

RELATIVE PERFORMANCE OF CoMET® MODELS

AMP3D’s platform of CoMET® models uses all available data streams of vital signs charted by nurses (VS), laboratory test results (Labs) and, uniquely, continuous physiological dynamics from cardiorespiratory monitoring (Continuous). This paper examines how CoMET models that (1) use VS and Labs and (2) add Continuous monitoring, contrast with other monitoring approaches that also use VS and Labs. One can compare CoMET VS and Labs models, for example, to EWS, APACHE, and Early Sense (which all use VA and Labs, but not Continuous) in an apples-to-apples way. HeRO likewise relies just upon Continuous heart rate characteristics, and for pediatric patients only. We cannot calculate precisely the Rothman Index (which uses nurses’ assessments), the Masimo Halo index (which uses proprietary spectroscopy signals), nor the Philips Orb score (which uses proprietary rules), although we can criticize their underlying approaches.

Unlike competitors and in an utterly unique way, CoMET employs an “aware” architecture that recognizes which data are available and the context of the patient (i.e., where in the hospital the patient resides at any time) and then deploys the correct and optimum models for prediction based upon these data. CoMET in this sense is not “one size fits most” but bespoke in its approach. If a particular data stream is not available (e.g. labs and EHR in outpatients, continuous monitoring in ward patients, EHR vitals in hospitals without integration) then CoMET is capable of using the data that are available to make the best prediction possible—but does not simply use proxies (like averages or other “guesses”) for what may be critical inputs. The CoMET platform and database approach likewise allows real-time model updating (bespoke models) and cross-site prediction based (K-nearest neighbor across all monitored sites). ***For each venue and critical illness, then, CoMET models outperform conventional early warning scores, and the performance of CoMET models improves as more data streams are incorporated.***

Only CoMET models add Continuous physiological dynamics data streams to VS and Labs.

Table 1 compares how these models and predictors rank across specific venues (1 hospital floor, and 2 ICUs) and target illness events. For floor/ward patients, the event is illness leading to ICU transfer. For the ICU patients, the events are respiratory failure leading to urgent unplanned intubation, hemorrhage leading to large unplanned transfusion, and sepsis. For all the result shown here, events were identified by individual chart reviews except for hemorrhage, which was determined from Blood Bank data query. The individual color-coded cells in **Table 1** show the average rank of the predictor variable or model (the rows) in early detection of the event and venue (the columns). For example, the CoMET combined model was the best detector of **sepsis** in the MICU and SICU, **hemorrhage** in the SICU and **ICU transfer** from the floor. Based on this methodology, we show the top 30 ranking approaches, along with EarlySense and APACHE. It is important to note that members of the CoMET family of models were *consistently* the best performing predictors overall, and that *the CoMET combined model, which adds Continuous data to VS and Labs, had the highest average overall rank.*

Table 1

Comparative Ranking of Models and Predictors across Venues and Target Events

Rank	Predictor variable	SICU Hemorrhage	MICU Hemorrhage	SICU Intubation	MICU Intubation	SICU Sepsis	MICU Sepsis	Ward
1	CoMET combined	1	4	2	5	1	1	1
2	CoMET VS + LABS	2	6	7	1	2	2	3
3	CoMET EKG monitor + LABS	3	3	1	4	5	3	5
4	CoMET EKG monitor	9	7	3	2	7	5	6
5	CoMET VS + EKG monitor	6	9	5	6	4	7	2
6	CoMET VS (Features from NEWS)	5	10	8	3	3	6	4
7	CoMET LABS	4	5	9	16	10	4	10
8	mean heart rate from VS	21	27	17	8	8	31	13
9	mean heart rate from EKG monitor	15	23	21	9	9	44	15
10	lactic acid	11	12	34	20	45	13	29
11	NEWS based on EKG monitor	12	48	35	35	14	12	11
12	NEWS	29	75	18	7	11	20	8
13	SIRS	54	37	13	15	26	15	9
14	mean RR interval	25	31	22	17	13	51	17
15	qSOFA	38	63	12	22	20	11	14
16	ViEWS	31	76	20	11	16	19	7
17	CoMET density score	16	32	23	26	18	32	38
18	NEWS component with value of 3	49	70	16	24	21	17	16
19	CoMET local dynamics score	30	58	19	28	19	37	35
20	bilirubin	47	19	43	18	47	30	28
21	standard deviation pulse ox from EKG monitor	66	17	11	19	53	34	91
22	Glasgow coma scale from VS	33	68	40	54	12	10	19
23	detrended fluctuation analysis	43	52	25	21	25	50	22
24	mean respiration rate from EKG monitor	61	50	4	12	36	58	18
25	mean respiration rate from VS	73	57	10	14	42	35	12
26	BUN	64	18	27	46	24	46	20
27	systolic blood pressure from EKG monitor	17	33	58	39	37	28	91
28	fraction inspired O2 from VS	20	47	26	55	15	53	32
29	Hgb	10	2	33	68	35	14	87
30	mean pulse ox from EKG monitor	50	44	30	34	31	25	91

38	EarlySense	70	62	6	10	43	71	31
54	APACHE II	7	8	76	13	76	76	90

Table 1: rank of each predictor (row) for predicting each critical illness (column). The following components—not readily or reliably available in a continuous way—were excluded from APACHE II: right atrial pressure, CPK-MB or acute MI, PVCs, urine output, serum amylase, anergy, positive cultures, and serum osmolarity. Cells colors identify more important predictors in green and less important predictors in red. Predictors are ordered by mean rank.

Weaknesses of other predictive scores and models.

While other models can perform comparatively well in particular instances, they all have critical weaknesses. For instance:

- EarlySense only reports when the patient is lying still in bed.

- EWS, qSOFA, SIRS, APACHE, and Rothman Index do not use continuous measures, so they update only a few times per day—compared with all CoMET models that include EKG monitoring, which update automatically every 15 minutes.

- EWS, qSOFA, and SIRS are not statistical models targeted to individual patient populations and events, but rather counts of abnormal vital signs.

- Rothman Index has several weaknesses, including:

- (1) It was trained to predict mortality within the next 12 months, a poor surrogate for imminent deterioration in acute care.

- (2) It uses nursing notes from the EHR and classes the assessment as “abnormal” or “normal” without adding further important and discriminatory detail.

Detailed Evaluations of Models and Predictors

In the Tables that follow, we report the performance of univariate predictors, existing multivariate scores and models, and the family of proprietary CoMET models for early identification of decompensating patients. Each Table gives results for numerous predictor and models assessed for each venue and diagnosis. The rows denote the predictors and models; the columns list their performance characteristics (ROC area, chi-squared) and data inputs (VS, Labs, Continuous). For context, ROC area measures the ability of the model to detect patients at times near events. A value of 1 means that the model is perfect, and a value of 0.5 means it is worthless. The chi2-dof (chi squared minus the number of degrees of freedom) column reports on the agreement of the model predictions with the observed data. A large value means relatively more agreement.

The tables show the top 20 predictors for (1) ICU transfer in ward patients, (2) respiratory decompensation leading to emergent intubation in the surgical and medical ICU, (3) hemorrhage leading to large transfusion in the surgical and medical ICU, and (4) severe sepsis defined by chart review and the Surviving Sepsis Campaign guidelines in surgical and medical ICU. Neither hematocrit nor hemoglobin was used as a predictor in CoMET models for hemorrhage. Predictors are ordered by goodness-of-fit. Inputs for each model are identified by asterisks in the column for the appropriate data stream (*i.e.*, EHR vital signs, laboratory measurements, and continuous data from EKG monitoring). Existing early warning scores (NEWS, ViEWS, qSOFA, SIRS, Early Sense, APACHE II*) were evaluated for each illness and unit.

For each venue and critical illness CoMET models outperform conventional early warning scores, and the performance of CoMET models improves as more data streams are incorporated.

ICU transfer in ward patients (8105 patients – 395 events)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	CoMET combined	0.742	415.9	*	*	*	*
2	CoMET VS + EKG monitor	0.712	372.3	*	*		*
3	CoMET VS + LABS	0.726	358.2	*	*	*	
4	CoMET VS (Features from NEWS)	0.692	335.7	*	*		
5	CoMET EKG monitor + LABS	0.713	263.2	*		*	*
6	CoMET EKG monitor	0.660	201.6	*			*
7	ViEWS	0.652	193.8		*		
8	NEWS	0.652	193.0		*		
9	SIRS	0.641	162.3		*	*	
10	CoMET LABS	0.649	153.7	*		*	
11	NEWS based on EKG monitor	0.636	144.6		*		
12	mean respiration rate from VS	0.583	116.3		*		
13	mean heart rate from VS	0.621	95.2		*		
14	qSOFA	0.593	94.6		*		
15	mean heart rate from EKG monitor	0.627	93.3				*
16	NEWS component with value of 3	0.569	69.5		*		
17	mean RR interval	0.631	61.3				*
18	mean respiration rate from EKG monitor	0.589	49.2				*
19	Glasgow coma scale from VS	0.532	48.2		*		
20	BUN	0.575	39.2			*	
21	pulse ox from VS	0.561	29.5		*		
22	detrended fluctuation analysis	0.561	29.1				*
23	WBC	0.565	26.2			*	
24	AST	0.530	23.2			*	
25	glucose	0.557	21.5			*	
31	EarlySense	0.508	11.6	*			*
90	APACHE II	0.566	-8.3	*	*	*	

Intubation in surgical ICU (2006 patients – 103 intubations in 87 admissions)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	CoMET EKG monitor + LABS	0.785	125.8	*		*	*
2	CoMET combined	0.786	125.5	*	*	*	*
3	CoMET EKG monitor	0.727	111.8	*			*
4	mean respiration rate from EKG monitor	0.702	100.7				*
5	CoMET VS + EKG monitor	0.737	97.3	*	*		*
6	EarlySense	0.606	73.1	*			*
7	CoMET VS + LABS	0.719	61.6	*	*	*	
8	CoMET VS (Features from NEWS)	0.667	49.1	*	*		
9	CoMET LABS	0.697	42.8	*		*	
10	mean respiration rate from VS	0.647	32.9		*		
11	standard deviation pulse ox from EKG monitor	0.530	18.4				*
12	qSOFA	0.624	15.6		*		
13	SIRS	0.640	15.5		*	*	
14	cross-correlation of respiration and pulse ox	0.541	13.5				*
15	glucose	0.599	13.2			*	
16	NEWS component with value of 3	0.608	11.7		*		
17	mean heart rate from VS	0.608	11.6		*		
18	NEWS	0.637	11.5		*		
19	CoMET local dynamics score	0.578	11.3	*			*
20	ViEWS	0.634	10.9		*		
21	mean heart rate from EKG monitor	0.601	9.8				*
22	mean RR interval	0.611	9.1				*
23	CoMET density score	0.591	8.6	*			*
24	pulse ox from VS	0.526	8.1		*		
25	detrended fluctuation analysis	0.587	6.8				*
76	APACHE II	0.593	-13.4	*	*	*	

Hemorrhage in surgical ICU (4943 patients – 472 events in 398 admissions)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	CoMET combined	0.760	515.5	*	*	*	*
2	CoMET VS + LABS	0.735	509.7	*	*	*	
3	CoMET EKG monitor + LABS	0.754	491.7	*		*	*
4	CoMET LABS	0.688	360.4	*		*	
5	CoMET VS (Features from NEWS)	0.676	260.1	*	*		
6	CoMET VS + EKG monitor	0.707	239.9	*	*		*
7	APACHE II	0.685	207.2	*	*	*	
8	hematocrit	0.707	190.6			*	
9	CoMET EKG monitor	0.687	173.1	*			*
10	Hgb	0.677	134.0			*	
11	lactic acid	0.621	97.6			*	
12	NEWS based on EKG monitor	0.566	58.8		*		
13	PO4	0.586	58.0			*	
14	systolic blood pressure from VS	0.579	56.4		*		
15	mean heart rate from EKG monitor	0.576	55.3				*
16	CoMET density score	0.581	52.3	*			*
17	systolic blood pressure from EKG monitor	0.578	51.7				*
18	PT/INR	0.604	51.4			*	
19	base excess	0.605	51.1			*	
20	fraction inspired O2 from VS	0.554	50.8		*		
21	mean heart rate from VS	0.579	50.3		*		
22	CO2 from basic metabolic panel	0.579	49.2			*	
23	prothrombin time	0.584	48.9			*	
24	total protein	0.609	47.9			*	
25	mean RR interval	0.580	45.3				*
29	NEWS	0.570	38.1		*		
31	ViEWS	0.569	36.8		*		
38	qSOFA	0.541	25.5		*		
54	SIRS	0.538	7.2		*	*	
70	EarlySense	0.506	0.2	*			*

Sepsis in surgical ICU (1806 patients – 124 events in 124 admissions)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	CoMET combined	0.730	244.2	*	*	*	*
2	CoMET VS + LABS	0.701	230.8	*	*	*	
3	CoMET VS (Features from NEWS)	0.691	159.2	*	*		
4	CoMET VS + EKG monitor	0.720	151.9	*	*		*
5	CoMET EKG monitor + LABS	0.685	100.8	*		*	*
6	temperature from VS	0.641	92.4		*		
7	CoMET EKG monitor	0.664	62.4	*			*
8	mean heart rate from VS	0.600	45.6		*		
9	mean heart rate from EKG monitor	0.638	44.9				*
10	CoMET LABS	0.591	29.9	*		*	
11	NEWS	0.579	29.9		*		
12	Glasgow coma scale from VS	0.583	23.6		*		
13	mean RR interval	0.628	22.4				*
14	NEWS based on EKG monitor	0.568	21.5		*		
15	fraction inspired O2 from VS	0.540	18.7		*		
16	ViEWS	0.564	18.4		*		
17	CI	0.576	15.4			*	
18	CoMET density score	0.576	14.9	*			*
19	CoMET local dynamics score	0.545	9.9	*			*
20	qSOFA	0.537	9.1		*		
21	NEWS component with value of 3	0.547	9.0		*		
22	cross-correlation of heart and respiration rate	0.538	8.8				*
23	Na	0.544	8.2			*	
24	BUN	0.523	8.1			*	
25	detrended fluctuation analysis	0.544	7.0				*
26	SIRS	0.550	6.8		*	*	
43	EarlySense	0.511	1.5	*			*
76	APACHE II	0.515	-23.0	*	*	*	

Intubation in medical ICU (1328 patients – 72 intubations in 69 admissions)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	CoMET VS + LABS	0.809	72.7	*	*	*	
2	CoMET EKG monitor	0.784	70.7	*			*
3	CoMET VS (Features from NEWS)	0.781	66.2	*	*		
4	CoMET EKG monitor + LABS	0.811	61.3	*		*	*
5	CoMET combined	0.817	56.6	*	*	*	*
6	CoMET VS + EKG monitor	0.793	53.7	*	*		*
7	NEWS	0.715	47.2		*		
8	mean heart rate from VS	0.727	46.4		*		
9	mean heart rate from EKG monitor	0.731	44.3				*
10	EarlySense	0.616	44.3	*			*
11	ViEWS	0.706	43.6		*		
12	mean respiration rate from EKG monitor	0.687	35.2				*
13	APACHE II	0.743	32.0	*	*	*	
14	mean respiration rate from VS	0.695	31.9		*		
15	SIRS	0.729	30.4		*	*	
16	CoMET LABS	0.701	29.8	*		*	
17	mean RR interval	0.724	28.6				*
18	bilirubin	0.617	25.2			*	
19	standard deviation pulse ox from EKG monitor	0.557	21.1				*
20	lactic acid	0.621	18.1			*	
21	detrended fluctuation analysis	0.651	17.8				*
22	qSOFA	0.620	15.5		*		
23	pulse ox from VS	0.554	15.1		*		
24	NEWS component with value of 3	0.612	13.9		*		
25	prothrombin time	0.639	13.4			*	

Hemorrhage in medical ICU (3688 patients – 155 events in 141 admissions)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	hematocrit	0.736	163.7			*	
2	Hgb	0.731	131.0			*	
3	CoMET EKG monitor + LABS	0.740	129.5	*		*	*
4	CoMET combined	0.745	121.2	*	*	*	*
5	CoMET LABS	0.666	115.1	*		*	
6	CoMET VS + LABS	0.703	110.2	*	*	*	
7	CoMET EKG monitor	0.677	66.8	*			*
8	APACHE II	0.664	45.8	*	*	*	
9	CoMET VS + EKG monitor	0.687	45.8	*	*		*
10	CoMET VS (Features from NEWS)	0.650	43.7	*	*		
11	PT/INR	0.565	36.8			*	
12	lactic acid	0.562	36.7			*	
13	creatinine	0.536	34.2			*	
14	PTT	0.535	32.9			*	
15	prothrombin time	0.563	32.8			*	
16	PO4	0.569	32.5			*	
17	standard deviation pulse ox from EKG monitor	0.528	26.7				*
18	BUN	0.558	23.3			*	
19	bilirubin	0.543	21.6			*	
20	diastolic blood pressure from VS	0.590	20.3		*		
21	diastolic blood pressure from EKG monitor	0.601	20.0				*
22	K	0.564	18.0			*	
23	mean heart rate from EKG monitor	0.581	15.8				*
24	CO2 from basic metabolic panel	0.569	15.2			*	
25	base excess	0.549	14.9			*	
37	SIRS	0.541	3.6		*	*	
62	EarlySense	0.500	0.1	*			*
63	qSOFA	0.512	0.0		*		
75	NEWS	0.530	-1.7		*		
76	ViEWS	0.524	-2.0		*		

Sepsis in medical ICU (1253 patients – 80 events in 80 admissions)

Rank	Predictor variables	ROC area	chi2 - DOF	Proprietary	VS	Labs	Continuous
1	CoMET combined	0.734	76.0	*	*	*	*
2	CoMET VS + LABS	0.715	67.0	*	*	*	
3	CoMET EKG monitor + LABS	0.720	66.5	*		*	*
4	CoMET LABS	0.699	56.5	*		*	
5	CoMET EKG monitor	0.617	29.3	*			*
6	CoMET VS (Features from NEWS)	0.640	27.0	*	*		
7	CoMET VS + EKG monitor	0.674	26.9	*	*		*
8	alkaline phosphatase	0.513	21.0			*	
9	platelets	0.539	20.9			*	
10	Glasgow coma scale from VS	0.599	18.9		*		
11	qSOFA	0.617	15.2		*		
12	NEWS based on EKG monitor	0.609	13.3		*		
13	lactic acid	0.526	12.9			*	
14	Hgb	0.584	12.1			*	
15	SIRS	0.619	11.1		*	*	
16	hematocrit	0.595	10.8			*	
17	NEWS component with value of 3	0.597	10.6		*		
18	PO2	0.514	10.1				
19	ViEWS	0.612	7.8		*		
20	NEWS	0.605	7.8		*		
21	CO2 from basic metabolic panel	0.533	7.0			*	
22	base excess	0.537	5.9			*	
23	bicarbonate	0.541	5.7			*	
24	total protein	0.533	5.2			*	
25	mean pulse ox from EKG monitor	0.565	3.4				*
71	EarlySense	0.500	-1.0	*			*
76	APACHE II	0.603	-12.8	*	*	*	