



Eko Murmur Analysis Software (EMAS)

User Manual

Software Version: 1.2.0

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1.0 Introduction

This manual is intended to provide information to guide trained operators in the safe and effective operation of the Eko Murmur Analysis Software.

It is important that you read and understand all instructions in this manual before operating the device and pay careful attention to the warnings and cautions throughout the manual.



Caution

United States Federal law restricts the sale and use of this device to either by or on the order of a clinician.

Eko Health, Inc., assumes no responsibility for any injury to anyone, or for the improper use of the product that may result from failure to use this product in accordance with the instructions, cautions, warnings, or statement of intended use published in this manual.

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1.1 For Help and Assistance

For general and product related comments, questions, or concerns, please contact Eko directly.

Please report any injury or adverse event to Eko using any of the contact methods below.







Serious Incident Reporting

If a serious incident has occurred in relation to the device, it should be reported to the manufacturer and the competent authority of the Member State in which the user and/or patient is established. A serious incident means any incident that directly or indirectly led, might have led or, in case of recurrence, could lead to any of the following: the death of a patient, user or other person, the temporary or permanent serious deterioration of a patient's, user's, fetus or other person's state of health, or a serious public health threat.

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Manufacturer's Address:	Eko Health, Inc. 2100 Powell St., Suite 300 Emeryville, CA 94608, USA
General Assistance and FAQs:	ekohealth.com/ifu
Direct Contact:	support@ekohealth.com
Phone Support:	+1.844.356.3384 (US)
Product Reference and Information:	ekohealth.com
Patents:	Listing of applicable U.S. Patents in compliance with 35 U.S.C. §287: ekohealth.com/patents
Disclaimer:	The information contained in this document is subject to change without notice.

1.2 Safety Related Labels & Symbols

	Consult electronic instructions for use http://www.ekohealth.com/ifu
	Model Number
	Manufacturer
	Caution
	Medical Device
	Unique Device Identifier

1.3 Cautions

- **This is not a diagnosis, only a possible finding. Recording and analyzing all auscultation positions is recommended before making a diagnosis.** The interpretations of heart sounds offered by the Eko Murmur Analysis Software are meant only to provide clinical decision support to the clinician, who may use the result in conjunction with their own evaluation and clinical judgment. The interpretations are not diagnoses.
- The Eko Murmur Analysis Software can provide automatic computer interpretations. A computer-generated interpretation cannot replace sound medical reasoning by a trained professional. Therefore, a physician should always review the interpretation and final analysis should always be obtained by a physician. **Proper administration and implementation of this device is the physician's responsibility.**
- The quality of the computer interpretations depends heavily upon the quality of the inputted data. **Only analyze high quality recordings of heart sounds.**

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- The software only informs the clinician about the presence or absence of murmurs in the phonocardiogram, and if present, whether those murmurs are systolic or diastolic, and structural or innocent. The physician should conduct a more complete analysis of the detected murmur to determine from which valve(s) it emanates and the degree of disease severity it indicates. This may require additional testing, as indicated.
- The Eko Murmur Analysis Software is not intended as a sole means of diagnosis. The detection of abnormalities in heart sounds offered by the software are only significant when used in conjunction with physician interpretation.
- The software has been trained using sound recordings taken from the four standard cardiac auscultation positions (i.e., right upper sternal border, left upper sternal border, left lower sternal border, and cardiac apex). Device performance is unknown when analyzing sounds captured from elsewhere on the patient's body.

1.4 Indications/Intended Purpose

The Eko Murmur Analysis Software is intended to provide decision support to clinicians in their evaluation of patients' heart sounds. The software analyzes heart sounds and phonocardiograms (and ECG signals, when available). The software will automatically detect murmurs that may be present, and the murmur timing and character, including S1, S2, innocent heart murmurs, structural heart murmurs, and the absence of a heart murmur.

The Eko Murmur Analysis Software is not intended as a sole means of diagnosis and is for use in environments where healthcare is provided by clinicians. The interpretations of heart sounds offered by the software are meant only to provide decision support to the clinician, who may use the result in conjunction with their own evaluation and clinical judgment. The interpretations are not diagnoses. The Eko Murmur Analysis Software is intended for use on pediatric and adult patients.

1.5 Intended Users

The Eko Murmur Analysis Software is intended for clinician's use on pediatric and adult patients.

1.6 Compatibility

For the compatible Eko hardware and mobile devices, please refer to System Requirements at ekohealth.com.

1.7 Other Considerations

This manual provides instructions for the use of the Eko Murmur Analysis Software. It is assumed that the user is familiar with basic Eko software application use on mobile and desktop devices.

Standard procedures for auscultation should be followed including background noise reduction and optimal patient positioning when capturing data for the Eko Murmur Analysis Software.

Notifications made by this feature are potential findings, and are not a complete diagnosis of cardiac abnormalities. **The patient's medical history and physical examination results must be taken into consideration during the decision-making process.**

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The Eko Murmur Analysis Software is unable to return a result if the Eko CORE, CORE 500™, or DUO stethoscope is unable to connect to the mobile device over Bluetooth or if the mobile device is unable to connect to the internet.

The Eko Murmur Analysis Software requires a minimum internet connection speed. The recommended upload speed for the mobile app is 4 Mbps. 4G cellular data service or similar is recommended.

The software should not be used on patients where the physician has difficulty auscultating with the Eko CORE, CORE 500™, or DUO stethoscopes. Software accuracy may suffer when the patient is obese or has loud pulmonary sounds.

Final judgment on the diagnosis still lies with the qualified medical personnel.

2.0 Technical Description

Murmur Characterization

The Eko Murmur Analysis Software (EMAS) identifies possible murmurs in a heart sound recording, and if present, whether those murmurs are systolic or diastolic, and innocent or structural. These are not diagnoses, only potential finding(s). If indicated, you should conduct further evaluation if a murmur is detected. A murmur finding is often a recommendation for echocardiography or specialist referral.

The EMAS will only function if the user has subscribed to the appropriate Eko software package, and the package has been activated on the user's account. Once activated, the EMAS will function automatically, immediately after the user takes a sound recording. (The recording must be at least 5 seconds long.)

Once the recording has completed, the Eko companion mobile application will invoke the EMAS and the results of analysis will be displayed on the Eko mobile application in less than 10 seconds. No user intervention is needed to initiate, complete, or display the analysis.

The Eko Murmur Analysis Software will display to the user these possible results, examples of which are shown in Figure 1:

- Poor quality heart sounds
- No murmur detected
- Systolic murmur detected
- Diastolic murmur detected
- Innocent murmur detected
- Structural murmur detected

The causes of systolic murmurs vary; where the murmur is heard the loudest can help in diagnosis. Aortic stenosis, atrial septal defect, and pulmonic stenosis are heard best at the left and right upper sternal borders, whereas mitral regurgitation is heard best at the cardiac apex. These structural (pathologic) murmurs warrant referral to a cardiologist for further evaluation.¹⁻³

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Diastolic murmurs, such as those caused by mitral stenosis or aortic regurgitation, are heard best at the cardiac apex and are also structural (pathologic) and warrant further evaluation, including referral to a cardiologist.³

Innocent systolic murmurs, like Still's murmur, are common in children and often disappear by adulthood. Depending upon the clinical situation, some clinicians may follow these patients with repeat auscultation only.^{4, 5}

The clinician should refer to recommended clinical management guidelines to determine appropriate actions for innocent and structural murmurs.



Note

Proper handling of the Eko digital stethoscope (the CORE, CORE 500™, or DUO) to minimize external background noise and hand rub/clicks should be practiced.



Note

The software will not detect cardiac conditions that do not cause heart murmurs.



Note

All heart sound listening positions should be analyzed before making a referral decision.



Note

This software does not analyze lung sounds.



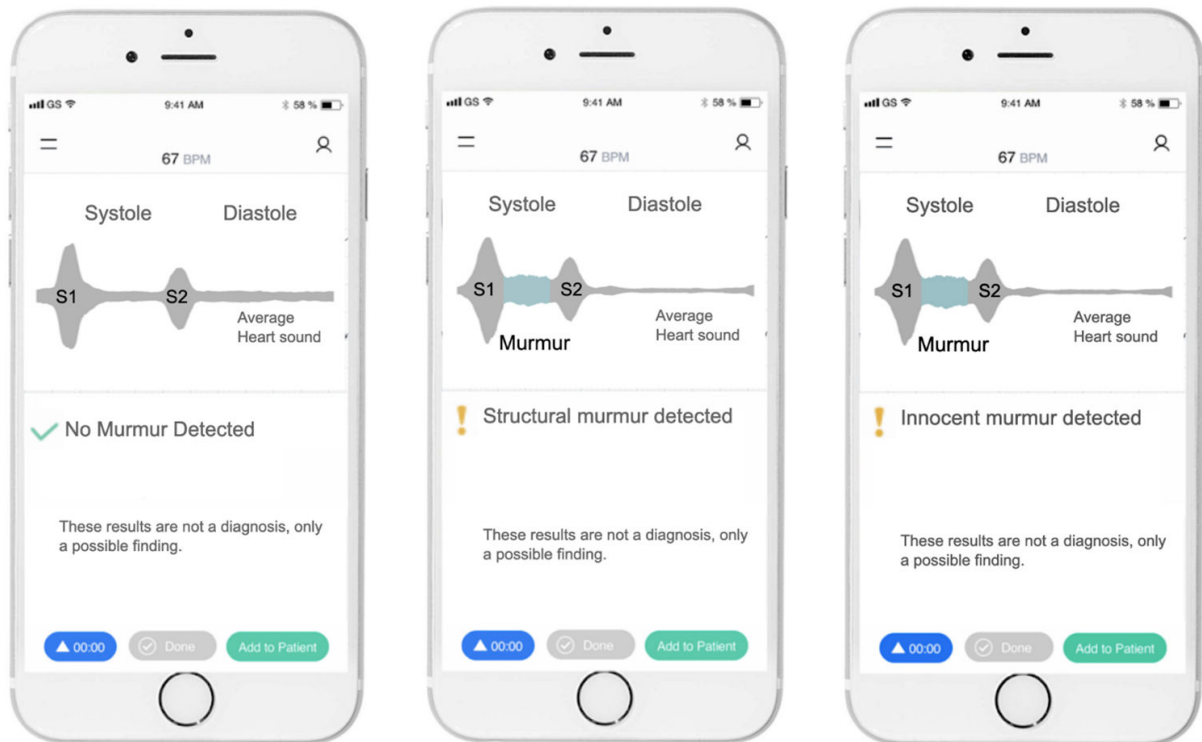
Note

In some circumstances, EMAS may incorrectly identify a continuous heart murmur as either systolic or diastolic. However, clinical decision making should not be affected, as the device will correctly identify continuous heart murmurs as 'structural' 85.6% of the time based on our clinical validation.

Eko Murmur Analysis Software (EMAS)

References

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2. Chorba JS, Shapiro AM, Le L, Maidens J, Prince J, Pham S, et al. Deep Learning Algorithm for Automated Cardiac Murmur Detection via a Digital Stethoscope Platform. J Am Heart Assoc 2021;10:e019905. doi:10.1161/JAHA.120.019905.
3. Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP, Gentile F, et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease: Executive Summary: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2021;143:e35–e71. doi:10.1161/CIR.0000000000000932.
4. Choi HJ. Evaluation and diagnostic approach for heart murmurs in children. J Korean Med Assoc 2020;63:398–403. doi:10.5124/jkma.2020.63.7.398.
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Averaged phonocardiogram with no murmur detected

Averaged phonocardiogram with structural murmur detected and highlighted during systole

Averaged phonocardiogram with innocent murmur detected and highlighted during systole

Figure 1: Example EMAS outputs as seen on a smartphone screen

3.0 Clinical Performance Summary

The Eko Murmur Analysis Software has been validated using retrospective analysis on a proprietary database. The database contains 2,380 unique heart sound recordings from 615 unique subjects. In the proprietary database, all heart sound recordings were collected using the Eko CORE (67.6%) or Eko DUO (32.4%) digital stethoscopes. The subject population was 42.6% female and had an age range of 0 to 95 years old. Race was recorded in 45% of the subjects and out of that subset, 98% were white, 1.5% were African American and 0.7% were Asian. No complications or adverse events were experienced during the use of the EMAS device.

All recordings were annotated by multiple cardiologists in respect to their quality and the presence of any murmur. Of the recordings identified as being good signal by the expert cardiologists, 45.8% had a confirmed structural murmur and 54.2% had a confirmed no murmur or innocent murmur. Ground truth for murmur classification was obtained via pairing cardiologist annotations with gold standard echocardiogram. Additionally, 299 heart sound recordings were annotated by expert cardiologists to obtain the timing of the S1 and S2 sounds. Cardiologists were blinded to all subject demographic data and echocardiogram findings during annotation.

No study subjects included in the training datasets were included in the test database. All algorithm testing was performed once the final EMAS version was locked.

The following tables demonstrate the results of the primary performance analyses (Murmur Classification and Heart Sound Timing).

Table 1. EMAS Murmur Classification Performance

	Sensitivity (%)	Specificity (%)
Murmur Classification	85.6 (95% CI: 82.6 – 88.7)	84.4 (95% CI: 81.3 – 87.5)

Table 2. EMAS Heart Sound Timing Performance

	Sensitivity (%)	PPV (%)
Heart Sound Timing	S1 Detection (95% CI: 94.9 – 97.4)	96.2 (95% CI: 96.3 – 98.0)
	S2 Detection (95% CI: 90.3 – 94.3)	92.3 (95% CI: 93.4 – 95.1)

Table 3. Expected EMAS Performance Across Age-ranges²

	Expected Prevalence ⁶ (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
age ≤ 18	5	82.0	82.9	22.3	98.9
age > 18	20	90.2	90.6	70.6	97.4

Assuming a structural murmurs prevalence of 5% in pediatrics, we expect to see a PPV of 22% and an NPV of 99%. Namely, 22% of the recordings where the algorithm returns a positive finding are expected to have a true structural murmur and 99% of the recordings where the algorithm returns a negative finding are expected to not have a structural murmur.

Similarly, assuming a structural murmurs prevalence of 20% in adults, we expect to see a PPV of 60% and an NPV of 97%. Namely, 60% of the recordings where the algorithm returns a positive finding are expected to have a true structural murmur and 97% of the recordings where the algorithm returns a negative finding are expected to not have a structural murmur.

The algorithm performs better at detecting murmurs with a high grade. In addition, the algorithm shows higher sensitivity on recordings where a panel of cardiologists agree that a murmur is present (Sensitivity = 88%, Specificity = 83%). Sensitivity is lower on recordings where a panel of cardiologists cannot reach an agreement and an additional cardiologist was used for final confirmation (Sensitivity = 25%, Specificity = 87%).

Table 4. Diastolic Murmur Detection Performance

	Sensitivity (%)	Specificity (%)
	EMAS	EMAS
Diastolic Murmur Detection	80.8 (95% CI: 60.6 – 100.0)	89.8 (95% CI: 84.5 – 95.2)

² References:

6. Menashe, V. (2007). Heart murmurs. *Pediatrics in review*, 28(4), e19-e22.

4.0 Eko App

Download the Eko App, available on the App Store® or Google Play Store® and follow the on-screen setup instructions to access the Eko Murmur Analysis Software.

5.0 Regulatory Information



Eko Health, Inc.
2100 Powell St., Suite 300
Emeryville, CA 94608 USA
www.ekohealth.com



Authorized UK Responsible Person:
Emergo Consulting (UK) Limited
c/o Cr360 – UL International
Compass House, Vision Park Histon
Cambridge CB24 9BZ
United Kingdom



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