EXG 12L Electrode System In-Field Clinical Study

Saint Louis Community Fire Protection District, St. Louis, MO

Study Period: February 14, 2025 – June 30, 2025

Comparison Period: March 1, 2024 – June 30th, 2024

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ABSTRACT

Background:
Electrocardiogram (ECG) accuracy is critical for timely cardiac care, with standards set by the American Heart Association, American College of Cardiology, and Heart Rhythm Society. Prehospital ECG acquisition is often performed in adverse environments and frequently lacks key quality steps such as full chest exposure, skin preparation, supine positioning, and precise lead placement. Electrodes are frequently applied over clothing or undergarments, without hair removal or epidermal abrasion, leading to misplacement and signal degradation. The EXG radiolucent electrode system (C-Booth Innovations, Carlsbad, CA) was developed to address these gaps by standardizing ECG application and improving diagnostic workflow and improve accurate and timely healthcare.

Methods:
We conducted a before-and-after quality improvement study within the St. Louis Community Fire District, comparing patients with chest pain or rhythm disturbances managed with the EXG system (February 2025 onward) to a historical cohort using conventional Ambu® BlueSensor electrodes. All ECGs were acquired using Stryker LIFEPAK 15 monitors. Paramedics using EXG were trained to fully expose the chest, remove undergarments when applicable, shave and abrade electrode sites, and apply electrodes using indexed anatomical markers. Time intervals and ECGs were analyzed using electronic records and a convenience sample was reviewed for signal quality.

Results:
Among 299 patients, EXG use was associated with a shorter median time from first medical contact (FMC) to ECG (6 minutes vs. 7 minutes; p=0.22) and a slightly longer median scene time (13 minutes vs. 12 minutes; p=0.011); however, EXG was not independently associated with prolonged scene times in adjusted analysis (OR 0.62; 95% CI 0.30–1.31; p=0.21). EXG cases showed fewer uninterpretable ECGs (3.2% vs. 7.2%) and numerically more clean tracings (OR 1.88; p=0.066). Use of the 150 Hz filter, more frequent in EXG cases (28% vs. 20%) was significantly associated with tremor artifact (OR 32.4; p<0.001) and decreased likelihood of clean tracings (OR 0.10; p<0.001).

Conclusions:
Compared to conventional electrode application often performed over clothing and without skin prep, the EXG system enabled more accurate, consistent, and guideline-concordant ECG acquisition, without delaying scene time. These findings support its integration as a high-fidelity, standardized approach to prehospital cardiac assessment.

INTRODUCTION

Accurate prehospital electrocardiograms (ECGs) are critical for early identification and treatment of acute cardiac events.[1] However, traditional ECG application in clinical field settings is often inconsistent due to factors such as limited patient chest exposure, inadequate or no skin preparation, and variable lead placement, including frequent lead misplacement and lead reversal errors. In addition, patients are often in a seated, nearly upright torso position further deviating from ECG standards.[2–4] These issues can lead to misclassified ECGs, noise artifacts, and incorrect clinical decision-making. False negative tracings lead to missed or delayed diagnosis of STEMI, while false-positive emergent activation of cardiac catheterization teams diverts resources.[5–10] To address these challenges we developed the EXG system (CB Innovations, Carlsbad, California): a radiolucent, wearable, anatomically indexed 12-lead ECG electrode array designed for rapid deployment, standardized placement, and compatibility across prehospital and in-hospital monitors through a single cable and universal adapter.

With approval from the Community Fire District's Chief Medical Officer, this quality improvement study was undertaken to evaluate the operational and diagnostic performance of the EXG system in a real-world EMS setting. The primary objective was to compare EXG against traditional electrodes (Ambu® BlueSensor) in terms of ECG acquisition timing, scene time, and signal quality during EMS encounters for patients with identified chest pain or cardiac rhythm disturbances. A secondary aim was to assess whether EXG implementation influenced workflow efficiency or diagnostic reliability. Feedback related to ECG wastage was only collected anecdotally from medics post-study.

METHODS

Study Design: We conducted a retrospective, observational before-and-after study in the St. Louis Community Fire Protection District (CFD), examining two time periods: a control period using traditional ECG electrodes and cables (March 1, 2024 – June 30, 2024) and an use period using the EXG system (February 14, 2025 – June 30, 2025).

Population and Inclusion Criteria: Eligible encounters included all consecutive patients with chest pain or rhythm disturbance documented in the electronic patient care record (ePCR). Process times were included even if ECG tracings were unavailable. Signal quality was assessed only for cases with attached ECG tracings.

Device Description: The 12-lead EXG is a single-use, radiolucent, wearable electrode system that standardizes anatomical lead placement using indexed reference markers

(Figure 1). It is designed for continuous diagnostic use, enabling seamless connection to all standard prehospital monitors and in-hospital cardiographs through a universal adapter. The nature of the EXG mitigates against lead reversal errors due to common human factors by the nature of its visual-spatial geometric placement.

During the EXG evaluation period, paramedics were trained to:

- Fully expose the chest (including clothing/bra removal if applicable)
- Prepare skin at each electrode site using a disposable razor
- Position patients in a supine posture
- Apply electrodes according to indexed anatomical markers near the ideal nipple line for V1/V2 for accurate positioning in the parasternal 4th intercostal space, using the mid-clavicular line (MCL) marker to place V4 in the 5th intercostal space, the mid-axillary line (MAL) marker for V6 horizontal to V4, and limb leads onto the proximal limbs

Data Collection: Demographic data, time intervals (first medical contact to ECG, scene time), and ECG quality indicators were abstracted from ePCRs. A convenience sample of ECGs was used for signal quality analysis.

Time Intervals

Electronic records were manually reviewed for key time stamps, including *arrival on scene*, *arrival at the patient*, and *departure from scene*. Although additional timestamps such as *time of call*, *dispatch time*, and other pre- and post-patient intervals are available, this study focuses on two core intervals:

- **First Medical Contact (FMC) to ECG**: Defined as the time between *arrival at the patient* and the *ECG acquisition time*, which is recorded on the printed ECG and occasionally documented as a procedure time in the electronic record
- **Scene Time**: Defined as the time between *arrival on scene* and *departure from scene*, excluding transport times both to the scene and to the destination hospital

The American Heart Association (AHA) has established key benchmarks for timely care in chest pain patients: FMC-to-ECG within ≤10 minutes and total scene time within ≤15 minutes. This analysis compares raw interval data using medians, and adjusted analyses are used to assess compliance with these benchmarks.

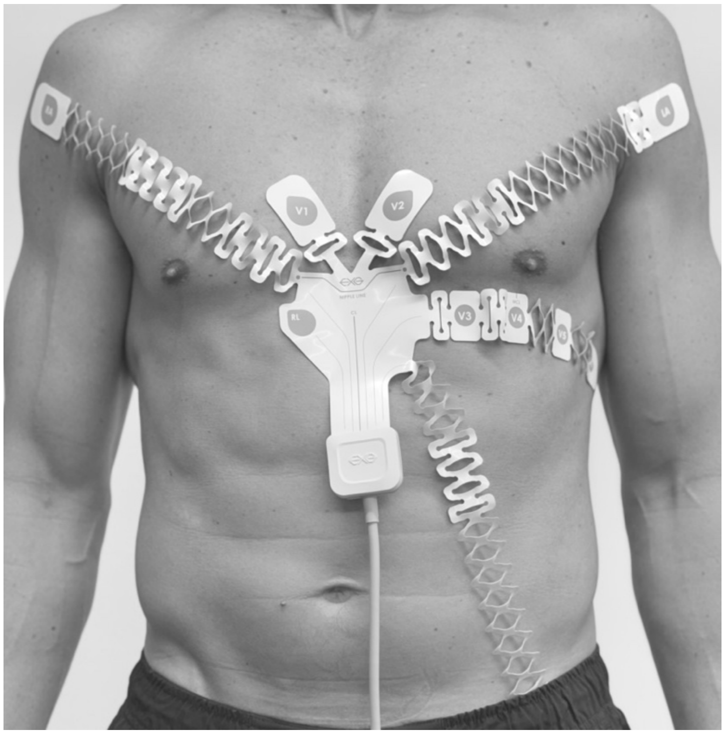
ECG Interpretation and Review Process

All prehospital ECGs were reviewed and scored by board-certified emergency physicians actively practicing in high-acuity emergency departments. These physicians routinely interpret ECGs in real time and make time-sensitive treatment decisions, including activation of cardiac catheterization labs. The assessment of ECG interpretability was based on a clinical threshold, defined as the ability to reasonably evaluate rhythm, ST-segment changes, and conduction abnormalities to identify potentially life-threatening conditions such as acute ischemia, infarction, or significant dysrhythmia.

ECGs were not assessed by cardiologists, as this would not reflect the standard clinical environment in which EMS-initiated ECGs are typically acted upon. Instead, interpretation focused on operational relevance: whether an emergency physician could have used the ECG to make timely, actionable clinical decisions in real time. Interpretability scoring was conducted in consensus, and ambiguous cases were adjudicated through group discussion.

Statistical Analysis: Descriptive statistics were computed for demographic and time variables. Differences between EXG and traditional cohorts were assessed using t-tests for continuous variables, chi-square tests for proportions, and Mann-Whitney U tests for non-normally distributed variables. Logistic regression modeling was employed to evaluate independent predictors of benchmark scene time (≤15 minutes) and benchmark ECG timing (FMC-to-ECG ≤10 minutes). Analyses were performed using STATA (College Station, TX) statistical software.

Figure 1. *12-lead EXG Applied with a Model Patient Supine, Skin Abraded Beneath Each Electrode and Correctly Positioned Electrodes. The geometry provides visual-spatial guidance that mitigates against lead reversal.*



RESULTS

Demographics

There were no significant differences between the EXG and traditional groups in age, gender, or weight (Table 1).

Age (years) - Traditional: 56.6 (SD 17.0), EXG: 54.5 (SD 17.2), p=0.28

Female (%) - Traditional: 46%, EXG: 56%, p=0.09

Weight (kg) - Traditional: 90.3 (SD 28.6), EXG: 87.3 (SD 24.5), p=0.34

TABLE 1: Demographics for patients with chief complaint of chest pain and/or cardiac rhythm disturbance (n = 299)

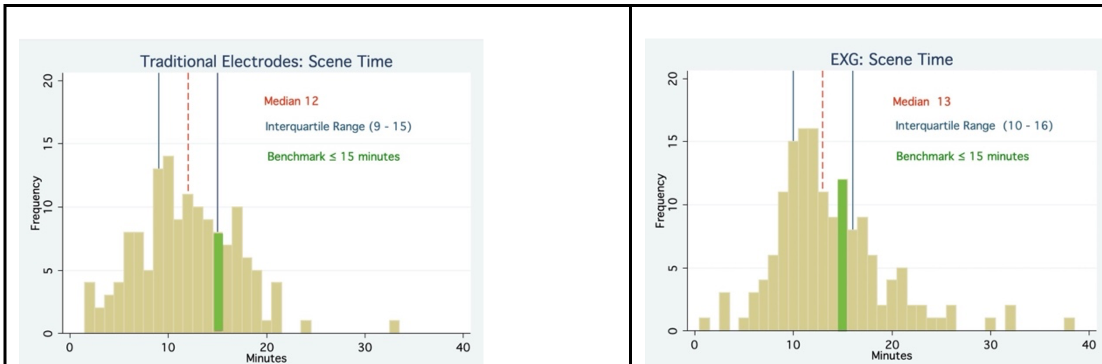
Variable	Baseline (traditional electrodes) n = 145	EXG n = 154	Statistical test	
Age, years (mean, SD)	56.6 (17.0)	54.5 (17.2)	t-test	p=0.28
Female (n, %)	67, (46%)	87 (56%)	χ^2	p=0.09
Weight, kg (mean, SD)	90.3 (28.59)	87.3 (24.50)	t-test	p=0.34
Scene Time, min (median, IQR)	12 (9 – 15)	13 (10 –16)	Mann-Whitney	**p=0.01**
FMC to ECG, min (median, IQR)	7 (5 – 9) (n=91)	6 (4 – 8) (n=103)	Mann- Whitney	p=0.22
Weekend -Sa/Su (n, %)	47 (32%)	39 (25%)	χ^2	p=0.17
Night Shift (7p-7a) (n, %)	66 (46%)	64 (41%)	χ^2	p=0.46
c/o Chest pain (n, %)	127 (88%)	143 (92%)	χ^2	p=0.18

Operational Performance

SCENE TIMES

Raw median scene time was 1 minute longer in the EXG group (13 minutes [IQR 10–16] vs. 12 minutes [9–15], p=0.01). Figure 2 illustrates the distribution of these scene time differences along with annotating the benchmarked goal of departure from scene within 15 minutes. This observation warranted a further investigation of the descriptive statistics related to this metric (Table 2).

FIGURE 2: Histograms of Scene Time (minutes) by Electrode type



In a subgroup analysis, significant differences in scene intervals were observed among patients who achieved the benchmark First Medical Contact (FMC)–to–ECG time of ≤10 minutes and those attended during nighttime hours (7:00 p.m.–7:00 a.m.) (Table 2). Scene intervals in these groups were approximately two minutes longer, prompting further review of case narratives.

Among patients with prolonged scene times (≥15 minutes), those treated with EXG electrodes had a median FMC-to-ECG time of 8 minutes (IQR 6–14; n=29), compared with 10 minutes (IQR 7–13; n=21) for those treated with traditional electrodes (p=0.48). Narrative review of cases with more pronounced delays (≥20 minutes) indicated that extended scene times were primarily attributable to external factors, including patients leaving against medical advice (AMA), individuals in legal custody requiring interagency coordination, difficulty accessing the patient, or the need to prioritize other clinical tasks before transport. These delays were not related to the performance of the ECG itself.

When evaluating the benchmark of scene time ≤15 minutes using univariate logistic regression, significant associations were observed with FMC-to-ECG ≤10 minutes and weekend presentation (Table 4). In multivariable logistic regression (Table 5 and Figure 3-Forest Plot), use of EXG electrodes was not significantly associated with prolonged scene time (OR 0.62; 95% CI, 0.30–1.31; p=0.21). The strongest independent predictor of shorter scene time was achieving FMC-to-ECG ≤10 minutes (OR 7.32; 95% CI, 3.09–17.32; p<0.001).

TABLE 2: Subgroup Evaluation of Median Scene Times (min)

Variable	Baseline (traditional electrodes) n = 145	EXG n = 154	Statistical test	
	Scene Time, min [median (IQR)]	Scene Time, min [median (IQR)]	Mann-Whitney	
Male	11 (8 – 15) (n=77)	12 (10 –17) (n=67)		p=0.09
Female	12 (9 –15) (n=66)	13 (11 – 16) (n=87)		p=0.08
Weight >90kg	12 (9 – 16) (n=63)	12 (10 – 16) (n=63)		p=0.29
Age >70	13 (11 – 17) (n=36)	14 (12 – 18) (n=29)		p=0.25
FMC to ECG <10 min	10 (8 – 14) (n=75)	12 (10 – 15) (n=87)		**p=0.01**
Weekend (Sa/Su)	10.5 (7 – 13) (n=46)	12 (10 –14) (n=39)		p=0.10
Nights (7p-7a)	10 (7 – 16) (n=64)	12 (10 –17) (n=63)		**p=0.04**

In subgroup analysis, patients who received an ECG within benchmark time (≤10 minutes) or at night (7p-7a) had longer scene intervals when evaluated with the EXG system.

Table 3: Scene Time ≥ 20 Minutes – narrative review

Electrode Type	Age	Gender	Scene Time (min)	ECG Time (min)	Barriers / Notes
EXG	68	M	20	16	Difficulty accessing chest port
	65	M	20	8	9 min to patient placing on PPE
	64	F	20	8	Unsuccessful IV; 4 min to patient
	56	F	20	9	AMA
	38	F	20	Refused	Refused ECG and transport (AMA)
	71	F	21	11	ETOH++, in clinic
	63	F	21	.	Conserved patient; consented conservator for care ECG not attached
	45	M	21	18	Uncooperative, tased, LEO custody
	69	M	21	.	Slow to respond; carried to stretcher. ECG not attached
	76	M	21	7	ECG time recorded, no image
	31	M	22	20	Moved in shackles; required LEO discussion
	53	F	22	10	AMA
	31	M	25	3	Delayed on scene waiting for additional LEO
	58	M	26	8	AMA; private ambulance transport
	76	M	26	19	Locked home; had to break in; obstructed entry
	38	M	30	.	Non-compliant; transported by PD ECG not attached
	56	F	32	13	First BP and ECG at 13 min
	72	M	32	.	Refused transport (AMA); waited with patient for private ambulance ECG not attached
	95	F	38	.	IV and fluids administered prior to transport; ECG not attached
Traditional	57	F	20	.	Minor STE II, III by report; no ECG in record
	65	F	21	11	
	86	F	21	9	
	28	M	21	8	Signed AMA for PD to transport
	56	M	21	.	No ECG in record
	74	F	24	7	AF-paced; walker assist; family disputing destination hospital
	41	M	30	25	Delays for PD; transported by PD

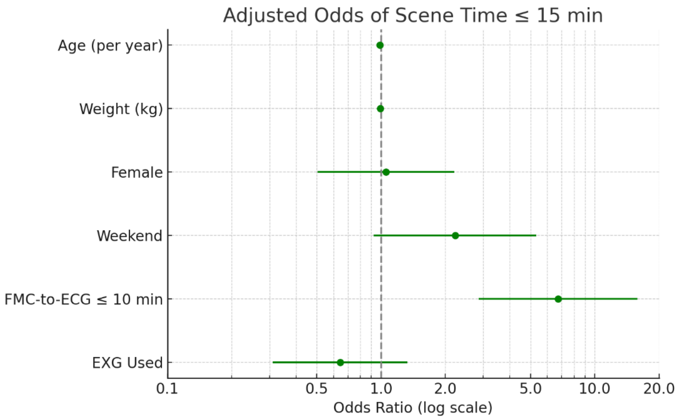
TABLE 4: Univariate logistic regression analysis of Benchmark Scene Time ≤15 minutes

Univariate Analysis of Benchmark Scene Time ≤15 Min	Odds Ratio	95 % Confidence Interval	Prob > chi2
Age (+10-year increments); n=296	0.92	0.79, 1.06	p=0.26
Female; n=297	0.98	0.59, 1.64	p=0.94
Weight (+10 kg increments); n=296	1.00	0.91, 1.10	p=0.95
FMC to ECG ≤10 min; n=194	**7.33**	**3.24, 16.62**	**p<0.001**
Weekend (Sa/Su); n=297	**3.78**	**1.84, 7.75**	**p<0.001**
Nights (7p-7a); n=297	0.85	0.51, 1.42	p=0.53
EXG; n=297	0.76	0.46, 1.27	p=0.30

TABLE 5: Multivariate Logistic Regression Analysis of Benchmark Scene Time ≤ 15 Minutes

Multivariate Analysis of Benchmark Scene Time ≤ 15 Min n=194	Odds Ratio	95 % Confidence Interval	Prob > chi2
EXG	0.62	0.30, 1.31	p=0.21
Age (continuous)	0.98	0.96, 1.01	p=0.15
Female	1.08	0.51, 2.28	p=0.85
Weight (continuous)	0.99	0.98, 1.00	p=0.14
FMC to ECG ≤10 min	**7.32**	**3.09, 17.32**	**p<0.001**
Weekend (Sa/Su)	2.09	0.86, 5.06	p=0.10

FIGURE 3: Forest-Plot of Multivariate Logistic Regression of Scene Time ≤ 15 minutes



ECG TIMES

The distribution of FMC-to-ECG times is illustrated below (Figure 4) and were slightly lower in the EXG group (6 [4–8] minutes vs. 7 [5–9] minutes), though not statistically significant (p=0.22). The subgroup analysis did not demonstrate any significant association between groups and EXG (Table 6). Similarly, the univariate logistic regression analysis did not identify significant association between groups and EXG (Table 7). The odds ratio of obtaining an ECG within benchmark of ≤ 10 minutes was observed more often with EXG [OR=1.30 (95%CI 0.59, 2.87)] but did not meet statistical significance when adjusted for potential confounding variables (Table 8 /Figure 5).

FIGURE 4: Histograms of First Medical Contact to ECG (minutes) by Electrode Type

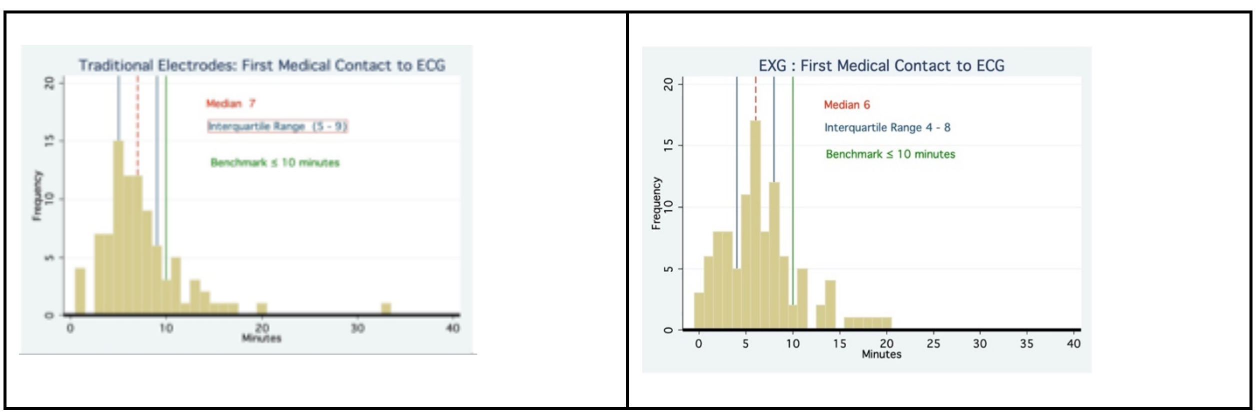


TABLE 6: Subgroup Evaluation of Median First Medical Contact-to-ECG Times (min)

Variable	Baseline (traditional electrodes) n = 91	EXG n = 102	Statistical test	
	FMC-to-ECG, min ; median (IQR)	FMC-to-ECG, min; median (IQR)	Mann-Whitney	
Male	6 (5 – 8) (n=52)	6 (3 - 8) (n=47)		p=0.19
Female	7 (5 –10) (n=39)	6.5 (5 – 9) (n=56)		p=0.40
Weight >90kg	7 (5 – 9) (n=44)	6 (3 – 8) (n=47)		p=0.34
Age ≥70 yo	7 (5 – 9) (n=21)	6.5 (5 – 8.5) (n=20)		p=0.61
Weekend (Sa/Su)	5 (4 – 8) (n=30)	6 (3 –8) (n=26)		p=0.54
Nights (7p-7a)	6 (5 – 8) (n=43)	5 (3 –8) (n=45)		p=0.24

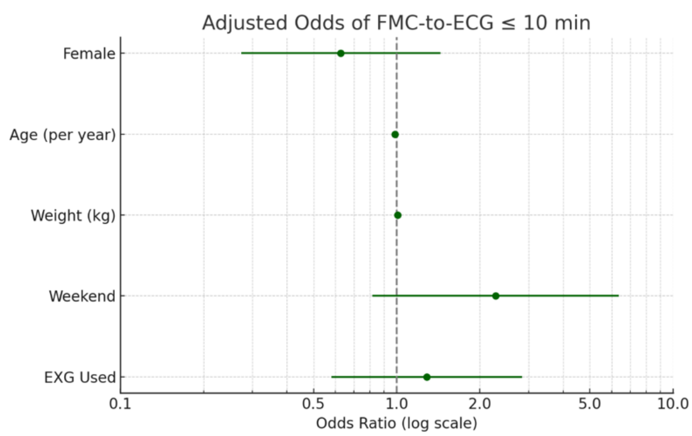
TABLE 7: Univariate Logistic Regression Analysis of Benchmark First Medical Contact-to-ECG ≤ 10 minutes

Univariate Analysis of Benchmark FMC_ECG ≤ 10 Min N=194	Odds Ratio	95 % Confidence Interval	Prob > chi2
Age (+10-year increments)	0.83	0.65, 1.05	p=0.12
Female	0.52	0.24, 1.13	p=0.10
Weight (+10 kg increments)	1.11	0.94, 1.32	p=0.22
Weekend (Sa/Su)	2.48	0.90, 6.81	p=0.08
Nights (7p-7a)	1.26	0.58, 2.72	p=0.56
EXG; n=297	1.16	0.54, 2.48	p=0.70

TABLE 8: Multivariate Logistic Regression Analysis of Benchmark First Medical Contact-to-ECG ≤ 10 minutes

Multivariate Analysis of Benchmark FMC_ECG ≤ 10 Min N=194	Odds Ratio	95 % Confidence Interval	Prob > chi2
EXG	1.30	0.59, 2.87	p=0.52
Age (continuous)	0.98	0.96, 1.01	p=0.24
Female	0.62	0.27, 1.42	p=0.26
Weight (continuous)	1.01	0.99, 1.02	p=0.45
Weekend (Sa/Su)	2.33	0.84, 6.50	p=0.11

FIGURE 5: Forest-Plot of Multivariate Logistic Regression of First Medical Contact-to-ECG ≤ 10 minutes



SIGNAL QUALITY

Table 9 compares the ECG signal quality to traditional electrodes amongst 178 patients that had attached ECGs to their electronic record. There is some overlap within groups as quality indicators were not mutually exclusive. Figure 5 demonstrates these exact percentages for each category and illustrates where the overlaps occurred with all signals being interpretable except for the uninterpretable category which may be related to either one or both noise sources.

EXG was associated with numerically:

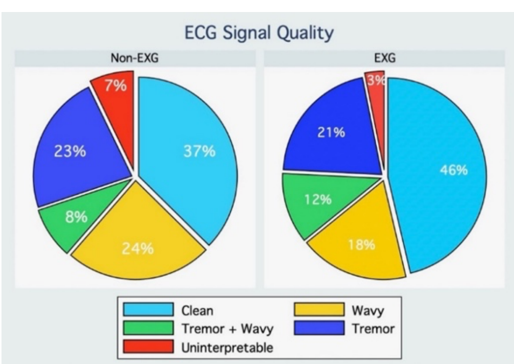
- Lower rate of uninterpretable ECGs (3.2% vs. 7.2%, p=0.22)
- Higher proportion of clean ECGs (46% vs. 37%, p=0.23)
- Comparable rates of wavy baseline (32% vs. 37%) and tremor artifact (35% vs. 39%)

In multivariate analysis (Table 10), EXG use showed a favorable trend toward clean ECGs (OR 1.88; 95% CI, 0.96–3.69; p=0.066). Use of the 150 Hz filter was significantly associated with increased tremor artifact (OR 32.4; 95% CI, 11.6–90.3; p<0.001) and reduced odds of clean tracings (OR 0.10; 95% CI, 0.04–0.28; p<0.001).

TABLE 9: Descriptive Statistics for ECG quality by Electrode Type

Variable	Baseline (traditional electrodes) n = 83	EXG n = 95	Statistical test χ^2	
Wavy Baseline; n, %	31 (37%)	30 (32%)		p=0.42
Tremor; n, %	32, (39%)	33 (35%)		p=0.59
Uninterpretable; n, %	6 (7.2%)	3 (3.2%)		p=0.22
Clean; n, %	31 (37%)	44 (46%)		p=0.23
150Hz ECG	17 (20%)	27 (28%)		p=0.22

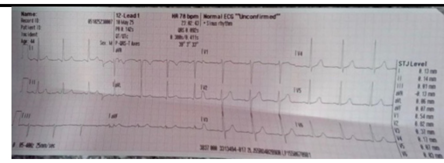
FIGURE 6: ECG Quality by Electrode Type



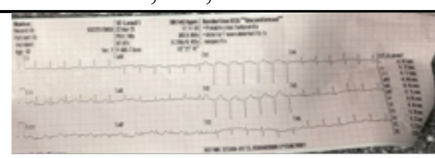
There is a spectrum of wavy baseline and tremor artifact that may still allow for ECG interpretation, and the examples provided below are intended to illustrate that range. Both severe artifact and clean tracings are included for reference. The total number of ECGs corresponding to these observations is indicated in the upper-right corner of the first grading scale. Specific leads are annotated to help guide attention to the relevant findings within each tracing.

Examples of graded results of signal quality:

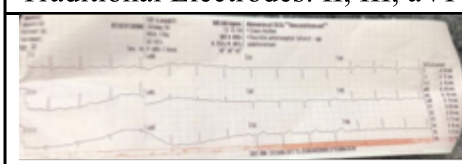
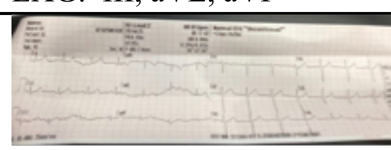
Grade: clean + interpretable

Traditional Electrodes: clean n=31	EXG: clean n=44
	

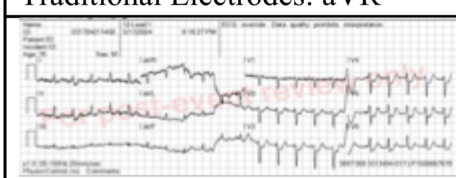
Grade: some wavy baseline; no tremor, + interpretable

Traditional Electrodes: aVL, aVF n=30	EXG: aVF, V2, V3 n=28
	

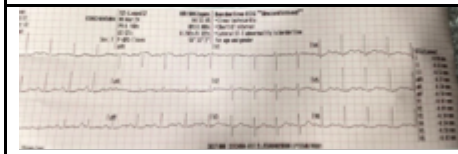
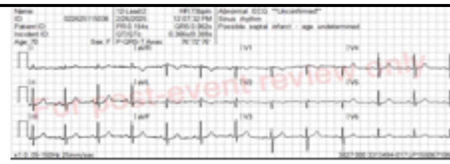
Grade: some wavy baseline; no tremor, + interpretable

Traditional Electrodes: II, III, aVF	EXG: III, aVL, aVF
	

Grade: severe wavy baseline: -not interpretable

Traditional Electrodes: aVR n=1	EXG: V3 n=2
	

Grade: some tremor.   +interpretable

Traditional Electrodes: III, aVl, aVF n=27	EXG: I, II, III n=32
	

Grade some tremor.   +interpretable

Traditional Electrodes: I, III, aVL	EXG: diffuse
	

Grade: Severe tremor. – not interpretable

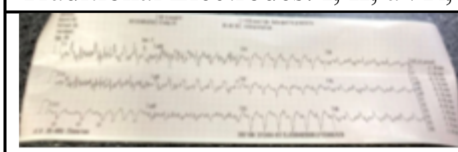
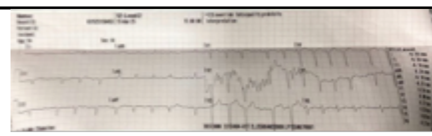
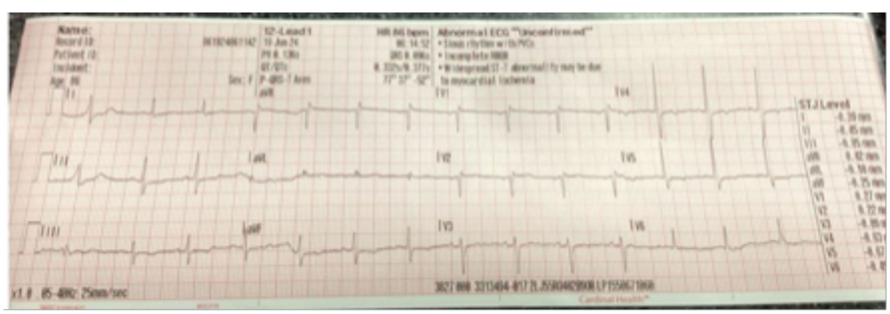
Traditional Electrodes: I, II, aVR, aVF n=5	EXG: V2 n=1
	

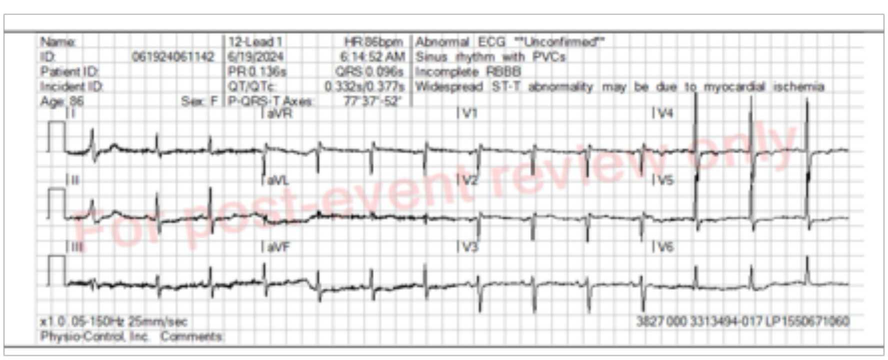
TABLE 10: Multivariate Logistic Regression Analysis of Clean quality ECG (without tremor or baseline wander)

Multivariate Analysis of Clean ECG, n=178	Odds Ratio	95 % Confidence Interval	Prob > chi2
EXG	1.88	0.96, 3.69	p=0.07
Age (continuous)	1.00	0.96, 1.01	p=0.69
Female	0.54	0.27, 1.08	p=0.08
Weight (continuous)	0.99	0.97, 1.00	p=0.13
150Hz ECG	**0.10**	**0.04, 0.28**	**p<0.001**

The association between use of the 150 Hz filter and the presence of tremor artifact (high-frequency, low-amplitude baseline artifact) was substantial, with logistic regression yielding an odds ratio of 32.4 (95% CI: 11.6–90.3; n=178). In contrast, no significant association was observed between the 150 Hz filter and wavy baseline artifact (OR = 1.13; 95% CI: 0.55–2.30).

The ECGs below are from the same patient: the printed ECG was acquired using a 40 Hz high-pass filter, while the uploaded version utilized a 150 Hz filter and displays markedly increased high-frequency / low-amplitude noise consistent with tremor artifact.





While not an objective of this study, it was also noted the electrode waste was significantly reduced with the EXG as compared to the traditional electrodes which has a tendency to dry out from non-use in open packaging and/or require replacement from falling off the patient.

DISCUSSION

This quality improvement initiative demonstrated that EXG implementation did not delay care and may support improved ECG signal quality. Despite slightly longer raw scene times with EXG, adjusted analyses showed no independent association with delayed benchmarks. Rather, scene time delay appeared to be driven by unrelated operational variables. Notably, patients with faster ECG acquisition (≤10 minutes from FMC) were substantially more likely to meet the ≤15-minute scene time goal.

The trend toward fewer uninterpretable tracings and more clean ECGs aligns with EXG's design intent: anatomical indexing, EXG electrode design, skin preparation, and full chest exposure likely reduce lead misplacement and skin-electrode impedance. These findings are consistent with prior literature documenting frequent misplacement errors in standard practice and the diagnostic consequences of poor-quality tracings. [5,6,10]

The EXG system also enables continuity of monitoring across transitions of care, from the prehospital to the in-hospital setting and serial ECGs, which could further enhance longitudinal data fidelity and support ED and inpatient interpretation.[11–13]

A reasonable concern with the introduction of any new medical device in high-tempo, prehospital environments is whether it adds procedural complexity that delays care. To address this, our study included all scene and process times, regardless of whether an ECG was captured in the record, to assess whether the device introduced delays or discouraged providers from completing the ECG. Notably, the frequency of ECG acquisition increased during the EXG implementation period, which argues against any adverse impact on workflow or clinical diligence. Cui et al. has previously reported how there are disparities in scene times related to gender, acquisition of ECG, and time of day.[12] In a follow-up discussion with the fire department's chief medical officer, the informal conclusion was that the higher proportion of women during the EXG period reflected improved care practices: the training and use of EXG encouraged medics to obtain ECGs more consistently in women.

Skepticism among some providers, particularly those less inclined to adopt new practices, has centered on the additional steps now emphasized with EXG use, such as clothing removal, skin preparation, and patient positioning. These tasks are viewed by some as new and/or unnecessary, despite their alignment with guideline-recommended best practices. A future study could be designed to prospectively assess conformance of conventional and EXG tracing acquisition with guideline recommendations.

Importantly, our findings suggest that EXG does not prolonged scene times. Among patients with extended scene durations (≥15 minutes), the median time from First Medical Contact (FMC) to ECG acquisition was faster with EXG (8 minutes, IQR 6–14) compared to traditional electrodes (10 minutes, IQR 7–13), though this difference did not reach statistical significance. The prolonged scene intervals were primarily attributable to non-device factors, including patient refusal, custody and legal constraints, delayed IV access, and complex extrications.

Furthermore, it is important to recognize that the temporal comparisons made in this study are not task-equivalent: during the EXG period, additional steps, such as laying patients supine, removing clothing, and prepping skin, were systematically emphasized. That these more thorough processes were implemented without increasing scene times is a critical finding that supports both the efficiency and clinical utility of the EXG system.

While AHA benchmarks emphasize timely ECG acquisition, these procedural targets are often met in EMS systems circumventing best-practices by performing ECGs on clothed, seated patients during concurrent assessments such as blood pressure measurement. However, this approach compromises diagnostic accuracy: seated posture alters cardiac anatomy and shifts the heart's electrical axis, even when electrodes are placed correctly. The AHA explicitly advises against elevating or rotating patients during ECG acquisition for this reason.[2] Under time pressure, critical preparatory steps such as skin cleaning are frequently skipped. Numerous studies have shown that paramedics misplace one or more precordial electrodes in over 80% of cases, with ECG misclassification rates ranging from 17–24%.[5,6,10,14,15]

The EXG device enforces best practices by requiring clothing removal to identify anatomical landmarks, prompting skin preparation, and promoting supine positioning, thus standardizing acquisition and reducing the risk of inaccurate tracings that may mislead providers and disrupt timely diagnosis and treatment.

Ownbey et al. describe how transitions in care can lead to procedural delays, particularly when there are discrepancies between prehospital and in-hospital ECGs regarding ST-segment findings, contributing to a median delay of 19 minutes in diagnostic catheterization.[11] More recently, Naas et al. reported that approximately 67% of ST-elevation myocardial infarctions (STEMIs) showed resolution of ST elevation upon emergency department arrival, further complicating decision-making.[13] Despite these findings, the literature has largely overlooked a key contributor to this diagnostic inconsistency: variability in electrode placement across providers. When different technicians apply electrodes without strict anatomical standardization, variations in landmarking can lead to serial ECGs that vary not merely on patient cardiac status, but exogenous human factors driven by the healthcare team. Further, misplaced leads are a common occurrence in traditional tracing acquisition, Consequently, the resulting ECGs become difficult to compare, reducing diagnostic confidence. This variability introduces unnecessary friction into the transition of care and can delay critical interventions. These observations underscore the clinical importance of standardized electrode placement to ensure consistent ECG interpretation and support timely, accurate decisions across the continuum of care. The EXG system is designed to systematically mitigate and attenuate these susceptibilities.

Studies comparing ECG quality must account for the impact of low-pass filter settings, as these directly influence the signal characteristics being analyzed. A 40Hz cutoff has been noted to result in an increased rate of optimal quality ECGs compared to the 150Hz cutoff (93.4% vs 54.6%; $p<0.001$) and a lower rate of non-interpretable tracings (0.25% vs 4.80%; $p<0.001$).[16] ECG devices use automated algorithms to calculate axis, intervals, and J-point elevation based on filtered signals, typically processed at a default 150 Hz low-pass setting for diagnostic 12-leads, regardless of the visual output. In contrast, monitor leads and defibrillator paddles often apply more aggressive filtering, typically around 30 Hz, which suppresses high-frequency components and makes the ECG appear cleaner.

Importantly, while low-pass filters have minimal impact on baseline wander (a low-frequency artifact), they strongly affect high-frequency, low-amplitude noise, such as tremor artifact. Many clinicians are unaware that different filters may be applied to the same ECG depending on the source of the display (monitor screen, printed strip, or stored digital file). For example, a signal may appear clean on the bedside monitor, slightly noisy on the printed ECG, and significantly noisy during administrative review, all due to differences in low-pass filter settings rather than changes in patient physiology or electrode quality.

Automated ECG interpretations are based on the internally processed 150 Hz signal, but users often assess printouts filtered differently. This mismatch introduces a potential confounder in signal quality studies. Therefore, comparative studies of ECG systems should adjust for filter settings and ensure transparency about the mode and filter parameters used during acquisition and analysis.

Limitations include the retrospective design, use of convenience sampling for ECG tracings, and absence of hospital outcome data. The mechanism in which ECGs are uploaded to the electronic record can be fraught with poor compliance as the electronic records and ECG images are stored in separate systems and if not uploaded will eventually be irretrievable due to memory restrictions on the device. This study did not demonstrate a significant difference in the ECG acquisition rates. Prospective studies linking EMS ECG quality to in-hospital diagnostics and outcomes are warranted.

CONCLUSIONS

In this EMS-based quality improvement initiative, the EXG 12-lead system performed comparably or better than traditional electrodes in terms of ECG acquisition time and signal quality. It did not increase scene time or delay benchmarks when adjusted for confounders. These results support its use as a high-fidelity, standardized option for prehospital cardiac assessment.

Future prospective evaluation of longitudinal ECG data capture and correlation with in-hospital findings and outcomes is warranted.

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