



February 26, 2025

Infraredx, Inc.
Stephen Sum
Senior Vice President R&D, Clinical, Quality, and Regulatory
28 Crosby Drive
Suite 100
Bedford, Massachusetts 01730

Re: K241576

Trade/Device Name: Makoto Intravascular Imaging System™ (TVC-MC10/TVC-MC10i);
Dualpro™ IVUS + NIRS Imaging Catheter (TVC-C195-42);
Claripro™ 014 Imaging Catheter (TVC-E195-42)
Regulation Number: 21 CFR 870.1200, 21 CFR 892.1560,
Regulation Name: Diagnostic Intravascular Catheter, Ultrasonic Pulsed Echo Imaging System,
Regulatory Class: Class II
Product Code: OBJ, OGZ, IYO
Dated: January 27, 2025
Received: January 27, 2025

Dear Stephen Sum:

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,

MARCO CANNELLA -S

for

Aneesh Deoras
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

Enclosure

Indications for Use

510(k) Number (if known)

K241576

Device Name

Makoto Intravascular Imaging System™ (TVC-MC10 / TVC-MC10i);

Dualpro™ IVUS+NIRS Imaging Catheter (TVC-C195-42);

Clarispro™ HD-IVUS Imaging Catheter (TVC-E195-42)

Indications for Use (Describe)

1. The Makoto Intravascular Imaging System™ is intended for the near-infrared examination of coronary arteries in patients undergoing invasive coronary angiography.

a. The System is intended for the detection of lipid-core-containing plaques of interest.

b. The System is intended for the assessment of coronary artery lipid core burden.

c. The System is intended for the identification of patients and plaques at increased risk of major adverse cardiac events.

2. The System is intended for ultrasound examination of coronary and peripheral intravascular pathology.

a. Intravascular ultrasound imaging is indicated in patients who are candidates for transluminal coronary and peripheral interventional procedures. The System is not indicated for use in the cerebral vessels.

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.

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510(k) Summary

Prepared On

02/03/2025

Contact Details

Applicant Name	Infraredx, Inc.
Applicant Address	28 Crosby Drive Suite 100, Bedford, MA 01730 USA
Applicant Telephone	781.345.9651
Applicant Contact	Dr. Stephen Sum
Applicant Contact Email	ssum@infraredx.com

Device Name

Device Trade Name	Makoto Intravascular Imaging System™ (TVC-MC10 / TVC-MC10i); Dualpro™ IVUS+NIRS Imaging Catheter (TVC-C195-42); Clarispro™ HD-IVUS Imaging Catheter (TVC-E195-42)
Common Name	Diagnostic intravascular catheter Ultrasonic Pulsed Echo Imaging System
Classification Name	Catheter, Intravascular, Plaque Morphology Evaluation
Regulation Number	870.1200, 892.1560
Product Code(s)	OGZ, IYO, OBJ

Legally Marketed Predicate Devices

Predicate Number	Predicate Trade Name	Product Code
K213303	TVC-E195-42, TVC-C195-42 & TVC-MC10/MC10i	OBJ, IYO, OGZ

Device Description Summary

The Makoto Intravascular Imaging System™ is an intravascular imaging device with the ability to simultaneously assess vessel composition and structure using near-infrared spectroscopy (NIRS) and intravascular ultrasound (IVUS). This dual-modality instrument performs near-infrared spectroscopic analysis of the vessel to detect lipid core-containing plaques of interest (LCP) displayed in a map called a Chemogram, and simultaneously generates high resolution IVUS images that display structural details of the vessel and plaque in transverse and longitudinal views.

Intended Use/Indications for Use

1. The Makoto Intravascular Imaging System™ is intended for the near-infrared examination of coronary arteries in patients undergoing invasive coronary angiography.
 - a. The System is intended for the detection of lipid-core-containing plaques of interest.

- b. The System is intended for the assessment of coronary artery lipid core burden.
 - c. The System is intended for the identification of patients and plaques at increased risk of major adverse cardiac events.
2. The System is intended for ultrasound examination of coronary and peripheral intravascular pathology.
- a. Intravascular ultrasound imaging is indicated in patients who are candidates for transluminal coronary and peripheral interventional procedures. The System is not indicated for use in the cerebral vessels.

Indications for Use Comparison

The indications for use are the same.

Technological Comparison

The subject of this premarket notification is the addition of two software features on the Makoto Imaging System. These features are Automatic Border Contouring (referred to herein as ABC) and Guide Catheter Detection (referred to herein as GCD). The ABC software will assist physicians by automatically identifying the borders of the lumen and external elastic membrane (EEM) within the vasculature. The GCD software will assist physicians by automatically detecting the guide catheter edge during imaging procedures.

The proposed device has the same scientific principles of operation, principal technological characteristics, and safety profile as the currently marketed predicate device (K213303). Only minor design changes to the predicate device have been implemented. The tables below compare the general, catheter, controller, and console characteristics of the proposed and predicate devices.

General Characteristics			
Characteristic	PROPOSED DEVICE Infraredx TVC-E195-42, TVC-C195-42 & TVC-MC10/ MC10i	PREDICATE DEVICE Infraredx TVC-E195-42, TVC-C195-42 & TVC-MC10/ MC10i (K213303)	Comparison with Predicate Device
Product Function	Near Infrared and Ultrasound Imaging System	Near Infrared and Ultrasound Imaging System	Same
Intended Use	The Makoto Intravascular Imaging System™ is intended for the near-infrared examination of coronary arteries in patients undergoing invasive coronary angiography. The System is intended for the detection of lipid-core-containing plaques of interest. The System is intended for the assessment of coronary artery lipid core burden. The System is intended for the identification of patients and plaques at increased risk of major adverse cardiac events. The System is intended for ultrasound examination of coronary and peripheral intravascular pathology. Intravascular ultrasound imaging is indicated in patients who are candidates for transluminal coronary and peripheral interventional procedures. The System is not indicated for use in the cerebral vessels.	The Makoto Intravascular Imaging System™ is intended for the near-infrared examination of coronary arteries in patients undergoing invasive coronary angiography. The System is intended for the detection of lipid-core-containing plaques of interest. The System is intended for the assessment of coronary artery lipid core burden. The System is intended for the identification of patients and plaques at increased risk of major adverse cardiac events. The System is intended for ultrasound examination of coronary intravascular pathology. Intravascular ultrasound imaging is indicated in patients who are candidates for transluminal coronary interventional procedures.	Same
Where Used	Coronary and Peripheral	Coronary and Peripheral	Same
System Components	NIR/IVUS Catheter Portable or Fixed Console (Laser, SBC, power supply) and Controller	NIR/IVUS Catheter Portable or Fixed Console (Laser, SBC, power supply) and Controller	Same
Classification	Catheter – Product Code OGZ, OBJ 21 CFR 870.1200 System Product Code IYO 21 CFR 892.1560	Catheter – Product Code OGZ 21 CFR 870.1200 System Product Code IYO 21 CFR 892.1560	Same

Catheter Characteristics			
Characteristic	PROPOSED DEVICE Infraredx TVC-E195-42, TVC-C195-42 & TVC-MC10/ MC10i	PREDICATE DEVICE Infraredx TVC-E195-42, TVC-C195-42 & TVC-MC10/ MC10i (K213303)	Comparison with Predicate Device
Usable Length	160 cm	160 cm	Same
Sheath Distal Tip Profile	2.4 F	2.4 F	Same
Guidewire rail length	1.2 cm	1.2 cm	Same
Imaging window profile	3.2 F	3.2 F	Same
Imaging core pullback	15 cm	15 cm	Same
Number of RO Marker Bands	1 RO marker (0.5cm from distal tip)	1 RO marker (0.5cm from distal tip)	Same
Maximum guidewire OD	0.014 in.	0.014 in.	Same
Minimum guide catheter I.D.	6 F	6 F	Same
Method of Sterilization	EtO	EtO	Same
Materials supplied in sterile packaging	Intravascular NIR/IVUS catheter Priming accessory Controller sterile barrier	Intravascular NIR/IVUS catheter Priming accessory Controller sterile barrier	Same
Shelf Life	36 months	36 months	Same
Transducer Center Frequency	50MHz	50MHz	Same

Controller and Console Characteristics			
Characteristic	PROPOSED DEVICE Infraredx TVC-E195-42, TVC-C195-42 and TVC-MC10/ MC10i	PREDICATE DEVICE Infraredx TVC-E195-42, TVC-C195-42 and TVC-MC10/ MC10i (K213303)	Comparison with Predicate Device
Imaging Mode	Near Infrared light, Ultrasound	Near Infrared light, Ultrasound	Same
Output	NIR light RF Ultrasound	NIR light RF Ultrasound	Same
Hardware Components	CPU with 16GB RAM 1 Monitor and 1 Touchscreen Monitor Swept Source Laser	CPU with 16GB RAM 1 Monitor and 1 Touchscreen Monitor Swept Source Laser	Same
Laser Type	Swept Source Semiconductor Laser	Swept Source Semiconductor Laser	Same

Imaging element pullback speed	0.5, 1.0, and 2.0 mm/s	0.5, 1.0, and 2.0 mm/s	Same
Pullback Distance	150mm	150mm	Same
Controller Housing	Handle	Handle	Same
Controller RFID	Enabled for catheter type identification	Enabled for catheter type identification	Same
Controller User Interface	LCD screen	LCD screen	Same
Graphical User Interface	NIRS-IVUS image for coronary scanning (TVC-C195-42) IVUS image only for peripheral scanning (TVC-E195-42)	NIRS-IVUS image for coronary scanning (TVC-C195-42) IVUS image only for peripheral scanning (TVC-E195-42)	Same
Contouring of lumen and EEM borders in IVUS image	Automatic or manual contouring of vessel borders	Manual contouring of vessel borders	Substantially equivalent
Detection of guide catheter edge	Automatic detection of guide catheter edge based on IVUS	Automatic detection of guide catheter edge based on NIRS	Substantially equivalent

Non-Clinical and/or Clinical Tests Summary and Conclusions

Design verification and validation bench testing was conducted for the changes in scope of this premarket application. Animal and clinical testing were not performed.

The bench testing demonstrates that the proposed device is substantially equivalent to the predicate device.

The sterilization and shelf-life evaluations of the catheters reported in this premarket notification show that the sterilization process remains acceptable and that the proposed device maintains a 36-month shelf life, consistent with the predicate device.

The biocompatibility testing of the catheters was conducted for an external communicating device in circulating blood, with a limited contact duration of ≤ 24 hrs. The series of testing was conducted utilizing Good Laboratory Practice (GLP) following ISO 10993 and ASTM standards. Biocompatibility testing was performed for cytotoxicity, sensitization, irritation/intracutaneous reactivity, acute systemic toxicity, material mediated pyrogenicity, and hemocompatibility. All tests met the pre-determined acceptance criteria, as specified in the test protocols and associated test standards.

Minor hardware changes to accommodate the subject changes (ABC and GCD features) in the imaging console presented a potential impact on the electromagnetic interference (EMI) performance of the Makoto system. Testing of the system showed no significant increase in EMI.

Software verification and validation testing was also conducted for the subject changes included in this premarket application. The ABC and GCD testing successfully met all the criteria specified in the test protocol.

The following tables present the performance evaluation of ABC and GCD algorithms on blinded test data.

The ABC acceptance criteria were established based on an approved protocol and report which conducted an inter- and intra-reader variability study with three expert readers, 30 samples, and two trials. This study provided a benchmark for expected variability in manual contouring, ensuring that the algorithm's performance aligns with clinical practice standards.

Performance was assessed using error metrics, including diameter difference, area difference, and Hausdorff distance (HD) for lumen and EEM contours. For guide catheter detection, performance was evaluated based on detection accuracy, sensitivity, and specificity.

ABC Performance Evaluation Results on Test Data				
Performance Metric	Contour	Acceptance Criteria	ABC Performance Evaluation on Test Data	Result
Bland-Altman Plot Diameter Difference Limits of Agreement (95% CI) (mm)	Lumen	+/- 0.59	[-0.37, 0.41]	PASS
Bland-Altman Plot Diameter Difference Limits of Agreement (95% CI) (mm)	EEM	+/- 0.74	[-0.54, 0.52]	PASS
Bland-Altman Plot Area Difference Limits of Agreement (95% CI) (mm ²)	Lumen	+/- 3.46	[-2.3, 2.48]	PASS
Bland-Altman Plot Area Difference Limits of Agreement (95% CI) (mm ²)	EEM	+/- 6.18	[-4.5, 4.0]	PASS
Forward Hausdorff Distance 95% CI (mm)	Lumen	< 0.63	[0.27, 0.29]	PASS
Forward Hausdorff Distance 95% CI (mm)	EEM	< 0.66	[0.31, 0.35]	PASS
Reverse Hausdorff Distance 95% CI (mm)	Lumen	< 0.63	[0.26, 0.28]	PASS
Reverse Hausdorff Distance 95% CI (mm)	EEM	< 0.66	[0.29, 0.32]	PASS

Frame Level GCD Results			
Metric	Value	Acceptance Criteria	Result
AUC	0.98	0.9	PASS
Sensitivity	0.86		
Specificity	1.00		

Scan Level GCD Results			
Metric	Value	Acceptance Criteria	Result
Total Individual Scan Level GCD Failures*	2		
Sensitivity	0.93	0.9	PASS
Specificity	0.93	0.9	PASS

* False negatives and false positives

These results demonstrate that the subject device performs within clinically acceptable limits, as determined by inter-reader variability in manual contouring and predefined acceptance thresholds.

For scan level accuracy assessments, true positives were defined as results where a GC was correctly predicted within +/- 2 mm of the true location. True negatives were defined as results where no GC was predicted, when no GC was present according to ground truth. False positives were defined as scans where the predicted GC location was outside of the +/- 2 mm window of the true GC location, or when no GC was present according to the ground truth. False negatives were defined as scans where no GC location was predicted, while the truth showed a GC. Scans containing less than 2 mm of total GC length were defined as negatives for ground truth.

The following table provides a detailed breakdown of the test dataset, including the number of unique patients, frames, and scans. The test dataset consists of 18 unique patients, ensuring that the algorithm is evaluated on an independent dataset with no patient overlap from the calibration dataset. Among the 18 patients, 29 total scans were used for testing, with 12 of these from Japanese hospitals (5 patients across 3 sites), and 17 from US hospitals (13 patients across 3 sites). At the frame level, there were 381 frames included from Japanese hospitals and 609 frames included from US hospitals.

To ensure that the test dataset encapsulates clinically relevant disease states, patients are characterized based on the presence of calcium and stent struts, both of which are key indicators of disease severity. Calcium presence affects EEM contouring accuracy due to shadowing artifacts, while the presence of stent struts introduces additional challenges in segmentation. The test dataset also includes patient cases with guidewire and side branches, further ensuring that real-world imaging complexities are represented.

Test Data Summary and Characteristics							
Data Group	Frames	Patients	Scans	% Calcium Presence*	% Guidewire Presence*	% Side Branch Presence*	% Stent Strut Presence*
Test	981	18	29	38.9%	96.6%	9.2%	20.7%

* These percentages refer to % of frames

The fixed acquisition parameters of the Makoto Intravascular Imaging System™ are intrinsic to the Dualpro/Clarispro 014 IVUS transducer and TVC-M10/MC10i imaging system, and are not user-modifiable.

- Penetration Depth: The system offers a penetration depth of approximately

- 8 mm, corresponding to a 16 mm maximum field of view. This depth is preset to ensure optimal visualization of vascular structures. Notably, penetration depth is inversely related to ultrasound frequency.
- Focus: The focusing characteristics of the ultrasound beam are determined by the transducer's intrinsic properties. Key parameters include:
 - Focal Length: This is the distance from the transducer to the point where the ultrasound beam is most narrowly focused, optimizing lateral resolution. The focal length is influenced by the transducer's diameter and the ultrasound frequency.
 - Focal Point Diameter: This refers to the beam's width at its narrowest point. Larger transducer diameters and higher frequencies result in a reduced focal point diameter.
 - Frequency: The transducer operates at a nominal frequency of 50 MHz, with a variation range between 48 MHz and 53 MHz.
 - Operation Mode: The Makoto imaging system (TVC-MC10/MC10i) operates in B-mode, presenting images in a Cartesian coordinate system with fixed number of pixels along both the X and Y axes. These settings are pre-configured and cannot be modified by the user.

The reference standard for the testing dataset was established using six expert IVUS readers who served as ground truth annotators. The annotation process was standardized through the use of IVUS Tracing Guidelines and a proprietary in-house developed tracing software to ensure consistency and reproducibility. Annotators followed specific instructions for contour and structure identification, including:

- Guide catheter and stent regions: Identification of relevant structures.
- Guidewire marking: Placement of marking points at the brightest point or closest GW position.
- Lumen and EEM contours: Marking points used to delineate the lumen and EEM boundaries.
- Calcium arcs: Placement of marks on the luminal edge of each calcified feature.
- Stent struts: Marking the center of each identifiable stent strut.

The test dataset was annotated by 6 expert readers, two of whom did not participate in annotating the calibration dataset. While four annotators were shared between calibration and test datasets, the impact of this overlap was mitigated through randomized site allocation and diverse annotation styles to ensure the model did not learn specific annotator tendencies.

The differences in the truthing process between calibration and test datasets were designed to reduce potential bias and ensure an independent performance evaluation. Although some annotators and sites overlapped, there was no patient overlap, and the diverse set of readers provided variability in annotation styles, preventing the model from overfitting to a single annotation methodology.

Several steps were taken to ensure that the test dataset remained independent from the training dataset, preventing data leakage and enabling an unbiased evaluation of model

performance.

First, there was no patient overlap between the calibration and test datasets, ensuring that the model was assessed on previously unseen patient cases. This prevented the algorithm from memorizing specific anatomical features or imaging patterns from training patients, reinforcing its generalizability.

Second, the test dataset was collected from 6 clinical sites. While 3 of these test sites overlapped with calibration sites, half of the test sites were entirely new, ensuring that the model encountered imaging conditions not previously seen during training. This approach helped validate the model's ability to generalize across different imaging environments.

Third, a diverse set of annotators was used in both the calibration and test datasets to introduce variability in annotation behaviors. The test dataset was annotated by 6 readers, two of whom were not involved in the calibration dataset. This diversity ensured that the model was not exposed to a single annotation style, allowing it to generalize across different annotation behaviors commonly seen in clinical practice.

Additionally, annotators were randomly assigned data from different sites, preventing systematic biases related to site-specific annotation tendencies. The inclusion of multiple annotators with varied annotation styles further ensured that the truthing process for the test dataset remained independent of model development, preventing annotation bias from influencing test results.

Finally, the test dataset was blinded, meaning the algorithm developers had no exposure to the test patient cases during training or tuning (and the annotators had no exposure to the algorithm). This ensured that model evaluation reflected real-world clinical performance rather than learned biases from prior exposure. These measures collectively ensured that the test dataset provided an independent, unbiased assessment of model performance, supporting regulatory requirements for substantial equivalence.