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SIMULATED PATIENT PHYSIOLOGIC PARAMETER ANALYSIS FOR PERFORMANCE FEEDBACK NEAR REAL-TIME DURING TRAINING AND SIMULATION

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Disclosures

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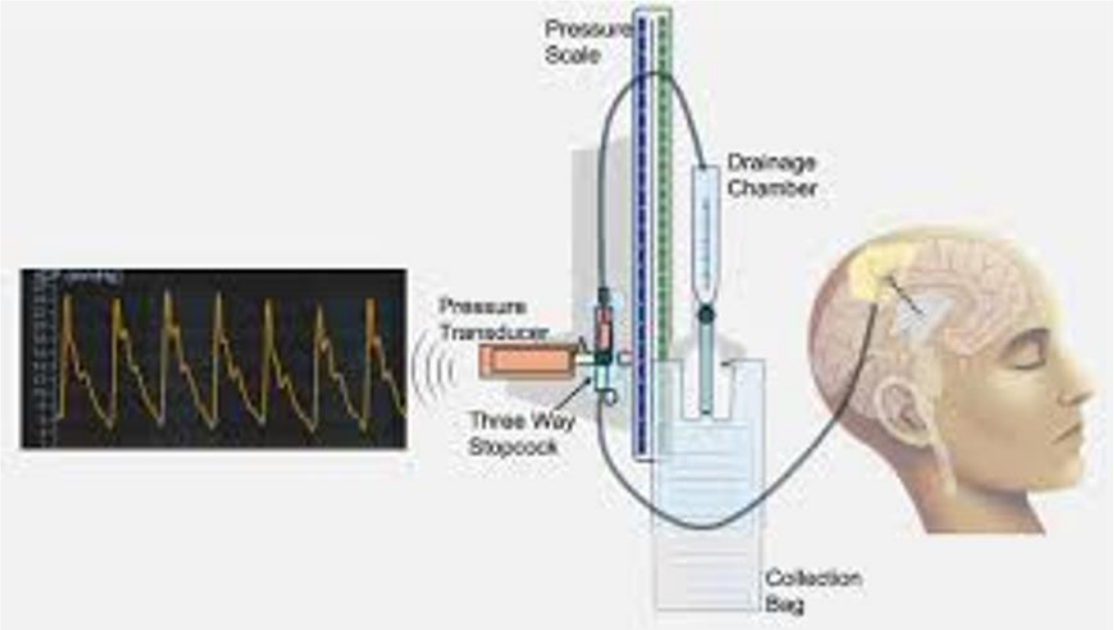
Overview

- Background
- Introduction
- Aims & Objectives
- Summary of Research Methods
  - App Data Flow
  - Data and Statistical Methods in Medical Reports
- Progress
- Results
- Lessons Learned
- Next Steps
- Summary

Background

- Hemodynamic abnormalities
  → morbidity/mortality
- In-flight significant events
- Force multiplier for instructors



Introduction

- Hypothesis: Providing near real-time physiologic data of simulated patients during training will provide valuable training feedback for teams.

- Assess team performance during training scenarios, transitions of care, and quality improvement of curriculum and CPGs


PATIENT MOVEMENT RECORD ENROUTE CRITICAL CARE

[redacted]

Aims & Objectives

Aim 1. Develop application that automates patient summary report to illustrate frequency & duration of vital sign values during simulated patient care episode

- Objective 1: Identify vital sign thresholds for CPG compliance for each CCAT validation simulation.
- Objective 2: Write a program to analyze, trend, and summarize the raw data from the Zoll monitor for each simulation.

Aim 2. Conduct a feasibility & end-user assessment of utilizing data summary in CCATT advanced courses

- Objective 3: Survey CCAT Advanced Cadre regarding the feasibility of using this report in formal feedback with students.

Aim 3. Analyze trends in vital sign threshold compliance across simulations during CCAT Advanced to find opportunities for training strategies to mitigate non-compliance

- Objective 4: Identify trends by scenario and CPG for non-compliance and target for training and JTS CPG review.

Summary of Research Methods

- Composed the study team
- Acquired Zoll SDK for Android integration
- Developed Android application
- Implemented data analysis algorithms
- Created automated medical report generation pipeline
- Conducted validation simulations across multiple clinical scenarios
- Performed iterative evaluations of data summaries
- Assessed accuracy and effectiveness of algorithms
- Refined algorithms to improve accuracy and utility

Application Architecture and Data Flow

Training Mannequins → VitalsBridge → Zoll Monitor → WiFi → Android App → Storage → Analysis → UI → Report

Hardware | Data Acquisition | Storage & Analysis | User Interface | Report Export

Training Mannequins

High-fidelity simulation mannequins generating continuous physiologic parameters

- Up to 5 mannequins per simulation
- Scenario-specific physiology
- HR, BP, SpO2, ICP, EtCO2, Temp, RR

VitalsBridge →

Zoll Propaq MD Monitor

Clinical patient monitor displaying real-time vital signs during simulation

- HR, SBP, MAP, ICP, SpO2
- Parameters vary by clinical scenario
- VitalsBridge hardware-software interface

WiFi (mDNS) →

Android App — Data Acquisition

Zoll SDK wireless connectivity with automatic device discovery and persistent connections

- Zoll SDK: mDNS auto-discovery
- 1-second polling intervals
- Multi-monitor simultaneous capture
- Foreground service + wake-lock
- Watchdog auto-reconnection (>30s loss)
- Data quality indicators per reading

ZollMonitorDataSource.kt

SQLite Database

Room persistence library with 90+ fields per record, millisecond timestamps

- Session metadata: course, team, sim, mannequin
- Auto-normalization at storage
- Data quality status per reading
- Deidentified; cloud disabled

Room Database + Repository

Data Streams →

Analysis Engine

CPG compliance calculation, %TTR metrics, and statistical benchmarking

- VS %TTR per vital sign
- Global %TTR (equal-weighted mean)
- Non-compliance event detection
- Hedges' g effect size
- Percentile ranking within cohort

ViewModel + Report Generator

UI State →

Real-Time Monitor
Live vital signs

CPG Compliance
Guideline adherence

Data Explorer
Historical analysis

Visualizations
Interactive charts

Export →

Performance Report

HTML-to-PDF pipeline via Android WebView with cohort benchmarking

- Global %TTR ranking
- Non-compliance timeline map
- Individual VS performance table
- Cohort statistics & Hedges' g
- PDF export to Downloads

HtmlEnhancedReportGenerator.kt

Data Management

- Data stored securely on Android device using local database
- Each session record captures info such as vital signs, data quality, session metadata
- Metadata: course, team, simulation, mannequin, clinical scenario
- Data is automatically standardized when saved
- Millisecond-precision timestamps on all readings
- Student names excluded to maintain deidentification
- Data exportable in CSV/Excel formats via Apache POI library

Data Reliability

- Data collection runs continuously in background including when device is locked
- Each data point is labeled to indicate its quality (valid, invalid, or error) based on monitor's reported signal status
- The system automatically detects extended signal loss (>30 sec)
- Auto-reconnects without creating artificial or estimated data
- Unmonitored periods excluded from statistical calculations and displayed as distinct segments on non-compliance timelines

Outcome Measures

Primary Metric: %TTR
VS %TTR = (Time in target / Vital monitoring duration) x 100
Per-vital duration approach accounts for parameters monitored at different times
Global %TTR = arithmetic mean of all VS %TTR values per patient
Equal weighting: all CPG thresholds equally important
Vital sign thresholds from **JTS and AHA** Clinical Practice Guidelines
9 clinical scenarios with scenario-specific thresholds
Invasive BP takes precedence over non-invasive when both available
CPP = MAP - ICP (derived for TBI scenarios)

Outcome Measures

Secondary Metrics & Benchmarking
Non-compliance events detected chronologically
Categorized: Warning (2-5 min) and Critical (>5 min)
Historical cohort benchmarking across all prior simulations
Rolling statistics for all %TTR values
Hedges' g effect size with small-sample correction
g = ((Team TTR - Cohort Mean) / SD) x J
Percentile rank: non-parametric ranking within cohort
No normality assumption required for small samples (N = 10-12)

Data & Statistical Methods in Medical Report

Report Generation Pipeline

- **HTML-to-PDF** pipeline rendered through Android WebView

- Python offline analysis script for cohort-level statistics

- Data source: filtered CSV export (232,759 records, 62.1 hours)

%TTR Calculation Method

- **VS %TTR** = (Time in target / Vital monitoring duration) x 100

- **Global %TTR** = arithmetic mean of all VS %TTR (equal weighting)

- Non-compliance events detected chronologically; Warning (2-5 min) or Critical (>5 min)

Medical Report

Cohort Benchmarking

- Historical cohort: all teams across courses for same sim/mannequin

- **Hedges' g** effect size: g = ((Team TTR - Cohort Mean) / SD) x J

- **Percentile rank**: non-parametric ranking (no normality assumption)

- Cohort descriptive stats: N, Mean +/- SD, Median, IQR

Report Output Contents

- Patient name, scenario, CPG thresholds analyzed

- Global %TTR value and ranking (e.g., "3rd out of 12 teams")

- **Non-compliance timeline** map: in-range, warning, critical, unmonitored

- Individual VS table: VS %TTR, percentile, Hedges' g, cohort stats

Statistical Analysis

Group Comparisons

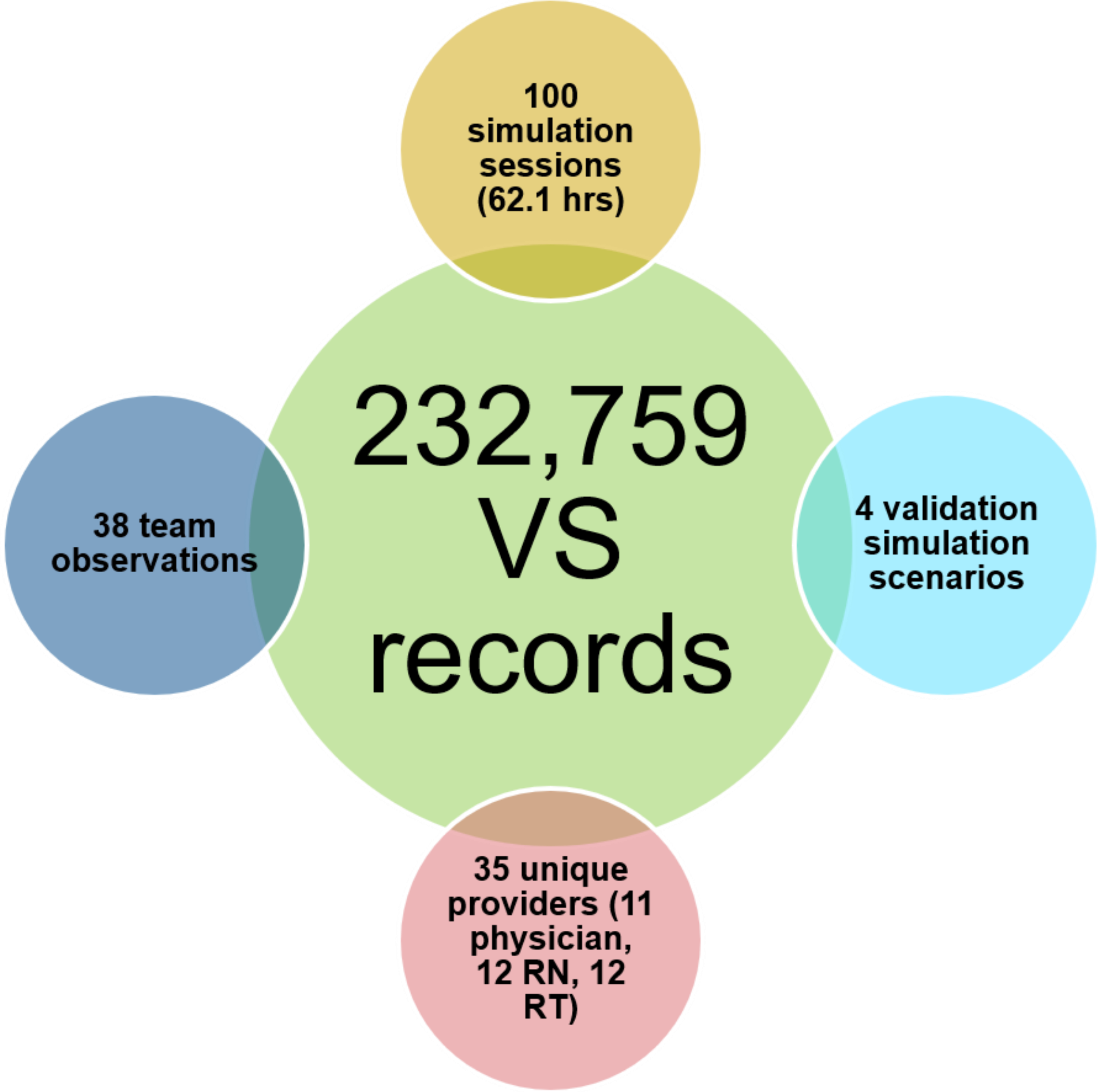
- **Kruskal-Wallis** test for Global %TTR differences across simulations
- Pairwise **Mann-Whitney U** tests for post-hoc comparisons
- Non-parametric tests (small sample sizes: n = 7-11)
- No assumptions about data distribution required

Provider Score Correlations

- **Spearman rank** correlations: Global %TTR vs provider scores
- Technical Skills (TS) and Non-Technical Skills (NTS) per role
- Roles: physician (MD), nurse (RN), respiratory therapist (RT)
- Computed **within each simulation** separately
- Avoids conflating observations across differing scenarios
- Spearman chosen over Pearson: small samples, ordinal NTS ratings
- Exploratory analysis; no correction for multiple comparisons
- Significance at alpha = 0.05

Results: Data Collection

- Default 1-second sampling rate for all sessions
- Val Sim 2 excluded (no continuous monitoring by design)



Results (cont.)

Global %TTR by Simulation

Simulation	n	Mean	SD	Min	Max	Median	IQR
Val Sim 1	10	87.5	4.0	82.8	93.4	87.2	83.7–90.7
Val Sim 3	10	85.0	6.1	72.1	91.4	86.3	83.1–89.1
Val Sim 4	11	92.0	2.5	87.8	95.7	91.9	90.0–93.8
Val Sim 5	7	79.2	6.6	70.0	90.7	78.2	75.8–82.1
Overall	38	86.6	6.4	70.0	95.7	88.3	82.9–91.4

Abbreviations: SD, standard deviation; IQR, interquartile range. Kruskal-Wallis H = 17.49, p = 0.001.

Results (cont.)

Provider Performance Scores by Simulation

Simulation	MD TS	MD NTS	RN TS	RN NTS	RT TS	RT NTS
Val Sim 1	0.88 (0.06)	3.21 (0.61)	0.89 (0.09)	3.20 (0.82)	0.87 (0.10)	3.34 (0.45)
Val Sim 3	0.88 (0.09)	3.30 (0.45)	0.88 (0.09)	3.59 (0.53)	0.90 (0.13)	3.37 (0.80)
Val Sim 4	0.95 (0.04)	3.47 (0.56)	0.97 (0.04)	4.03 (0.61)	0.95 (0.03)	3.77 (0.55)
Val Sim 5	0.85 (0.12)	3.06 (0.85)	0.89 (0.10)	3.46 (0.98)	0.87 (0.11)	3.26 (0.55)

Note: Values are mean (SD). TS = Technical Skills (0–1 scale); NTS = Non-Technical Skills (1–5 scale).

Results (cont.)

Spearman Correlations: Provider Scores and Global %TTR by Simulation

Predictor	Val Sim 1 (n=10)	Val Sim 3 (n=10)	Val Sim 4 (n=11)	Val Sim 5 (n=7)
MD TS	0.38 (.285)	0.62 (.058)	−0.21 (.535)	0.79 (.036)*
MD NTS	0.72 (.018)*	0.70 (.024)*	−0.16 (.649)	0.63 (.129)
RN TS	0.81 (.004)*	0.46 (.182)	−0.02 (.956)	0.69 (.086)
RN NTS	0.65 (.040)*	0.70 (.024)*	0.06 (.852)	0.75 (.052)
RT TS	−0.10 (.794)	0.25 (.493)	−0.14 (.687)	0.50 (.248)
RT NTS	−0.37 (.287)	0.29 (.424)	0.60 (.049)*	0.27 (.554)

*Note: Values are ρ (p-value). TS = Technical Skills; NTS = Non-Technical Skills. *p < 0.05.*

Results (cont.)

Usability Assessment (SUS)

Initial SUS score: **57.3** (below 68 benchmark = marginal)

n = 15 grading cadre completed survey

Strengths:

- 73.3% intend to use frequently; 73.3% well-integrated
- 66.7% agreed most people would learn quickly
- 60.0% found the application easy to use
- 60.0% disagreed they needed to learn a lot
- 53.3% disagreed they would need technical support

Concerns:

- 33.3% found it awkward to use
- 33.3% perceived unnecessary complexity
- Only 46.7% reported confidence in use
  - *Report interface* ***refined*** *based on this feedback*

System Usability Survey

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I think that I would like to use this application frequently.	○	○	○	○	○
I found the application unnecessarily complex.	○	○	○	○	○
I thought the application was easy to use.	○	○	○	○	○
I think that I would need the support of a technical person to be able to use this application.	○	○	○	○	○
I found the various functions in this application were well-integrated.	○	○	○	○	○
I thought there was too much inconsistency in this application.	○	○	○	○	○
I would imagine that most people would learn to use this application very quickly.	○	○	○	○	○
I found the application very awkward to use.	○	○	○	○	○
I felt very confident using the application.	○	○	○	○	○
I needed to learn a lot of things before I could get going with this application.	○	○	○	○	○

Successes

- Created VS thresholds list to maintain for conditions that appear in simulations (JTS CPGs, EBM SOC)
- Creation and integration of feedback application (C-STARS APP) into the training at CCAT Advanced course
- End user (cadre) and student feedback on the tool and its effectiveness

In Progress

- Identify training gaps update curriculum
- Identify potential guideline aberrancies and provide input to JTS for CPG update considerations and adjust training curriculum

Performance Report: Pre-SUS & Post-SUS Refinement

Pre-SUS (Initial Version)

Simulation Performance Report

Mannequin: Chuck • Scenario: Aortic Dissection • Type: Graded • Team: Alpha

32m 56s Dec 11, 2025

79% Overall Compliance (Readings in Target Range)

AORTIC DISSECTION - VITAL SIGNS THRESHOLD REFERENCE

PRIMARY VITALS (MOST CRITICAL)	SECONDARY VITALS	HEMODYNAMIC VITALS
IBP_SYS: ≤120mmHg	HR: 60-80bpm	SpO2: 90-100%

CLINICAL PERFORMANCE SUMMARY

Session Grade: **C+** *Solid session with excellent SpO2 control. Primary area for growth: reducing Heart Rate variability within target ranges*

Stability Control 70%	Critical Event Prevention 79%	Deviation Burden 91%
How steady are values when in range? Lower variability = higher score.	% of session without violations lasting >2 minutes.	Total time × severity outside thresholds. Less exposure = higher score.

Note: Above scores analyze clinical decision patterns, separate from time-in-range compliance.

NON-COMPLIANCE TIMELINE

Direction: Above threshold Below threshold **Intensity:** Light (slight deviation) → Dark (severe deviation)

Height: Taller bars = longer duration **White space:** Compliant (within threshold)

Red = above threshold, Blue = below threshold. Color intensity shows deviation severity. Taller bars = longer duration.

INDIVIDUAL VITAL SIGNS PERFORMANCE

Vital Sign	Compliance	Time Out of Range	Statistics	Violation Breakdown
Heart Rate	45%	18m 9s	Min: 40 | Max: 74 Mean: 57 | Med: 59 SD: ±7.97	Brief: 0 Warning: 0 Critical: 2
IBP_SYS	91%	3m 2s	Min: 26.0 | Max: 133.0 Mean: 106.8 | Med: 104.0 SD: ±8.15	Brief: 0 Warning: 1 Critical: 0
SpO2	100%	0s	Min: 92.0 | Max: 94.0 Mean: 93.2 | Med: 93.0 SD: ±0.40	✓ No violations

Violation Duration: Brief (<1 min) Warning (1-5 min) Critical (>5 min)

Post-SUS (Refined Version)

Performance Report

Course **2026D** Simulation **Sim4** Team **Alpha** Patient **Chuck** Scenario **Aortic Dissection**

VITAL SIGNS (VS) THRESHOLDS

Systolic Blood Pressure (SBP)	<120 mmHg
Heart Rate (HR)	60–80 bpm
Peripheral Capillary Oxygen Saturation (SpO2)	90–100 %

Measures: Vital Signs % Time in Target Range (VS %TTR), Average of all VS %TTR (Global %TTR)

RANKING OF GLOBAL %TTR

Team **Alpha** maintained **Chuck's** vitals in CPG range **78.0%** of the time. They ranked **11th** out of **11** teams, placing them in the **9th** percentile.

Patient **Chuck's** Global %TTR shows **a large** practical difference from the historical cohort mean, falling **below** the cohort (Hedges' g = -1.89). Cohort: Mean 88.6% ± 5.2%, Median 88.4% (IQR 85.0–93.0%).

NON-COMPLIANCE TIMELINE

INDIVIDUAL VITAL SIGNS PERFORMANCE

Vital Sign	VS %TTR	Percentile	Hedges Effect Size	Cohort VS %TTR	% Time in 2-5 min event(s)	% Time in >5 min event(s)
SBP	90.5%	36th	-0.47	Mean 94.3% ± None%, Median 98.5% (IQR 89.8–100.0%)	9.5%	0.0%
HR	43.5%	9th	-2.01	Mean 71.6% ± None%, Median 76.1% (IQR 65.1–80.8%)	0.0%	56.5%
SpO2	100.0%	100th	–	Mean 100.0% ± None%, Median 100.0% (IQR 100.0–100.0%)	0.0%	0.0%

Lessons Learned

Hardware	General Issues	Positive Outcomes
• ETCO2 • ICP	• Simulation time • CPG threshold differences • CPG gaps	• No network issues • Seamless integration • Quick tech issue resolution

Next Steps

We will continue to utilize the program algorithm in the background of future courses to collect data and further analyze.

We hope to integrate refined reporting tool in the future and can repeat SUS survey amongst cadre.

We will define and summarize trends and potential training gaps thus creating opportunities for us to inform the curriculum and the Joint Trauma System CPGs

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Questions?

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