Making improved predictions of Non-invasive Continuous Arterial Blood Pressure through leveraging EHR medication data

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Introduction & Background

Hypotension (a sustained decrease in blood pressure) within critical care patients is associated with a higher risk of mortality and other severe complications. It is periodically monitored non-invasively for all ICU patients. Continuous blood pressure monitoring via arterial line catheters has been shown to lead to faster response times but is also associated with complications such as infection. With recent advances in machine learning, we take an innovative approach and train a model that is able to predict Arterial Blood Pressure continuously and non-invasively through the following three measures: Electrocardiogram, Photoplethysmography, and EHR Vasopressors medication.

OBJECTIVE: Current Blood Pressure → continuously Predict non-invasively → Future Blood Pressure
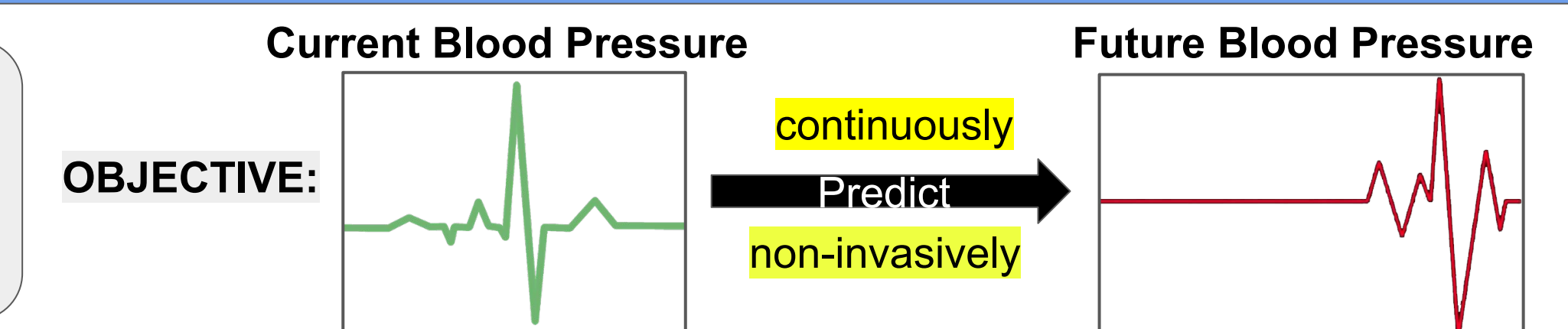
MIMIC-III Data

MIMIC-III is a large, freely-available database comprising deidentified health-related data associated with over 40,000 patients who stayed in critical care units.
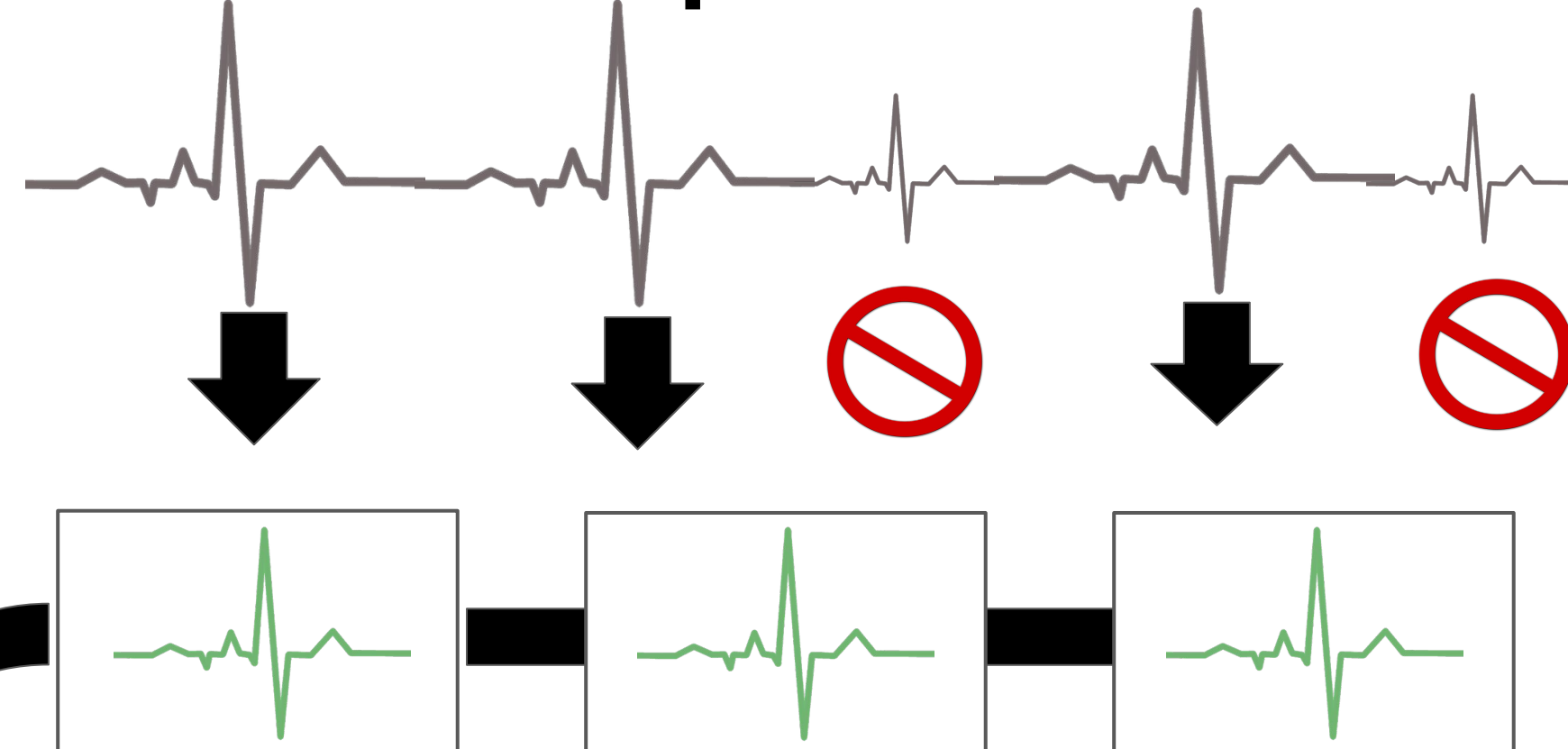
	Training	Testing
Patient Samples	18	2
Frames (400 msec)	218,649	24,295
BP mean (mmHg)	72.9	73.7
Data Size (Gb)	129.70	14.41

Methods

1. Load data *NEW*

EKG   PPG   vasopressors

2. Preprocess Data

3. Train Model

1D-Vnet Deep Learning Model

Results

Figure 1

(a) True ABP, 1D V-Net, 1D V-Net with Medication

(b) True ABP, 1D V-Net, 1D V-Net with Medication
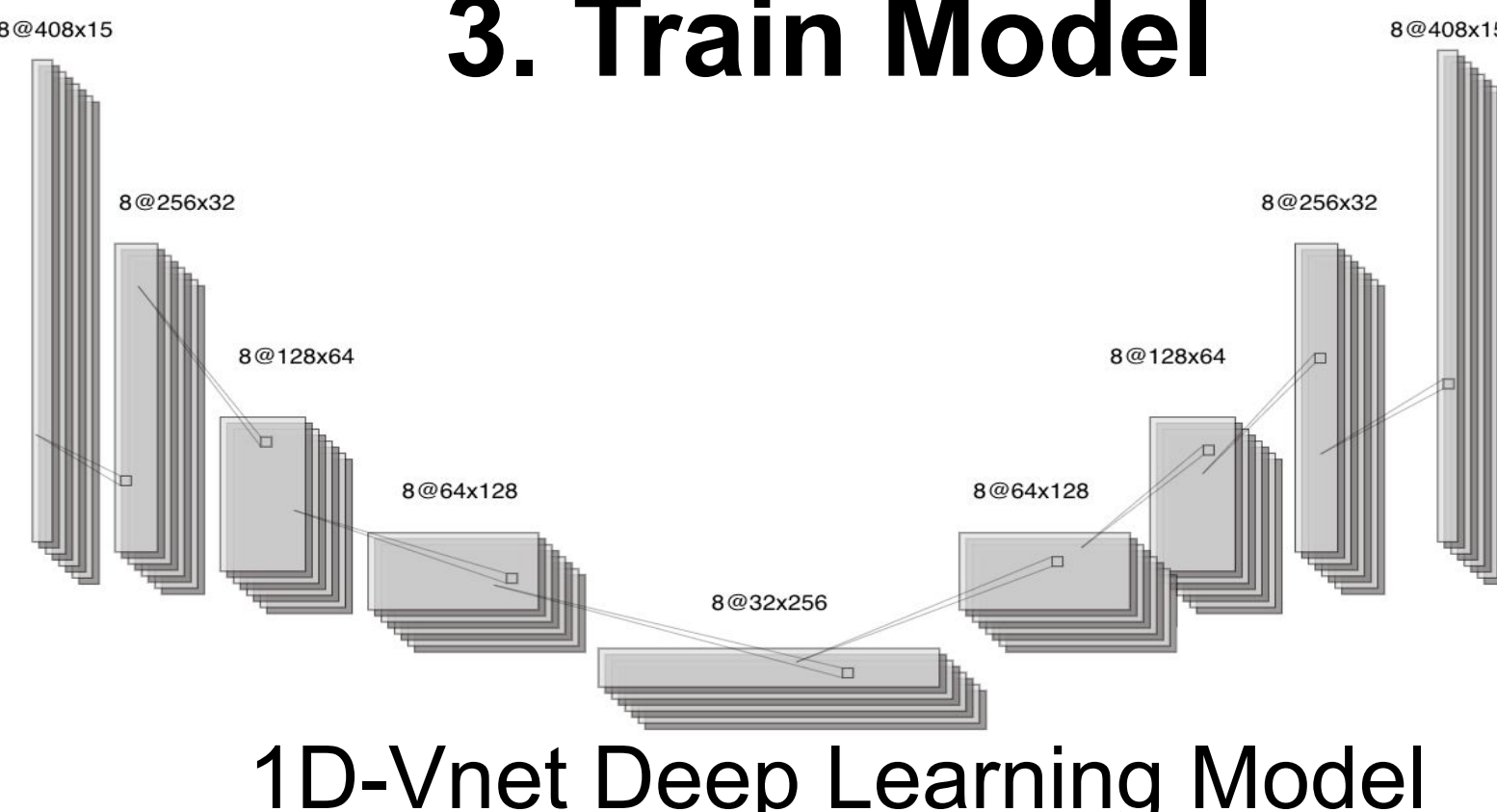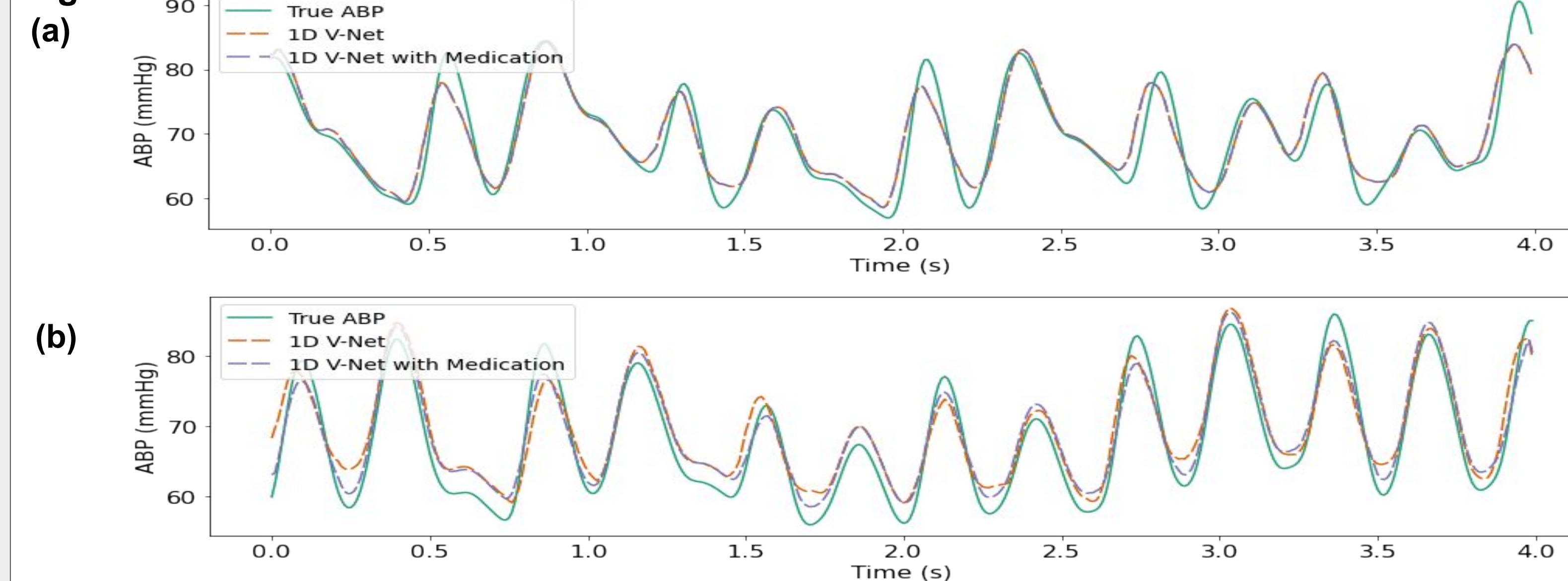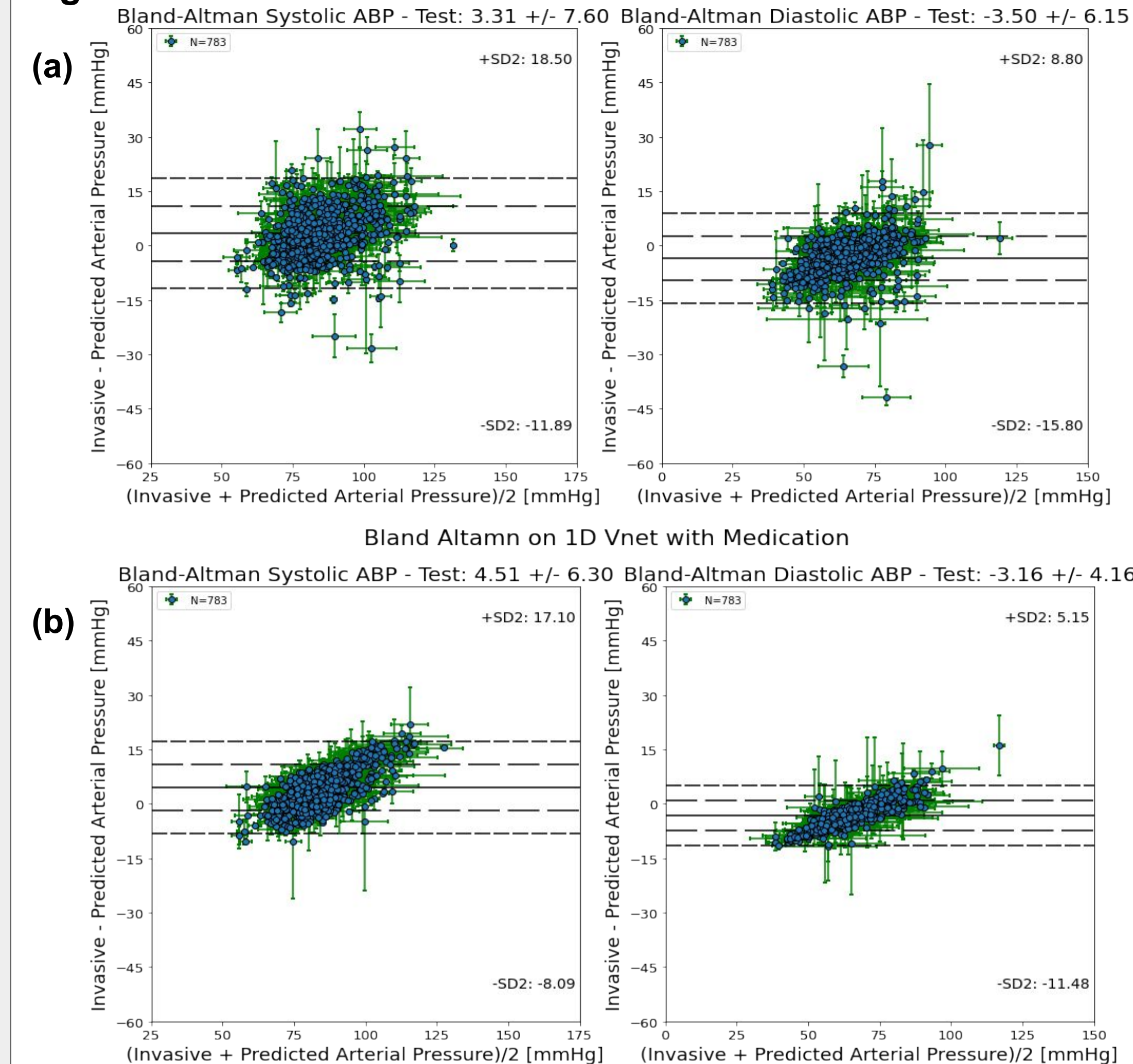
Fig. 1a Displays a predicted waveform with a patient with no vasopressor medication administered. By no surprise, we see that the predictions are identical. In **Fig. 1b**, we see differentiation between the first model versus our current model which takes into account clinical interventions. In this particular frame, the prediction is performing better than the original.

Figure 2

Bland Altann on 1D Vnet

(a) Bland-Altman Systolic ABP - Test: 3.31 +/- 7.60   Bland-Altman Diastolic ABP - Test: -3.50 +/- 6.15

Bland Altann on 1D Vnet with Medication

(b) Bland-Altman Systolic ABP - Test: 4.51 +/- 6.30   Bland-Altman Diastolic ABP - Test: -3.16 +/- 4.16

- Bland–Altman plots for the MIMIC ICU test cohorts. Systolic BP measurements per patient (left), and Diastolic BP measurements per patient (right) using a four second window.
- In **Fig. 2a**, we see the Bland-Altman of our original model which has a Systolic ABP mean of 3.31 +/- 7.60 standard deviations and a Diastolic ABP mean of -3.50 +/- 6.15 standard deviations.
- In **Fig. 2b**, we notice that the mean of the Systolic ABP is slightly larger at 4.31 but has a smaller standard deviation. We also notice that the Diastolic ABP outperforms the original model in both its average and standard deviation.
- Although our mean average is slightly larger in our newer model by 0.43, we see that our new model has data that is more mean centered with its smaller standard deviation. This evaluates that our newer model is performing better because the distribution of our data is widely clustered around our mean range and can signify that it has better precision than before.

Discussion & Conclusion

	ABP Imputer	ABP Imputer w/ med
$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Predicted_i - Actual_i)^2}{N}}$	6.106 (5.855-6.356)	5.665 (5.259-6.085)
$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{[\sum(x-\bar{x})^2(y-\bar{y})^2]}}$ Correlation	0.860	0.904

- The Diastolic Blood Pressure Measurement is drastically better at predicting Arterial blood when we included the vasopressor medication.
- As briefly mentioned in the results section, our distribution of data is centered more towards the mean which implies that our mean is highly representative and that there are less poorly predicted waveforms
- We have presented a novel method for imputing the arterial blood pressure waveform that is continuous, non-invasive, accurate, for patients in the ICU setting and beyond, without the need for any additional instrumentation.

Future Works

- Optimize and scale the approach up to massive datasets.
- Test on additional datasets collected from different patient populations
- Explore optimal approaches of representing clinical interventions

References & Code

1. Hill, B.L., Rakocz, N., Rudas, Á. *et al.* Imputation of the continuous arterial line blood pressure waveform from non-invasive measurements using deep learning. *Sci Rep* 11, 15755 (2021). https://doi.org/10.1038/s41598-021-94913-y

Special Thanks