table S3: **Descriptive statistics for the all class ratios run on the multiclass classification using SMOTE and our ensemble classifier. DTA; Double-Trigger Asynchrony. BSA; Breath Stacking Asynchrony**