September 19, 2025

BunkerHill Health
℅ John Smith
Partner
Hogan Lovells LLP
555 Thirteenth Street, NW
Washington, District of Columbia 20004

Re: K250649
Trade/Device Name: Bunkerhill ECG-EF
Regulation Number: 21 CFR 870.2380
Regulation Name: Cardiovascular Machine Learning-Based Notification Software
Regulatory Class: Class II
Product Code: QYE
Dated: March 3, 2025
Received: March 4, 2025

Dear John Smith:

We have reviewed your section 510(k) premarket notification of intent to market the device referenced above and have determined the device is substantially equivalent (for the indications for use stated in the enclosure) to legally marketed predicate devices marketed in interstate commerce prior to May 28, 1976, the enactment date of the Medical Device Amendments, or to devices that have been reclassified in accordance with the provisions of the Federal Food, Drug, and Cosmetic Act (the Act) that do not require approval of a premarket approval application (PMA). You may, therefore, market the device, subject to the general controls provisions of the Act. Although this letter refers to your product as a device, please be aware that some cleared products may instead be combination products. The 510(k) Premarket Notification Database available at https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm identifies combination product submissions. The general controls provisions of the Act include requirements for annual registration, listing of devices, good manufacturing practice, labeling, and prohibitions against misbranding and adulteration. Please note: CDRH does not evaluate information related to contract liability warranties. We remind you, however, that device labeling must be truthful and not misleading.

If your device is classified (see above) into either class II (Special Controls) or class III (PMA), it may be subject to additional controls. Existing major regulations affecting your device can be found in the Code of Federal Regulations, Title 21, Parts 800 to 898. In addition, FDA may publish further announcements concerning your device in the Federal Register.

Additional information about changes that may require a new premarket notification are provided in the FDA guidance documents entitled "Deciding When to Submit a 510(k) for a Change to an Existing Device" (https://www.fda.gov/media/99812/download) and "Deciding When to Submit a 510(k) for a Software Change to an Existing Device" (https://www.fda.gov/media/99785/download).

Your device is also subject to, among other requirements, the Quality System (QS) regulation (21 CFR Part 820), which includes, but is not limited to, 21 CFR 820.30, Design controls; 21 CFR 820.90, Nonconforming product; and 21 CFR 820.100, Corrective and preventive action. Please note that regardless of whether a change requires premarket review, the QS regulation requires device manufacturers to review and approve changes to device design and production (21 CFR 820.30 and 21 CFR 820.70) and document changes and approvals in the device master record (21 CFR 820.181).

Please be advised that FDA's issuance of a substantial equivalence determination does not mean that FDA has made a determination that your device complies with other requirements of the Act or any Federal statutes and regulations administered by other Federal agencies. You must comply with all the Act's requirements, including, but not limited to: registration and listing (21 CFR Part 807); labeling (21 CFR Part 801); medical device reporting (reporting of medical device-related adverse events) (21 CFR Part 803) for devices or postmarketing safety reporting (21 CFR Part 4, Subpart B) for combination products (see https://www.fda.gov/combination-products/guidance-regulatory-information/postmarketing-safety-reporting-combination-products); good manufacturing practice requirements as set forth in the quality systems (QS) regulation (21 CFR Part 820) for devices or current good manufacturing practices (21 CFR Part 4, Subpart A) for combination products; and, if applicable, the electronic product radiation control provisions (Sections 531-542 of the Act); 21 CFR Parts 1000-1050.

All medical devices, including Class I and unclassified devices and combination product device constituent parts are required to be in compliance with the final Unique Device Identification System rule ("UDI Rule"). The UDI Rule requires, among other things, that a device bear a unique device identifier (UDI) on its label and package (21 CFR 801.20(a)) unless an exception or alternative applies (21 CFR 801.20(b)) and that the dates on the device label be formatted in accordance with 21 CFR 801.18. The UDI Rule (21 CFR 830.300(a) and 830.320(b)) also requires that certain information be submitted to the Global Unique Device Identification Database (GUDID) (21 CFR Part 830 Subpart E). For additional information on these requirements, please see the UDI System webpage at https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance/unique-device-identification-system-udi-system.

Also, please note the regulation entitled, "Misbranding by reference to premarket notification" (21 CFR 807.97). For questions regarding the reporting of adverse events under the MDR regulation (21 CFR Part 803), please go to https://www.fda.gov/medical-devices/medical-device-safety/medical-device-reporting-mdr-how-report-medical-device-problems.

For comprehensive regulatory information about medical devices and radiation-emitting products, including information about labeling regulations, please see Device Advice (https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance) and CDRH Learn (https://www.fda.gov/training-and-continuing-education/cdrh-learn). Additionally, you may contact the Division of Industry and Consumer Education (DICE) to ask a question about a specific regulatory topic. See the DICE website (https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-

assistance/contact-us-division-industry-and-consumer-education-dice) for more information or contact DICE by email (DICE@fda.hhs.gov) or phone (1-800-638-2041 or 301-796-7100).

Sincerely,

Jackson Hair -S

Digitally signed by Jackson Hair -S
Date: 2025.09.19 13:41:37 -04'00'

for

LCDR Stephen Browning
Assistant Director
Division of Cardiac Electrophysiology,
Diagnostics, and Monitoring Devices
Office of Cardiovascular Devices
Office of Product Evaluation and Quality
Center for Devices and Radiological Health

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Food and Drug Administration

Indications for Use

Form Approved: OMB No. 0910-0120
Expiration Date: 07/31/2026
See PRA Statement below.

510(k) Number *(if known)*
K250649

Device Name
Bunkerhill ECG-EF

Indications for Use *(Describe)*
Bunkerhill ECG-EF is software intended to aid in screening for Left Ventricular Ejection Fraction (LVEF) less than or equal to 40% in adults at risk for, but not already diagnosed with low LVEF.

Bunkerhill ECG-EF is not intended to be a stand-alone diagnostic device for cardiac conditions, should not be used for monitoring of patients, and should not be used on ECGs with a paced rhythm. A positive result may suggest the need for further clinical evaluation in order to establish a diagnosis of Left Ventricular Ejection Fraction (LVEF) less than or equal to 40%.

Additionally, if the patient is at high risk for the cardiac condition, a negative result should not rule out further non-invasive evaluation.

Bunkerhill ECG-EF is adjunctive and must be interpreted in conjunction with the clinician's judgment, the patient's medical history, symptoms, and additional diagnostic tests. For a final clinical diagnosis, further confirmatory testing, such as echocardiography, is required.

Type of Use *(Select one or both, as applicable)*

☒ Prescription Use (Part 21 CFR 801 Subpart D) ☐ Over-The-Counter Use (21 CFR 801 Subpart C)

CONTINUE ON A SEPARATE PAGE IF NEEDED.

510(K) SUMMARY

Bunkerhilll ECG-EF

Bunkerhill, Inc. 436 Bryant Street

San Francisco CA 94107

Phone: (516) 305-3596
Contact Person: Eren Alkan

Date Prepared: September 19, 2025

Proposed Device

Proprietary Name	Bunkerhill ECG-EF
Cardiovascular Machine Learning-Based Notification Software	Cardiovascular Machine Learning-Based Notification Software
Regulation Number	21 CFR 870.2380
Product Code	QYE
Regulatory Class	II

Predicate Device

Proprietary Name	Low Ejection Fraction AI-ECG Algorithm
Premarket Notification	K232699
Classification Name	Cardiovascular Machine Learning-Based Notification Software
Regulation Number	21 CFR 870.2380
Product Code	QYE
Regulatory Class	II

Reference Device

Proprietary Name	Eko Low Ejection Fraction Tool (ELEFT)
Premarket Notification	K233409
Classification Name	Cardiovascular Machine Learning-Based Notification Software
Regulation Number	21 CFR 870.2380
Product Code	QYE
Regulatory Class	II

Device Description

ECG-EF is a software-only medical device that employs deep learning algorithms to analyze 12-lead ECG data for the detection of low left ventricular ejection fraction (LVEF < 40%). The algorithm processes 10-second ECG waveform snippets, providing predictions to assist healthcare professionals in the early identification of patients at risk for heart failure.

ECG-EF algorithm receives digital 12-lead ECG data and processes it through its machine learning model. The output of the analysis is transmitted to integrated third-party software systems, such as Electronic Medical Records (EMR) or ECG Management Systems (EMS). The results are displayed by the third-party software on a device such as a smartphone, tablet, or PC.

ECG-EF algorithm produces a result indicating "Low EF Screen Positive - High probability of low ejection fraction based on the ECG", " Low EF Screen Negative - Low probability of low ejection fraction based on the ECG" or "Error – device input criteria not met " for cases that do not meet data input requirements. These results are not intended to be definitive diagnostic outputs but rather serve as adjunctive information to support clinical decision-making. A disclaimer accompanies the output, stating: “Not for diagnostic use. The results are not final and must be reviewed alongside clinical judgment and other diagnostic methods.”

The Low Ejection Fraction AI-ECG Algorithm device is intended to address the unmet need for a point-of-care screen for LVEF less than or equal to 40% and is expected to be used by cardiologists, front-line clinicians at primary care, urgent care, and emergency care settings, where cardiac imaging may not be available or may be difficult or unreliable for clinicians to operate. Clinicians will use the Low Ejection Fraction AI-ECG Algorithm to aid in screening for LVEF less than or equal to 40% and making a decision for further cardiac evaluation.

Intended Use / Indications for Use

Bunkerhill ECG-EF is software intended to aid in screening for Left Ventricular Ejection Fraction (LVEF) less than or equal to 40% in adults at risk for, but not already diagnosed with low LVEF.

Bunkerhill ECG-EF is not intended to be a stand-alone diagnostic device for cardiac conditions, should not be used for monitoring of patients, and should not be used on ECGs with a paced rhythm. A positive result may suggest the need for further clinical evaluation in order to establish a diagnosis of Left Ventricular Ejection Fraction (LVEF) less than or equal to 40%.

Additionally, if the patient is at high risk for the cardiac condition, a negative result should not rule out further non-invasive evaluation.

Bunkerhill ECG-EF is adjunctive and must be interpreted in conjunction with the clinician’s judgment, the patient’s medical history, symptoms, and additional diagnostic tests. For a final clinical diagnosis, further confirmatory testing, such as echocardiography, is required.

Table 1: Indications for Use Comparison

	Proposed Device: Bunkerhill ECG-EF Algorithm	**Predicate Device: Low Ejection Fraction AI-ECG Algorithm (K232699)**	**Reference Device: Eko Low Ejection Fraction Tool (K233409)**
Intended use / Indications for use	Bunkerhill ECG-EF is software intended to aid in screening for Left Ventricular Ejection Fraction (LVEF) less than or equal to 40% in adults at risk for, but not already diagnosed with low LVEF. Bunkerhill ECG-EF is not intended to be a stand-alone diagnostic device for cardiac conditions, should not be used for monitoring of patients, and should not be used on ECGs with a paced rhythm. A positive result may suggest the need for further clinical evaluation in order to establish a diagnosis of Left Ventricular Ejection Fraction (LVEF) less than or equal to 40%. Additionally, if the patient is at high risk for the cardiac condition, a negative result should not rule out further non-invasive evaluation. Bunkerhill ECG-EF is adjunctive and must be interpreted in conjunction with the clinician's judgment, the patient's medical history, symptoms, and additional diagnostic tests. For a final clinical diagnosis, further confirmatory testing, such as echocardiography, is required.	The Anumana Low Ejection Fraction AI- ECG Algorithm is software intended to aid in screening for Left Ventricular Ejection Fraction (LVEF) less than or equal to 40% in adults at risk for heart failure. This population includes, but is not limited to: • patients with cardiomyopathies • patients who are post-myocardial infarction • patients with aortic stenosis • patients with chronic atrial fibrillation • patients receiving pharmaceutical therapies that are cardiotoxic, and • postpartum women. Anumana Low Ejection Fraction AI-ECG Algorithm is not intended to be a stand- alone diagnostic device for cardiac conditions, should not be used for monitoring of patients, and should not be used on ECGs with a paced rhythm. A positive result may suggest the need for further clinical evaluation in order to establish a diagnosis of Left Ventricular Ejection Fraction (LVEF) less than or equal to 40%. Additionally, if the patient is at high risk for the cardiac condition, a negative result should not rule out further non-invasive evaluation. The Anumana Low Ejection Fraction AI-ECG Algorithm should be applied jointly with clinician judgment.	Eko Low Ejection Fraction Tool (ELEFT) is a software intended to aid clinicians in identifying individuals with Left Ventricular Ejection Fraction (LVEF) less than or equal to 40%. ELEFT takes as input ECG and heart sounds and is intended for use on patients at risk for heart failure. This population includes, but is not limited to, patients with: coronary artery disease; diabetes mellitus; cardiomyopathy; hypertension; and obesity. The interpretations of heart sounds and ECG offered by the software are meant only to assist healthcare providers in assessing Left Ventricular Ejection Fraction ≤ 40% , who may use the result in conjunction with their own evaluation and clinical judgment. It is not a diagnosis or for monitoring of patients diagnosed with heart failure. This software is for use on adults (18 years and older).

The intended use of the **Bunkerhill ECG-EF** is the same as that of the **Anumana Low Ejection Fraction AI-ECG Algorithm**, and reference device, Eko Low Ejection Fraction Tool (ELEFT) as the devices are software tools designed to aid in screening for Left Ventricular Ejection Fraction (LVEF) ≤40% in adults at risk for heart failure.

- Both devices assist certified medical professionals with analyze 12-lead ECG data for the rapid detection of low left ventricular ejection fraction (LVEF ≤ 40%).

- Both subject and predicate devices are not intended to be used stand-alone, can be used optionally by the physician and do not provide a definitive diagnosis. Both devices require the physician to use this information to decide next steps and/or additional diagnostic work up.

- Verification and validation testing, including performance assessment demonstrates that the Bunkerhill ECG-EF Device is as safe and effective as its predicate device.

Summary of Technological Characteristics

There are no major changes to technological characteristics in the subject device compared to the predicate device. Both the predicate and the subject device A) use machine learning algorithms to analyze 12-lead ECG data for the rapid detection of low left ventricular ejection fraction (LVEF ≤ 40%). Both the algorithms process 10-second ECG waveform snippets, providing predictions to assist healthcare professionals in the early identification of patients at risk for heart failure. However, they do not replace clinical evaluation and do not alter the standard of care.

The subject device and the predicate device are Software as a Medical Device (SaMD) provided as a software module packaged in a Docker container. The Algorithms do not provide a graphical user interface (GUI) of their own. They are integrated with other medical systems such as Electronic Medical Record (EMR) systems or ECG Management Systems (EMS). The third-party integrating software furnishes a 12-lead ECG digital waveform as input to the Low Ejection Fraction AI-ECG Algorithm and records the algorithm output for display via the integrated medical system or for printing in an offline report.

There are no major differences between subject device and reference device as well. The reference device can also analyze PCG signals when available. Any minor differences in the technology characteristics do not raise different questions of safety and effectiveness.

Table 2: Technological Comparison

	Proposed Device: Bunkerhill ECG-EF Algorithm	**Predicate Device:** Low Ejection Fraction AI-ECG Algorithm (K232699)	**Reference Device:** Eko Low Ejection Fraction Tool (K233409)	**Summary**
Product code	QYE	QYE	QYE	Same
Regulation number	21 CFR 870.2380	21 CFR 870.2380	21 CFR 870.2380	Same
Regulation Name	Cardiovascular machine learning-based notification software	Cardiovascular machine learning-based notification software	Cardiovascular machine learning- based notification software	Same
Operational Mode	Spot Check	Spot Check	Spot Check	Same
Patient population	Adults	Adults	Adults 18 and older	Same
Environment of Use	Primary care, urgent care, and emergency care settings	Primary care, urgent care, and emergency care settings	Primary care, urgent care, and emergency care settings	Same- Both devices are to be used in professional healthcare settings
Algorithm	Machine learning based algorithm	Machine learning based algorithm	Machine learning based algorithm	Same
Algorithm Calculation and Output	Detection of LVEF (Left Ventricular Ejection Fraction less than or equal to 40%) from an ECG signal	Detection of LVEF (Left Ventricular Ejection Fraction less than or equal to 40%) from an ECG signal	The Eko Low Ejection Fraction Tool (ELEFT) to identify individuals with Left Ventricular Ejection Fraction (LVEF) less than or equal to 40% by analyzing ECG and heart sounds from patients at risk for heart failure.	Same
Ground Truth for Model Training	Transthoracic echocardiogram (TTE) with disease	Transthoracic echocardiogram (TTE) with disease	gold standard echocardiogram	Same- Both devices rely upon established clinical diagnostic methods as ground truth
Physiological Parameter Inputs	12-Lead ECG waveform in digital format	12-Lead ECG waveform in digital format	ECG recording signals from single lead PCG recording signals (when available)	Same- Both devices utilize ECG digital waveforms as input
Data Displayed	Algorithm output is provided to third party software that displays the result to clinicians. Output provided for each ECG is “Low LVEF Detected” “Low	Algorithm output is provided to third party software that displays the result to clinicians. Output provided for each ECG is “Low LVEF Detected” “Low LVEF Not Detected”	Application Programming Interface (API) only, no user interface	Same- Both devices provide data suggesting the likelihood of the same cardiovascular disease or condition for further referral or diagnostic follow-up.

	Proposed Device: Bunkerhill ECG-EF Algorithm	**Predicate Device:** Low Ejection Fraction AI-ECG Algorithm (K232699)	**Reference Device:** Eko Low Ejection Fraction Tool (K233409)	**Summary**
	LVEF Not Detected" or "Error - device input criteria not met").	or "Error").		
Hardware	Compatible 12-Lead diagnostic ECG machines with 500Hz digital output	Compatible 12-Lead diagnostic ECG machines with 500Hz digital output	ECG recording signals from single lead PCG recording signals (when available)	Same
Software	Bunkerhill proprietary algorithm and application	Bunkerhill proprietary algorithm and application	proprietary algorithm and application	Same
Type of Interpretation	Adjunctive information	Adjunctive information	Same	Type of Interpretation
Intended User	Appropriately trained medical specialists such as cardiologists, front- line clinicians at primary care, urgent care, and emergency care settings	Appropriately trained medical specialists such as cardiologists, front- line clinicians at primary care, urgent care, and emergency care settings	Same	Intended User
Rx or OTC	Rx	Rx	Same	Rx or OTC

Performance Data

Safety and performance of the Bunkerhill ECG-EF algorithm has been evaluated and verified in accordance with software specifications and applicable performance standards through Software Development and Validation & Verification Process to ensure performance according to specifications, User Requirements and Federal Regulations and Guidance documents, "Content of Premarket Submissions for Device Software Functions" and a thorough cybersecurity assessment was performed per FDA Guidance "Cybersecurity in medical devices: Quality System Considerations and Content of Premarket Submissions".

The performance of the ECG-EF algorithm was validated through a retrospective study involving 15,994 patient records sourced from two health systems across the United States. The study aimed to assess the diagnostic accuracy of the algorithm in identifying patients with an ejection fraction (EF) < 40% within a clinically and demographically diverse population. The study sample was representative of the U.S population and was 65.5 % White, 18.8% Hispanic, 5.7% American Indian or Alaska Native, 3.9% Asian, 3.0% Black/African American, and 2.8% Other. The sample consisted of 53% Male and 47% Female. The pivotal dataset was be curated from 5 sites geographically distributed throughout the United

States. The ground truth was established from an echocardiogram using the Simpson's Biplane measurement method taken less than 15-days apart from the ECG scan.

Within this diverse dataset, a total of 1725 LVEF ≤ 40% cases were identified based on the echocardiogram from 15,994 samples (prevalence of 10.8%). The Bunkerhill ECG-EF device achieved a sensitivity of 82.66% (80.90–84.30), a specificity of 83.20% (82.60–83.80), a PPV of 37.20% (35.70–38.76), and NPV of 97.54% (97.28–97.83). The confidence intervals are available in the table below. The confusion matrix summarizing the results are available in *Figure 1: Bunkerhill ECG EF Confusion Matrix* below.

Performance Metric	Acceptance Criteria	Value	Bootstrap	Clopper-Pearson	Wilson	Pass/ Fail
Sensitivity	Se ≥ 80%	82.66%	(80.90–84.30)	(80.80 - 84.43)	(80.81 - 84..38)	Pass
Specificity	Sp ≥ 80%	83.20%	(82.60–83.80)	(82.56 - 83.80)	(82.56 - 83.79)	Pass
PPV	PPV ≥ 25%	37.20%	(35.70–38.76)	(35.75 - 38.84)	(35.76 - 38.38)	Pass
NPV	NPV ≥ 95%	97.54%	(97.28–97.83)	(97.25 - 97.81)	(97.25 - 97.80)	Pass

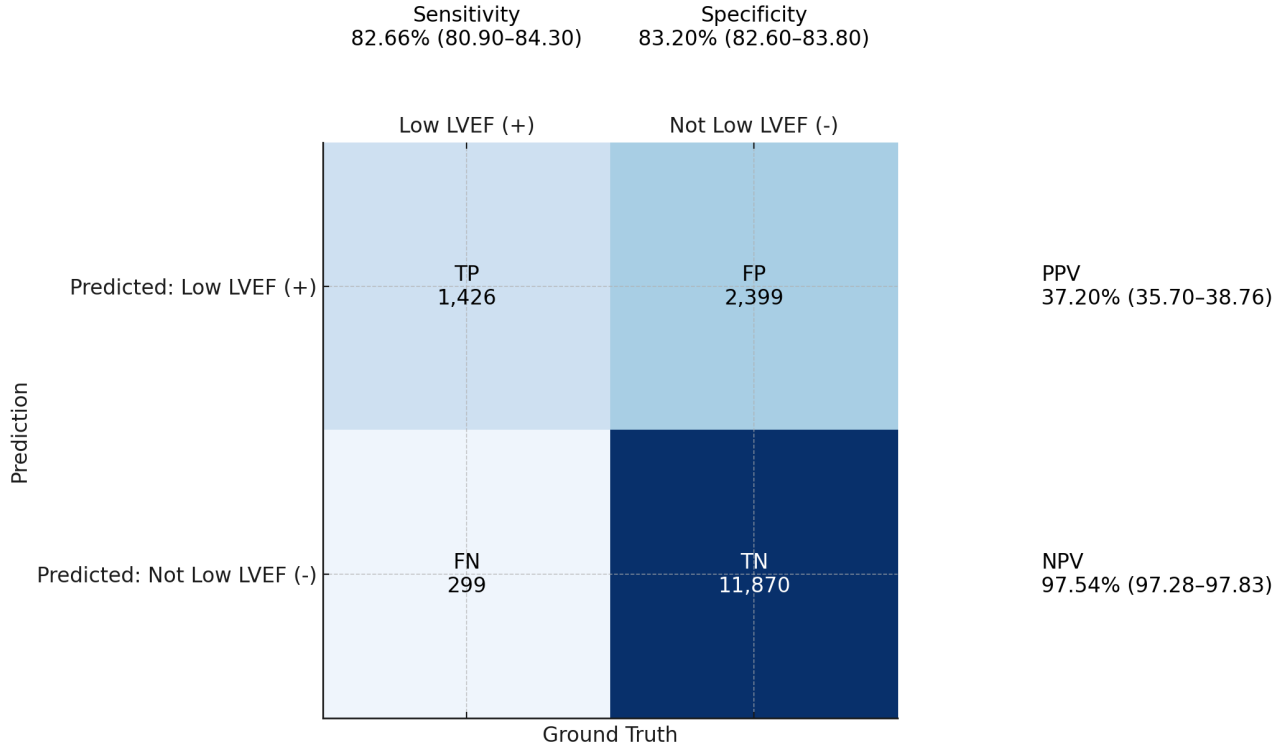

Figure 1: Bunkerhill ECG-EF Confusion Matrix

The primary endpoint was Detection of Low Left Ventricular Ejection Fraction and the acceptance criteria were Se/Sp ≥ 80, PPV ≥ 25%, NPV ≥ 95%. All the primary acceptance criteria were successfully met. The secondary acceptance criteria for Detection of Low Left Ventricular Ejection Fraction using AUROC plot was also met.

Subgroup assessments of diagnostic performance were conducted to determine if there was heterogenicity in device performance across clinical sites, demographics, clinical characteristics, co-morbidities, ECG manufacturer and ECG devices. The findings are summarized in *Table 3: Subgroup Analysis*:

Table 3: Sub-group Analysis

Subgroup Analysis	Result of Test for Heterogeneity
Clinical Site	Not statistically significant
Sex	Not statistically significant
Race/Ethnicity	Not statistically significant
Age Group	Diagnostic performance varied across age group strata ($p < 0.01$). The diagnostic odds ratio was higher than the overall estimate in patients aged 18-49 and 70-79 while it's lower in patients age group of 60-69 and 80+. In younger patients, sensitivity was higher while specificity was lower, whereas in patients of advanced age, sensitivity was lower while specificity was higher.
Clinical Characteristics	Diagnostic performance varied across certain elements of medical history derived from ICD9/ICD10 codes in patient medical records. The diagnostic odds ratio was higher in patients with Myocardial Infarction ($p<0.01$) and lower for Coronary Revascularization ($p < 0.01$) and Atrial Fibrillation/Flutter ($p < 0.01$). In each of these cases, there was a higher presence of low ejection fraction, the algorithm had higher sensitivity and lower specificity, and as a result there were robust PPV and NPV results.
Device / Manufacturer	Not statistically significant
Conduction Disorder	Not statistically significant

Note:

This device only should be used with 12-lead ECGs acquired using Ag-AgCl electrodes in the standard lead configuration on the following validated ECG acquisition systems: Philips PageWriter TC70, GE Dash 3000, GE MAC 5500 HD, GE MAC VU360.

Warning (Safety):

Use of non-validated ECG devices, alternative electrode types, or non-standard acquisition conditions may result in inaccurate results.

Conclusions

The Bunkerhill ECG-EF algorithm is as safe and effective as the predicate Low Ejection Fraction AI-ECG Algorithm (K232699). The subject device has the same intended uses and similar indications,

technological characteristics, and principles of operation as its predicate device. The minor differences in indications do not alter the intended diagnostic use of the device and do not affect its safety and effectiveness when used as labeled. In summary, any minor differences between the Low Ejection Fraction AI-ECG Algorithm and the Bunkerhill ECG-EF Device do not raise any issues of safety or effectiveness.