SUMMARY OF:

P010031/S513 bundled with
P080006/S085, P920015/S163, P930039/S140, P090013/S202 and P890003/S338
Amplia MRI and Compia MRI CRT-D SureScan Systems

EXECUTIVE SUMMARY/BACKGROUND

The CRT-D MRI devices are multi-programmable cardiac devices that monitor and regulate the patient's heart rate by providing single or dual chamber, rate-responsive bradycardia pacing, sequential biventricular pacing, ventricular tachyarrhythmia therapies, and atrial tachyarrhythmia therapies.

The Amplia MRI/Amplia MRI Quad CRT-D SureScan and Compia MRI/Compia MRI Quad CRT-D SureScan Implantable Cardioverter Defibrillator with Cardiac Resynchronization System (CRT-D MRI System) is an MR conditional system. The CRT-D MRI devices are compatible with the Attain Ability MRI SureScan (IS-1 bipolar) lead models and Attain Performa MRI SureScan (IS4 quadripolar) lead models and have system software Model SW034 that supports the SureScan feature in order to provide a complete MR conditional system.

The CRT-D MRI devices are intended to be compatible with any current and future approved SureScan right atrial pacing leads, including CapSureFix MRI SureScan Model 5086MRI and CapSureFix Novus MRI SureScan Model 5076 leads, and SureScan defibrillation leads, including the Sprint Quattro Secure MRI SureScan Lead Models 6935M and 6947M.

The CRT-D MRI devices may also be compatible with non-MR Conditional labeled leads; however, MRI scanning of the system with non-MR Conditional labeled components is contraindicated.

The CRT-D MRI device models leverage the form and functionality of the Viva/Brava and Viva/Brava quadripolar CRT-D devices, while additionally providing the SureScan feature set that allows for MR Conditional use in the MRI environment. Additional new and changed features are also included and intended to improve CRT response and reduce the longevity impact of events such as AT/AF episodes, wireless telemetry usage and high LV thresholds.

The SureScan technology included in the CRT-D MRI devices is identical to that included in the Evera MRI (P980016/S536, approved September 11, 2015).

INDICATIONS FOR USE

The non-MRI indications for use of the Amplia MRI /Amplia MRI Quad CRT-D SureScan and Compia MRI /Compia MRI Quad CRT-D SureScan devices are the same as those approved for the predecessor Viva/Brava devices.

The Indications for use for the Attain Ability MRI SureScan and Attain Performa MRI SureScan left ventricular lead models included in this submission are not changing.

The Indications for use for the Sprint Quattro, 5076 and 5086MRI SureScan lead models included in this submission are not changing.

DEVICE DESCRIPTION

The CRT-D MRI devices are based on the predecessor Viva/Brava family of devices (P010031/S318, January 2013) and the quadripolar models (P010031/S442, July 2014). The CRT-D MRI devices leverage the form and functionality of the Viva/Brava family of devices while additionally providing for the device and lead system to be labeled as MR Conditional for the MR environment. At a high level, the device changes required to address this additional environmental functionality consist of updates to the hybrid assembly, the firmware, identifying radiopaques in the connector modules, and product labeling (device markings, as well as manual content).

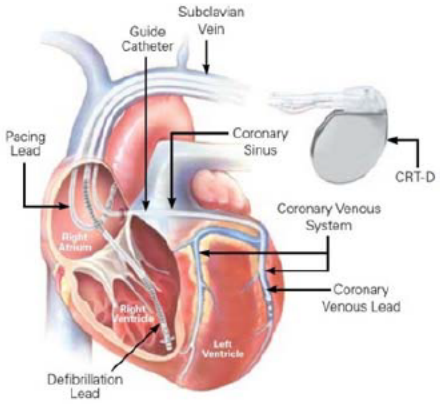
Although the predecessor devices are available with DF4 or DF-1 connector ports, the CRT-D MRI devices included in this submission include only DF4 connector ports. The Amplia MRI CRT-D devices and the Compia MRI CRT-D devices contain two IS-1 and one DF4 connector ports and the Amplia MRI Quad CRT-D devices and the Compia MRI Quad CRT-D devices contain one IS-1, one IS4, and one DF4 connector ports.

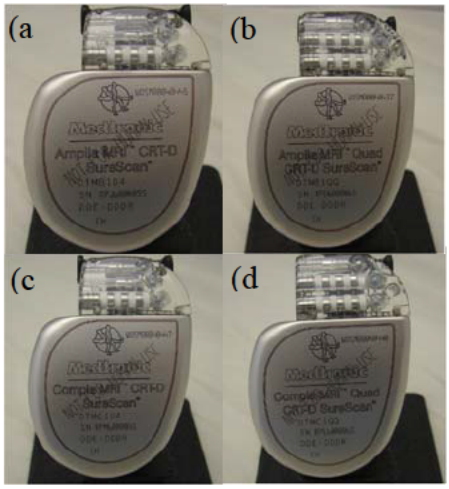
The CRT-D MRI devices all contain the same device firmware code and use the same software application, SW034. The CRT-D MRI devices firmware is based on the Evera MRI ICD firmware (P980016/S536, September 11, 2015). The Evera MRI firmware is based on the approved predecessor Viva/Brava/Evera family of devices firmware with updates to include the SureScan algorithm for ICDs (similar to IPG SureScan) and other MRI related enhancements. These MRI-related additions to the Evera MRI firmware are identical to those included in the CRT-D MRI firmware.

CRT-D MRI		Predecessors	
Models Name	Model Number	Models Name	Model Number
Amplia MRI CRT-D	DTMB1D4	Viva™ XT	DTBA1D4
Amplia MRI Quad CRT-D	DTMB1QQ	Viva™ XT Quad	DTBA1QQ
Compia MRI CRT-D	DTMC1D4	Brava™	DTBC1D4
Compia MRI Quad CRT-D	DTMC1QQ	Brava™ Quad	DTBC1QQ

The firmware for the CRT-D MRI devices also includes additional new and changed features compared to the Viva/Brava family of devices intended to improve CRT response and reduce the longevity impact of events such as AT/AF episodes, wireless telemetry usage and high LV thresholds. The software application SW034 is based on the predecessor Viva/Brava SW016 but with the inclusion of the SureScan feature set and additional new or modified features.

The principles of operation of the CRT-D MRI devices are the same as those of the predecessor Viva/Brava family of devices.





(a) Amplia MRI, (b) Amplia MRI Quad, (c) Compia MRI, (d) Compia MRI Quad.

Configuration / Feature	Viva / Brava CRT-D and Viva / Brava Quadripolar CRT-D Devices (P010031/S318 approved January 29, 2013 and Viva/Brava Quadripolar P010031/S442, approved July 3, 2014).	Amplia / Compia MRI CRT-D and Amplia /Compia MRI Quad CRT-D Devices (Subject of this submission)
Lead Connections Offered	Bipolar = Two IS-1 / One DF4† Quadripolar = One IS-1 / One DF4† / One IS-4	Bipolar = Two IS-1 / One DF4† Quadripolar = One IS-1 / One DF4† / One IS-4
Body Thickness (mm)	13.5	Same
Volume (cc)	35	Same
Mass (g)	Bipolar = 80 Quadripolar = 81	Bipolar = 80 Quadripolar = 81
Longevity (yrs)	6.1‡	Same
Rate Response Sensor	Accelerometer (1-beam)	Same
Capacitors	3-High Voltage wet electrolytic tantalum capacitors	Same
Maximum Energy (joules)	35	Same
Telemetry	Telemetry B, Telemetry C and Telemetry M (Telemetry M module operating in Telemetry C protocol mode)	Same
Case material	Titanium	Same
Battery	Lithium silver vanadium oxide/carbon monofluoride hybrid	Same

Six Medtronic LV lead models will be compatible with the Viva and Viva Quad MRI CRT-D devices: three bipolar Attain Ability lead models (4196, 4296, and 4396) and three quadripolar Attain Performa lead models (4298, 4398, and 4598). These leads have application for chronic pacing in the left ventricle via the cardiac vasculature when used in conjunction with a compatible Medtronic cardiac resynchronization therapy (CRT) system. These leads are not being physically modified in support of MR Conditional labeling, and no changes are needed for the leads to be used with a Viva or Viva Quad MRI CRT-D device. All six leads have market approval, with the following approval history:

Figure 1-2: Attain Ability MRI SureScan and Attain Performa MRI SureScan Lead Models

Figure 1-3: IS4 and IS-1 Lead Connctors

Lead Model	Approval
4196	P080006, April 2008
4296	P080006/S002, April 2011
4396	P080006/S004, March 2011
4298	P080006/S068, August 2014
4398	P080006/S073, December 2014
4598	P080006/S073, December 2014

Lead Model	Lead Lengths	Fixation	Connector
4196	78, 88 cm	Angled Body	IS-1
4296	78, 88 cm	Angled Body	IS-1
4396	78, 88 cm	Tined fixation	IS-1
4298	78, 88 cm	Angled Body	IS-4
4398	78, 88 cm	Tined fixation	IS-4
4598	78, 88 cm	S-shape Body	IS-4

In addition to the LV leads listed above, the firm is also including the Sprint Quattro Secure MRI SureScan Models 6947M and 6935M RV defibrillation leads as well as the RA CapSureFix MRI SureScan 5086MRI and CapSureFix Novus MRI SureScan 5076 pacing leads in this submission. These leads have been approved for use with the Evera MRI ICD system (P980016/S536, September 11, 2015).

PRECLINICAL/BENCH

The firm indicated that the safety and effectiveness of the Amplia and Compia MRI CRT-D devices were demonstrated through comprehensive device and system level verification and validation bench testing in conjunction with complementary modeling and animal testing; demonstrating that the devices meet their specifications in the intended environment. The firm furthermore stated that safety and effectiveness is supported through prior clinical data for the non-MRI Viva/Brava family of devices and the Evera MRI ICD (P980016/S536, approved September 11 2015) based on the close similarity of these device families.

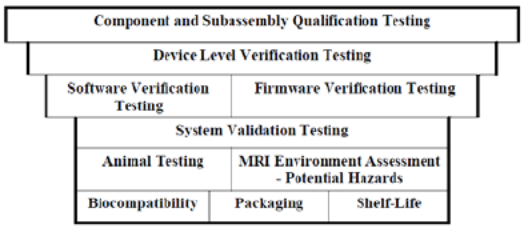


Figure 2-1: Overview of the Non-Clinical activities for the CRT-D MRI devices

The firm indicated that equivalency to design qualification, verification and validation testing activities were leveraged from the predecessor Viva/Brava family of devices and the Evera MRI ICD where possible and the firm included equivalency documentation in this submission.

The firm stated that testing for new design requirements for the CRT-D MRI devices related to the new device features and functionality that could not be verified by equivalency are presented in this submission. The associated testing structure consisted of the activities identified in Figure 2-1 above and is consistent with those completed for the predecessor devices.

The firm indicated that the Attain Ability and Attain Performa lead models have been verified and validated and are market released (see approval dates by lead model on previous page) . The firm asserted that the MR Conditional relabeled leads are identical to the market released leads. Since the verification and validation testing for these leads have already been reviewed the firm only included

system level testing for MR Conditional use of these leads as a part of the CRT-D MRI System in the potential MR hazards evaluation.

The Sprint Quattro Secure and Secure S Lead models have been verified and validated and are market released. The Sprint Quattro Secure MRI SureScan Lead models are the exact same leads and were relabeled for MR Conditional use per P980016/S536 (approved September 11, 2015) for use with the Evera MRI ICD system. Similarly, the 5076 and 5086MRI RA leads were approved for use with the Evera MRI ICD systems and have not been modified. The firm indicated that this submission includes data showing that the MR hazard evaluation for the Sprint Quattro, 5076 and 5086MRI leads for the Evera MRI ICD system is applicable for the Amplia/Compia CRT-D MRI systems.

BIOCOMPATIBILITY/MATERIALS

The firm indicated that the biocompatibility of the tissue-contacting materials used in the CRT-D MRI devices has been established in previous PMA applications. The materials and manufacturing processes used for the CRT-D MRI devices are the exact same as those used for the Viva/Brava family of devices.

Additionally, the biocompatibility that was demonstrated for the market released Attain Ability and Attain Performa leads during FDA PMA review is unchanged and remains valid. There are no changes to the tissue contacting materials or related manufacturing processes required for exposure of these leads to MRI in the clinical setting.

Regardless of the rationale, the firm included the biocompatibility report for the CRT-D MRI devices in Volume 5 of this submission.

Reviewer's Comment: The rationale regarding the biocompatibility of the device(s) and lead(s) is acceptable and in fact is extended to the Sprint Quattro, 5076 and 5086MRI leads.

MANUFACTURING/STERILIZATION/PACKAGING/SHELF LIFE

Sterilization is qualified by equivalence to the predecessor Viva/Brava CRT-D family of devices. The ethylene oxide sterilization process for the CRT-D MRI is the same as the approved sterilization process for other FDA approved Medtronic implantable devices, including Viva/Brava family of devices. The sterilization information for the CRT-D MRI devices was provided in the Sterilization section of this submission. Similarly, the ethylene oxide sterilization process that has been qualified for the market released Attain Ability and Attain Performa leads during FDA PMA review is unchanged and remains valid.

The firm states that the labeled shelf life of the CRT-D MRI devices is qualified by equivalence to the predecessor Viva/Brava family of devices and points towards the Shelf Life section in Volume 5 for the equivalence rationale. The equivalence testing is also applied to the leads.

The firm asserts that the CRT-D MRI devices use the identical packaging components and packaging processes as the predecessor Viva/Brava family of devices. The rationale for application of the package qualification testing to the CRT-D MRI devices was provided in section Device Level Verification Testing. The equivalence testing is also applied to the leads.

The firm indicates (Volume 6, page 9) that the manufacturing processes, including packaging and sterilization, are not changing for the leads included in this submission upon FDA approval for MR Conditional labeling for use with the Amplia/Compia CRT-D MRI device. All aspects of manufacturing and sterilization continue to be the same, regardless of MR conditional labeling.

The firm states (Volume 6, page 8) that the Amplia /Compia CRT-D SureScan devices will be manufactured at the facilities identified in Table 6-1 (Volume 6, page 8). These are the same manufacturing facilities that are approved for the predecessor Viva/Brava family of devices as well as the Evera MRI ICD (P980016/S536, approved September 11, 2015).

The firm asserts (Volume 6, page 10) that the manufacturing processes for the CRT-D MRI devices are the same as the manufacturing processes for the approved predecessor Viva/Brava family of devices as well as the Evera MRI ICD. The firm provided a high level flow diagram in Figure 6-1.

The firm indicated that some changes were made to the CRT-D MRI devices after the design verification and validation testing. In addition minor changes were made to the predecessor devices (IPGs and leads)

and have been approved but also apply to the devices under review. Furthermore, the firm lists what the firm would consider as annual reportable changes. All changes were reviewed, and an assessment was made if the changes could impact the MRI conditional labeling. The following changes were reviewed:

Change ID	Description of Change	Type / Approved for Other Products	Comment
NA	ON Semiconductor Converting Standard Packaging Method From Copper Wire to Gold Wire	Approved with this PMAs	(b) (4) [redacted]
8079	CRTD: New Case to Cover Welder	30DN P010031/S461	
7718	CRTD: Reduce frequency of monitoring at supplier	30DN P010031/S462	
7637	CRTD: (b) (4) 1 Transformer Shield Second Source	30DN P010031/S463	
7755	Leads: Update to MCRD Lead Drawing and Manufacturing Processes	30DN P080006/S071	
7697	Both: FACTORYworks 7.11	30DN P010031/S465 P080006/S072	
7472	CRTD: Changes to 9-Pin Feedthrough Design and Manufacturing Process	180 PMAs P010031/S466	
7920	CRTD: Reduction of Weld Frequency Monitoring for Battery	30DN P010031/S468	
7666	CRTD: DCST System 2.1	30DN P010031/S469	
8093	CRTD: New Crimp Press Equipment at MECC	30DN P010031/S470	
8021	CRTD: UBITS Software Update	30DN P010031/S471	
8302	CRTD: Add Inspection Step to Capacitor Epoxy Process	30DN P010031/S473	
NA	Approval for Attain Performa Lead Models 4398 and 4598	180 PMAs P080006/S073	
8316	CRTD: Gold Preform Second Source	30DN P010031/S475	
7925	CRTD: New Rework Manufacturing Process for Bonded Anode Subassembly used in Capacitor Manufacturing	30DN P010031/S476	
8314	CRTD: Revision of Allowable Chip Size on Multi-Polar Feedthrough Insulators	RTR P010031/S477	
8458	CRTD: Feed-through Insulator Tooling and Second Source Supplier Update and Minor Updates to Immersion Test Protocol	30DN P010031/S479	
8344	CRTD: Addition of Weld Strength Proof Test	30DN P010031/S480	
8535	CRTD: Addition of Automated Cleaning Process and New Cleaning Solution at Supplier (Ceramaret)	30DN P010031/S481	
8455	CRTD: IC Die Sorter Equipment Software Configuration Update	30DN P010031/S482	
8618	CRTD: New 3D Laser Marker at MJC	30DN P010031/S483	
8379	CRTD: Vision System for Connector and Radiopaque at SMO	30DN P010031/S484	
7049	CRTD: Manufacturing and Specification Change at Supplier Heraeus	30DN P010031/S486	

8517	CRTD: Implementation of a New Cognex Vision System at the Final Device Manufacturing Facilities	30DN P010031/S488	
8542	CRTD: Manufacturing Changes for the XE161 Crystal Component	30DN P010031/S489	
8584	CRTD: Alternative UV Irradiation Equipment for Die Prep Area	30DN P010031/S490	
8502	CRTD: Update to Final Visual Criteria for Hybrids	30DN P010031/S491	
8625	CRTD: Modification of M017 and M019 IC Test Software	30DN P010031/S492	
8678	CRTD: Blackwell Connector Module Inspection Updates at MECC	30DN P010031/S493	
8693	CRTD: Alternate Cleaning Process for Hybrid Build	30DN P010031/S494	
8220	Leads: Shrink Wrap Implementation for DELP and SLP Configuration	30DN P080006/S076	
8418	CRTD: Capacitor Manufacturing Optimization	30DN P010031/S495	
8688	CRTD: Additional Laser Welding System for Battery Assembly	30DN P010031/S496	
8716	CRTD: Implement Automated Inspection for Cracks	30DN P010031/S497	
8748	CRTD: Electrical Connector Monitoring Frequency Updates	30DN P010031/S498	
8386/ 8886	Leads: Sample Size & Control Limits Updated for Lead Models	30DN P080006/S077	
2940, 5733, 6900, 7111, 7161, 7697	Leads: Attain Performa Leads Manufacturing Changes to Align Production with Attain Ability Leads	30DN P080006/S078	
8711	Leads: Sample Size & Control Limit Updates on Attain Performa Leads	30DN P080006/S080	
8555/ 8556	Both: Use of SAP Gen 11 at Juncos, Villalba, and 3PL	30DN P010031/S501 P080006/S079	
8655	CRTD: Second Source Supplier of Anode Substrates	30DN P010031/S487	

Reviewer's Comments: Even though the title of the changes were in many cases sufficient to determine if the change could have an impact on the MR performance of the IPG/lead in some cases this was not possible and the firm was asked to provide additional information for the changes highlighted in yellow. The firm provided additional information in their November 04, 2015 e-mail. The information was reviewed and considered sufficient to show that the changes did not impact performance when the devices are exposed to the MRI scanner environment.

Additionally, the firm listed changes that were included in the last Annual Changes Report (see Table 6-4, Volume 6, page 119). These changes were reviewed and considered not relevant to the MR conditional labeling. The firm also included a list of Annual Reportable Changes to be included in the September 2015 ACR. The firm included detailed information about the pending changes on pages 126 to 275 (Volume 6). These changes were reviewed and found to not have an impact on MRI conditional labeling. Regardless, these changes will undergo a full review as part of the ACR review process and may require additional information not related to MRI conditional labeling at that time.

Finally, the firm discussed 30 Day Notices that were under review at the time of submission (Change ID 9106, Volume 6, page 280). The change is a simple change in hybrid marking and has not impact on MRI.

The firm filed an amendment (A001) on October 05, 2015 and included the additional changes that were previously submitted via 30 Day Notices. A review was performed with regards to impact on MRI only. None of the changes had an impact.

Change ID	Description of Change	Type / Approved for Other Products	Comment
8715	Additional Laser Welding System for Battery Header Weld	30DN P980016/S540, P010031/S504 P090013/S192, P980035/S430	Introduction of additional laser welding system to increase capacity does not impact MRI
9129	Manufacturing Change for Connector Molding Process	30DN P980016/S542, P010031/S506	The molding process does not change components or specifications within the connector and should not impact MRI performance
9341	60◦C Soak Oven Temperature Verification	30DN P980016/S543, P010031/S507	Introduction of an independent measurement of oven temperature. No impact on MRI
9370	(b) Continuous Monitoring System Implementation	30DN P980016/S546, P010031/S509 P090013/S196, P980035/S435 P010015/S277	Continuous monitoring of manufacturing processes does not change specifications of the components or their functionality. Therefore, no impact on MRI expected.

FIRMWARE/SOFTWARE

The Amplia/Compia MRI CRT-D device firmware is based on the Evera MRI ICD firmware (P980016/S536, approved September 11, 2015). The Evera MRI firmware is based on the approved Viva/Brava/Evera family of devices firmware approved in January 2013 (P010031/S318), updates included the SureScan algorithm for ICDs (similar to IPG SureScan) and other MRI related enhancements. Relevant and useful MRI diagnostics were also added for research purposes. These MRI-related additions to the CRT-D MRI firmware are identical to those included in the Evera MRI firmware.

The firmware for the CRT-D MRI devices also included additional new and changed features compared to the Viva/Brava CRT-D family of devices that are intended to improve CRT response and enhance device longevity (Volume 1, Detailed Description of Changes, summarized below).

New or Modified Features	Description
MRI Related Features	
MRI SureScan (1.5T)*	Provides the ability to configure the device to enter the MRI environment. This feature automatically disables all arrhythmia detection features and most clinical diagnostics, which may be affected by the MRI environment, and allows the physician to choose pacing options based on the patient's disease state. Upon disabling the MRI SureScan feature, the device returns to previously programmed settings, including arrhythmia detection and diagnostic data collection. This feature includes user messaging concerning device state during MRI SureScan mode and a checklist that must be followed for an MRI scan.
MRI SureScan timeout*	Provides a safety mechanism to ensure that patients are not left in the MRI SureScan mode for a prolonged period of time. The MRI SureScan timeout is automatically set to six hours when MRI SureScan mode is enabled by the user.
MRI SureScan POR recovery*	Provides a mechanism to ensure that MRI SureScan feature settings are recovered in the case where a device reset occurs while the device is in SureScan mode.
Enhanced Patient Information*	Provides a mechanism on the patient information screen for the user to enter data concerning the patient's implanted hardware and MRI eligibility.
MRI SureScan Checklist Programmer Screen Updates	Updated to remove specific radiology guidelines and to restrict capture threshold requirement to RV chamber and only for pacemaker dependent patients.
New Features	
Managed Ventricular Pacing (MVP)	Minimizes right ventricular pacing, for use in patients in whom CRT pacing is no longer viable or beneficial.
Longevity improvements for patients with AT/AF	Provides an option to turn off atrial sensing for patients in chronic AT/AF (use of the atrial port plug or otherwise), also reduces the impact of EGM on-time for patients in AT/AF.
Modified Features	
Battery conditioning intervals*	Increases the efficiency of the battery conditioning algorithm. Battery conditioning is occasionally performed to ensure that the battery can deliver the energy needed for a tachyarrhythmia therapy.
AdaptivCRT updates	Extends normal AV conduction cut-offs by 20ms and restricts VV delay adaptation to LV first. The device will be shipped Adaptive BiV and LV.
Left Ventricular (LV)	Provides new LVCM Safety Margin option to adapt the safety margin based on the stability of recent

Capture Management	LV capture thresholds.
Telemetry C Programmer Sessions	Provides a shorter Telemetry C inactivity timeout post implant, with the option to extend it to 2 hours.
Remaining Longevity	Provides updates to the Remaining Longevity to improve the estimate in certain circumstances, including prior to implant and when parameters are reprogrammed.
*Feature approved for Evera MRI ICD in P980016/S536.	

The application software model (programmer software) SW034 was planned, designed and implemented to be used with the CRT-D MRI devices. The baseline software for SW034 is SW033 that supports the Evera MRI devices (P980016/S536, approved September 11, 2015). The Evera MRI software is based on the approved Viva/Brava/Evera family of devices software (P010031/S318, approved January 2013), with updates to include the SureScan algorithm for ICDs (similar to IPG SureScan) and other MRI related enhancements. These MRI-related additions to the Evera MRI software are similar to those included in the CRT-D MRI device software with changes related to cardiac resynchronization therapy (CRT) functionality.

Table 5-1: CRT-D MRI Device Models Name and Numbers

Models Name	Model Number
Amplia MRI CRT-D	DTMB1D4
Amplia MRI Quad CRT-D	DTMB1QQ
Compia MRI CRT-D	DTMC1D4
Compia MRI Quad CRT-D	DTMC1QQ

With this submission the firm is seeking approval of the use of the CareLink Programmer Application software SW034 for the devices listed in Table 5-1. The software documentation in this submission includes the Claria MRI /Claria MRI Quad CRT-D SureScan device models (Claria MRI devices) and specific features that are only available for these devices. SW034 supports the Claria MRI devices and features specific to these devices; however, all features specific to the Claria MRI devices are latent for the devices under review in this submission. The scope of this submission is limited to the devices listed in Table 5-1 (page 5, Volume 5). Approval for the (b) (4) [redacted] e [redacted].

Programmer Software Application Model SW034: SW034 is based on the Viva/Brava Programmer Software Model SW016 with the addition of the MRI SureScan features and other new features for the CRT-D MRI models.

CareLink Instruments and Device Data Management Application (DDMA) Description: The CareLink Monitor Model 2490C, CareLink Express Monitor 2020B, CardioSight Reader Model 2020A, and the Device Data Management Application (DDMA) Model 2491 are currently approved system components that required changes to make them compatible with the CRT-D MRI devices.

The CareLink Monitor Model 2490C, CardioSight Reader Model 2020A, CareLink Express Monitor Model 2020B, and CareLink Network Device Data Management Application (DDMA) Model 2491) are currently approved devices and will also support the CRT-D MRI devices to provide patient data transfer. The CareLink Monitor Model 2490C and MyCareLink firmware were upgraded to support the CRT-D MRI devices as well as new features that affect these instruments. Changes to these instruments are described in detail in the section Patient Management.

The software and firmware changes were reviewed according to the "Guidance for Industry and FDA Staff -Guidance for the Content of Premarket Submissions for Software Contained in Medical Device, May 11 2005". The results of the review were summarized in the table below. Green indicated that the guidance was followed and the reviewer agrees with the firm, yellow indicated some deviation and potential need for additional information and red indicated missing information and a potential deficiency. The table summarized the review, i.e., a deviation may be either created by the software or the firmware aspect of the submission.

SOFTWARE DOCUMENTATION	MINOR CONCERN	MODERATE CONCERN	MAJOR CONCERN
Level of Concern	A statement indicating the Level of Concern and a description of the rationale for that level.		
Software Description	A summary overview of the features and software operating environment.		
Device Hazard Analysis	Tabular description of identified hardware and software hazards, including severity assessment and mitigations.		

SOFTWARE DOCUMENTATION	MINOR CONCERN	MODERATE CONCERN	MAJOR CONCERN
Software Requirements Specification (SRS)	Summary of functional requirements from SRS.	The complete SRS document.	
Architecture Design Chart	No documentation is necessary in the submission.	Detailed depiction of functional units and software modules. May include state diagrams as well as flow charts.	
Software Design Specification (SDS)	No documentation is necessary in the submission.	Software design specification document.	
Traceability Analysis	Traceability among requirements, specifications, identified hazards and mitigations, and Verification and Validation testing.		
Software Development Environment Description	No documentation is necessary in the submission.	Summary of software life cycle development plan, including a summary of the configuration management and maintenance activities.	Summary of software life cycle development plan. Annotated list of control documents generated during development process. Include the configuration management and maintenance plan documents.
Verification and Validation Documentation	Software functional test plan, pass / fail criteria, and results.	Description of V&V activities at the unit, integration, and system level. System level test protocol, including pass/fail criteria, and tests results.	Description of V&V activities at the unit, integration, and system level. Unit, integration and system level test protocols, including pass/fail criteria, test report, summary, and tests results.
Revision Level History	Revision history log, including release version number and date.		
Unresolved Anomalies (Bugs or Defects)	No documentation is necessary in the submission.	List of remaining software anomalies, annotated with an explanation of the impact on safety or effectiveness, including operator usage and human factors.	

Level of Concern: Firmware Level of Concern is set to "Major" (see page 4, Volume 4). Programmer Software Level of Concern is set to "Major" (see page 4, Volume 5).

Software Description: The firmware description is also found on page 4, Volume 4. The description is sparse and refers to the Evera MRI ICD. Many changes were included with the Evera MRI ICD this is acceptable. The software description is found on page 6 of Volume 5.

Device Hazard Analysis: A full firmware hazard analysis was performed in CRT-D MRI Risk Management Plan/Report DSN014481. The Plan/Report was part of Volume/Risk Management Section (Volume 1, page 405). The plan/report was reviewed and found to be sufficient. The same report contains the software hazard analysis. The software hazard analysis was reviewed and found to be acceptable.

Software Requirement Specifications: Firmware requirement specifications were not included due to the large size of the document (1300 pages). The firm only provided a table of contents. This was not sufficient and the firm was asked to, at a minimum, provide a delta analysis and provide sections that have changed over the baseline. The firm provided the missing information via e-mail attachment of November 05, 2015. The attachment was reviewed and found to be sufficient to address the stated concern.

The firm states on page 6, Volume 5 that out of the 3802 requirements, (b) are new or have changed in SW034 from SW033. The firm provided a detailed Traceability Matrix Report (DSN017432). The report was reviewed and found to be adequate. The firm also states (pg. 9, Volume 5) that the full design requirements specifications are available upon but was not include due to its large size (1953 pages). The reviewer found the delta analysis sufficient and will not require the full specification document.

Architecture Design Chart: The firm has indicated that the firmware architecture has not changed compared to the Evera MRI ICD (P980016/S536, approved September 11, 2015). This is acceptable. The firm indicated on page 10, Volume 5 that the software architecture did not change compared to the SW033 Evera MRI software baseline. The firm included the software architecture description DSN008231. The document was reviewed and found to be acceptable.

Software Design Specification (SDS): The firm indicated on page 5 of Volume 4 that the Design Specifications document DSN016628 exceeds 4300 pages and for that reason only the cover page and table of contents were provided (page 438 to 465). The firm indicated that the full document would be available upon request. The reviewer is of the opinion that the firm should submit a delta analysis instead of the full document. The firm provided an overview of the software design specifications on page 10 of Volume 5 and a detailed design plan in DSN014005. The document was reviewed and found to be sufficient. The firm provided the missing delta analysis on November 05, 2015 and the analysis was considered sufficient.

Traceability Analysis: The firm indicated on page 6 of Volume 4 that the Firmware Verification Traceability Report DSN016918 was over 2000 page and therefore only the signature and cover page was provided. Subsequently, the firm provided additional information in their November 05, 2015 e-mail attachment. A review concluded the information to be sufficient.

Software Development Environment Description: The firmware environment description was part of DSN014268 (Volume 4, page 9-66) and was marginally sufficient.

Revision Level History: The firmware revision was not fully clear and the firm did not provide a full history except for the statement. A revision history was provided with in their email attachment on November 15, 2015.

Unresolved Anomalies (Bugs or Defects): The firm stated on page 6 of Volume 4 for that there were no anomalous or unexpected operations. The firm filed an amendment (A001) on October 05, 2015 and indicated that an unresolved anomaly was identified:

(b) (4)
(b) (4)

The firm provided sufficient rationale on page 7 of the amendment that the anomaly if persistent does not represent a risk to patients. The reviewer agrees with the assessment made in the amendment.

Verification and Validation Documentation: The firm only provided a Verification Test Summary Report DSN016921. It summarizes the test results and indicated (broken down by individual tests) (b) (4) test cases were run, all passed. The approach is acceptable if the delta analysis mentioned under SDS and Traceability analysis would be provided linking the test cases to the changed specifications. The firm did provide the delta analysis in their e-mail attachment on November 05, 2015.

SYSTEM VALIDATION TESTING

System validation testing was conducted on the system components which included the Amplia MRI/Amplia MRI Quad CRT-D SureScan and Compia MRI/Compia MRI Quad CRT-D SureScan devices (CRT-D MRI devices), along with programmers, accessory devices, home monitors and application software. System testing consisted of evaluating the compatibility, interaction and functional operation of the system components when used together as a system.

The CRT-D MRI System Design Validation Plan DSN016870 describes the activities required to obtain validation evidence for the CRT-D MRI System design input requirements and manuals. It includes the design input requirements being validated, design validation methods, system components and sample information.

System validation testing was conducted per the validation protocols listed in Table 5-6 (page 192, Volume 5) using application software version SW034 V8.0 for use with the CareLink Model 2090 and Carelink Encore Model 29901 programmers.

System Validation Protocols & Report	Testing Conducted	Purpose of Testing
CRT-D MRI System Design Validation Protocol DSN017184 CRT-D MRI System Design Validation Report DSN017414	(b) (4)	

System Validation Protocols & Report	Testing Conducted	Purpose of Testing
	(b) (4)	
CRT-D MRI System Design Validation Protocol – Manuals DSN016999 CRT-D MRI System Design Validation Report DSN017414	(b) (4)	(b) (4)

The above mentioned protocols and reports were reviewed. As indicated by the firm on (page 286, Volume 5)
(b) (4)
(b) (4)

(b) (4)
validation testing and test results acceptable.

MRI DEVICE LEVEL VERIFICATION / VALIDATION TESTING

The clinical functionality of the CRT-D MRI devices is based on the predecessor Viva/Brava CRT-D family of devices. The additional specific features included in the CRT-D MRI devices to ensure MRI Conditionally safe performance are identical to those included in the Evera MRI ICD (P980016/S536 approved September 11, 2015).

The CRT-D MRI System, which is Medtronic's first MRI SureScan CRT-D system, includes an Attain Ability MRI SureScan or Attain Performa MRI SureScan lead in the left ventricle, a SureScan defibrillation lead in the right ventricle, and a SureScan pacing lead in the right atrium. In cases where no atrial lead is implanted (e.g., HF patients with chronic AF), the Medtronic Model 6725 pin plug may be used as a part of the MR Conditional system.

Device level design verification testing was performed on the CRT-D MRI System to ensure specified performance after the device is subjected to various electromagnetic, medical and mechanical environments (representative of those a device and/or patient may encounter) and to verify the device design for implantable use. Testing consisted of device Design Assurance Unit (DAU) mechanical, electrical, and EMC and MRI testing.

Electrical Design Verification Testing (EDVT) was performed on the CRT-D MRI System configuration to verify the MRI related electrical performance of the devices to specified functional operating parameters defined in the Hardware Requirements Specification (HRS).

MRI Interactions with the Implanted CRT-D and Lead System

The potential MRI environment hazards/risks inferred from ISO TS 10974 "Assessment of the Safety of Magnetic Resonance Imaging for Patients with an Active Implantable Medical Device", and the possible clinical impact associated with each hazard is presented in the Table below (page 139, volume 2). The subsequent sections provide additional detail on each hazard, including requirements definition and test results. The firm provided complete details in the referenced reports.

Table 1-13: Summary of MRI Hazards for Evera MRI System

Hazard	Field Interaction	Mechanism and Source of Hazard	Potential Clinical Impact
Lead Heating	Radiofrequency	The conductive device lead acts as an antenna, picking up radiofrequency energy. A portion of this energy is dissipated as heat in the cardiac tissue near the electrodes.	Tissue heating near the electrode may result in thermal cardiac tissue damage and affect pacing therapies, VT/VF detection or efficacy of defibrillation therapies.
Unintended Cardiac Stimulation	Gradient Radiofrequency	The gradient and radiofrequency fields will induce voltages along the leads that will be applied to the device lead electrodes. If these voltage pulses are large enough, they may directly stimulate the heart.	Cardiac stimulation may lead to a single or intermittent stimulation or a sustained tachycardia.
Vibration	Static Gradient	Gradient magnetic field induces electrical currents in the conductive surfaces of device components. Interaction of these currents with the static magnetic field causes the component to vibrate.	Device malfunction may affect pacing therapy.
Device Interactions	Static Gradient Radiofrequency	The static, gradient, and radiofrequency fields may adversely impact the electrical operation of the device system if its operation is not protected from the effects of those fields. The coupling mechanism can either be from the radiated field or conducted through the lead-device interface.	Potential device malfunction or failure due to component damage, modification of functional circuits (i.e., transformer core saturation) or noise induced on the system leading to oversensing or inhibition affecting pacing operations.
Force and Torque	Static	The static magnetic field will act on any ferromagnetic material in a device or lead, producing a translation or rotation force on the device or lead.	Device or lead movement may lead to patient discomfort or affect therapy.
Case Heating	Gradient Radiofrequency	Electrical currents on the conductive surface of the device case are dissipated as heat.	Tissue heating near the device case may lead to patient discomfort or tissue damage.

In addition to the hazards listed in the Table, the effect of the CRT-D System's impact on image artifact was also assessed and is discussed in Volume 2, beginning page 418 (device) and 467 (leads).

Lead Heating (Impact on PCT)

(b) (4)

Table 2-2: 99th percentile of dissipated power for a variety of LV lead models under different fluid level conditions

Lead Family	Lead Length	99% Dissipated Power (mW)			
		LHM 1.5 Non-Ingressed	LHM 1.5 Fully Ingressed	LHM 2.0 Non-Ingressed	LHM 2.0 Fully Ingressed
4196, 4396	(b) (4)				
4296					
4298, 4398, 4598					

Table 2-4: 99th percentile of dissipated power for a variety of lead models under different fluid level conditions (StFL - standard fluid level[2], WCFL-worst case fluid level[3])

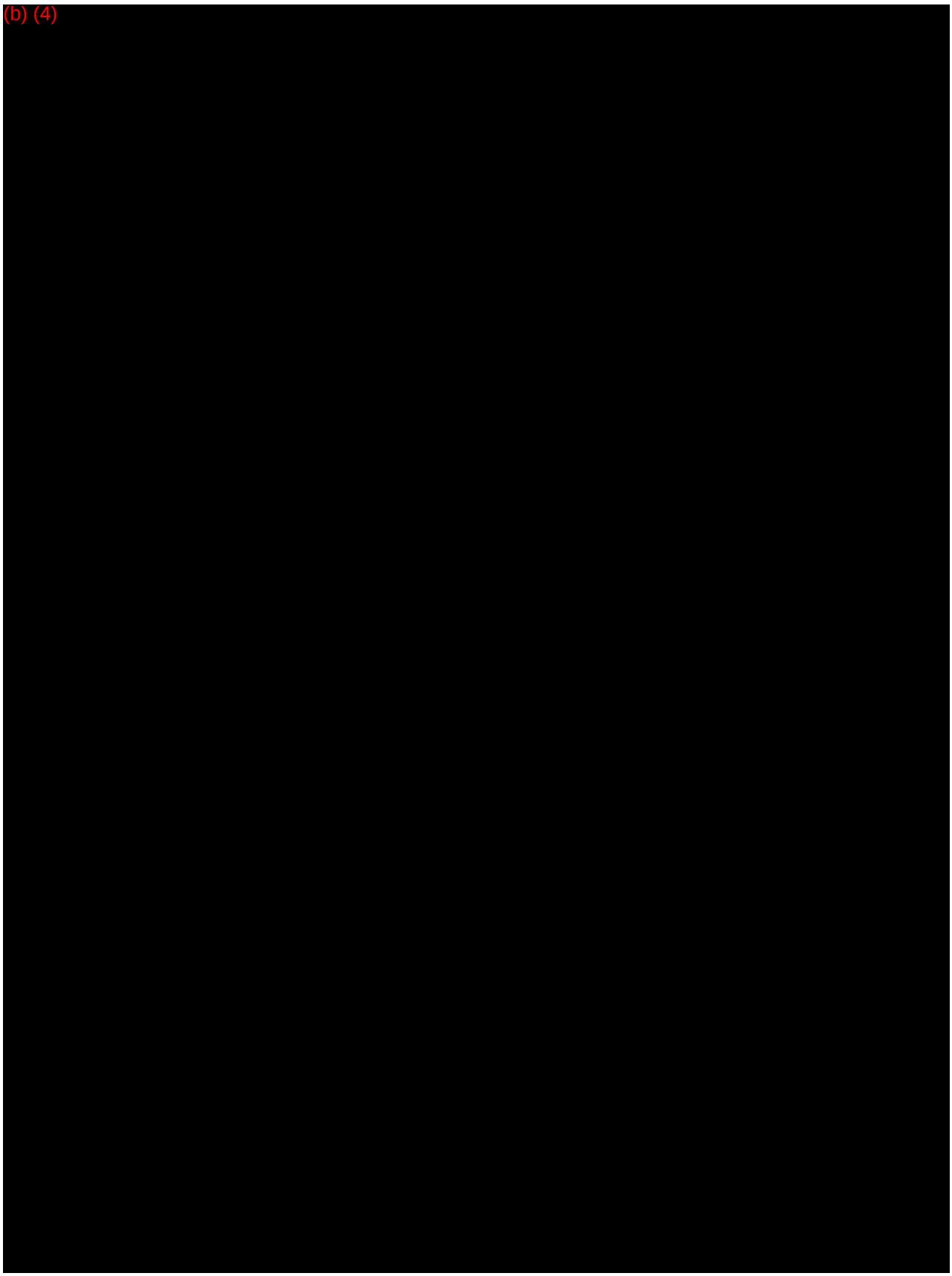
Lead Family	Lead Length	99% Dissipated Power (mW)		
		LHM 1.5 StFL	LHM 1.5 WCFL	LHM 2.0 StFL
5086MRI	(b) (4)			
5076				
6935M				
6947M	62 cm	245	410	115

(b) (4)

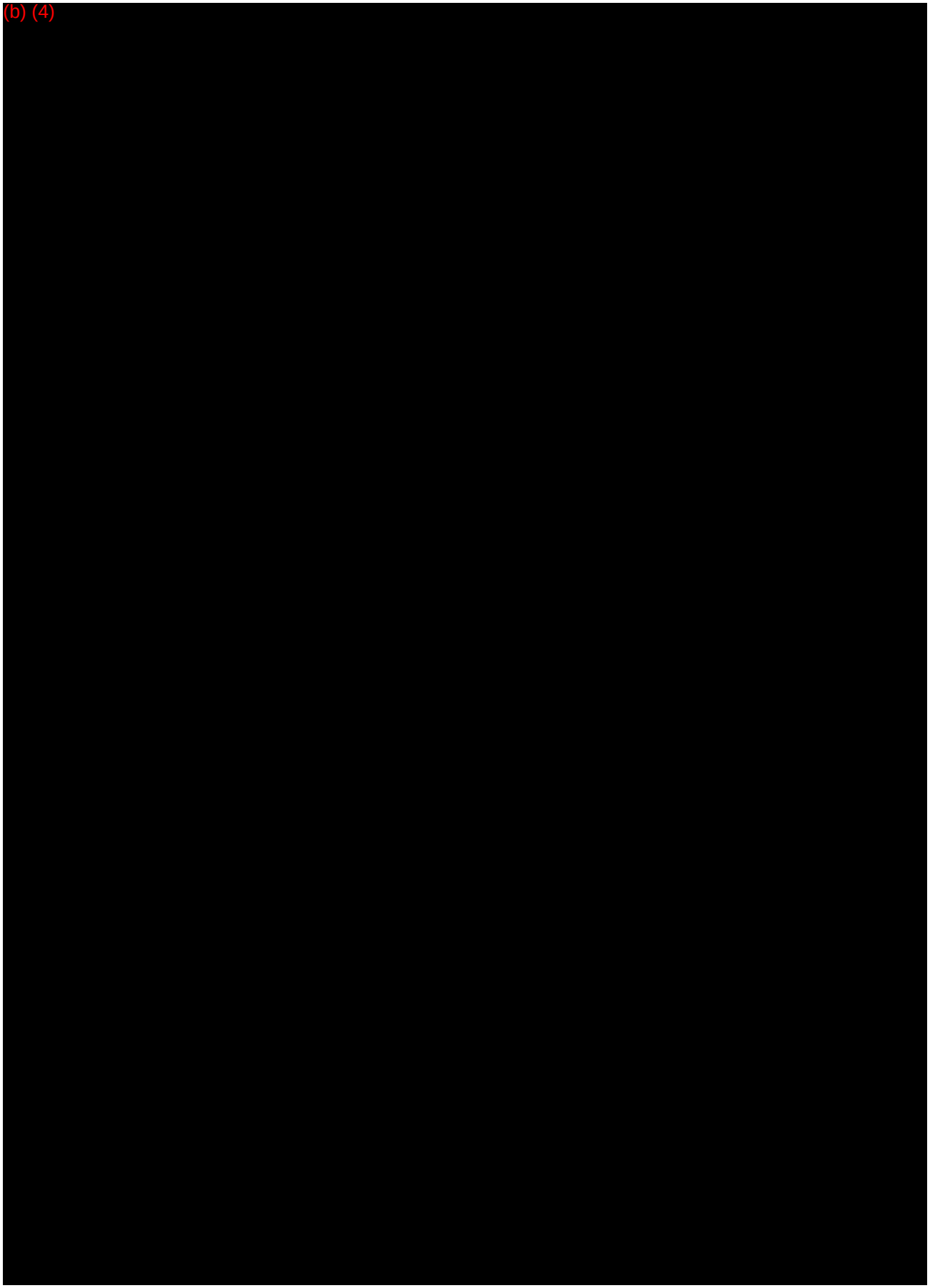
- Evera MRI ICD System Fluid Ingress Summary Memo BL0028094

The firm noted that the Left Ventricular (LV) leads are delivered over a guide wire and hence have an open lumen with a seal at the distal end. The distal seal design of LV leads will permit the

(b) (4)



(b) (4)



(b) (4)

Unintended Cardiac Stimulation (UCS)

(b) (4)

MRI Induced Force

The static field will act on any ferromagnetic material in a device or lead, which may produce translational movement of the device or lead. Device or lead movement may lead to patient discomfort or dislodgement.

(b) (4)

MRI Induced Torque

An MRI scanner's static magnetic field exerts alignment (torque) force on implanted medical device systems containing ferromagnetic components. Excessive movement could result in patient discomfort.

(b) (4)

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MRI Induced Vibration

Vibration of an implanted device occurs when the gradient field induces time-varying circulating currents, known as eddy currents, in the conductive surfaces of device components. When these eddy currents interact with the static field, time-varying forces are applied to the components, causing them to vibrate. Vibration could result in device malfunction and affect pacing and/or defibrillation therapies.

The CRT-D MRI hybrid and assembly methods are mechanically identical to those of Evera MRI, and therefore the vibrational forces generated during MRI vibration testing are equivalent. The device can is similar to that of the Evera MRI and even though the header is slightly larger, the vibrations induced by the MRI system are very similar to those seen for the Evera MRI ICD. The reviewer agrees with this assertion.

Device (Case) Heating

When a patient with an ICD undergoes an MRI scan, the device will be exposed to two time varying fields, the gradient field and radiofrequency (RF) field. Both of these fields couple energy into or around the device which may lead to heating of the device and surrounding tissue.

Device heating was evaluated by placing a device in a phantom containing gelled saline which simulates the electrical and thermal properties of the human body and then exposing the device to clinical worse case gradient and RF field conditions.

Device heating is primarily dependent on the size (i.e., conducting surface and dimensions) of the device. Because the CRT-D MRI device case is equivalent to the Evera MRI device case, the results of the testing conducted for Evera MRI can be directly applied to CRT-D MRI. Based on the Evera MRI device requirements, the maximum allowed device heating shall not exceed 15 cumulative equivalent minutes (CEM) at 43˚C. The result of the assessment was approximately two CEM at 43˚C which meets the requirement. The reviewer agrees with the equivalency statement and also agrees with the temperature (temperature dose) limits used by the firm.

Image Artifact

Image artifact was assessed in accordance with ASTM F2119-07 and documented in:

Image Distortion on Medtronic SureScan System V5 MDT1968222- R12056

The conclusions of the testing are summarized below:

1. Artifact from the Evera MRI device extends as much as 7.3cm beyond the case for spin echo images and as much as 11.8 cm beyond the case for gradient echo images. Artifact beyond the device is due to the internal ferromagnetic components.
2. Artifact along the length of the LV leads is modest and extends at most 8.6 mm beyond the lead.

The presence of metallic implants (i.e., IPG or ICD systems) in MRI can cause significant image artifacts, including signal loss, failure of fat suppression, geometric distortion, and bright pile-up artifacts. Medtronic CRDM's findings are consistent with the experiences of other radiologists and MR technologists. The firm included appropriate warnings in the manuals see for example volume 8, page 8-354.

Device Interactions

The static, gradient, and RF fields may adversely impact the operation of the device if its operation is not protected from the effects of those fields. Device malfunction could affect pacing and/or defibrillation therapies.

(b) (4) [redacted]

The static, gradient, and RF field testing primarily evaluates high voltage charging and delivery, pacing, sensing, telemetry, and device resets. Because the CRT-D MRI device is based on the same platform as the Evera MRI ICD and has nearly identical hardware, the results for most of the testing conducted for the Evera MRI ICD can be applied to the CRT-D MRI device. However, some of the tests were repeated due

(b) (4) [redacted]

(b) (4)

Impact of MRI on the Steroid Eluding Drug used in the Pacing and Defibrillation leads

(b) (4)

study is similar to what was provided for the Quattro Secure Model 6947 lead (in M140016/M003) as part of the Evera MRI System (P980016/S536, approved September 11, 2015) and the Model 5086MRI lead (in M080013/M005) as part of the Revo MRI system (P090013, approved February 8, 2011).

(b) (4)

he reviewer has examined the report and agrees with the firm's conclusion.

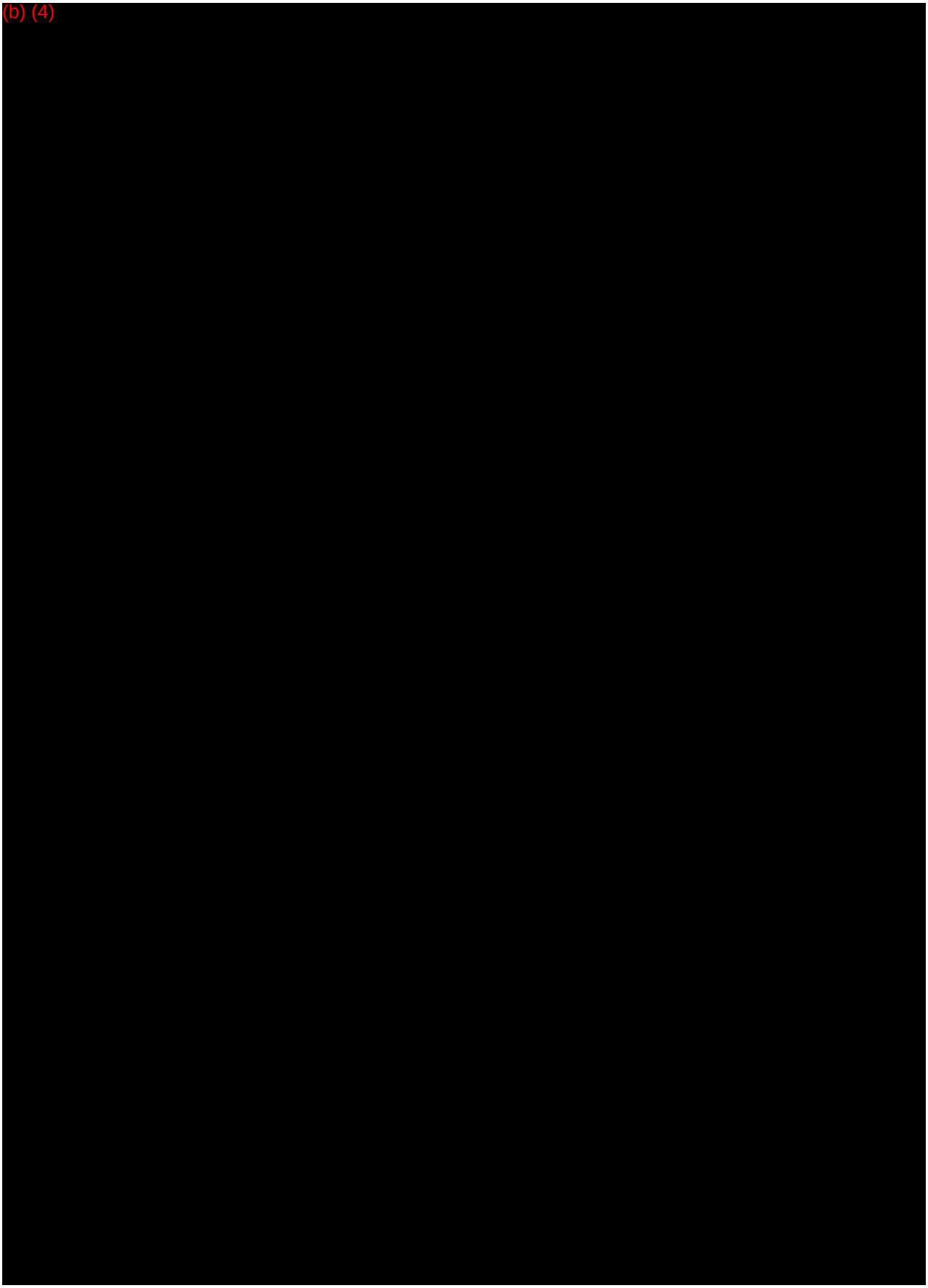
ANIMAL STUDIES

(b) (4)

(b) (4)

Figure 3-2, Page 3-20: In vivo modeling validation flow.

(b) (4)



(b) (4) [redacted]. *The reports substantiated the firm's assertions and the reviewer has no further concerns.*

CLINICAL DATA

No clinical data were submitted since FDA agreed with the firm that if the animal validation was sufficient, no clinical trial would be required. Given the combination of in-vitro and in-vivo validation for various lead models part of the Evera MRI ICD submission (P980016/S536, approved September 11, 2015) and this submissions, the reviewer believes that no clinical data are required to assess the safety of the LV leads. However, LV pacing capture threshold measurements post MRI should be made part of the Post Approval Study. A review of the submission by the clinical consultant follows below.

Clinical Reviewer's Comments

This PMA/S for the Compia/Amplia CRT-D family has much overlap with the Evera ICD PMA/S which is also currently under FDA review (Lead Reviewer: Evera MRI ICD has been approved shortly after this clinical review was received).

(b) (4) [redacted] Clinically, there were no concerns if they passed the appropriate tests.

(b) (4) [redacted]

POST APPROVAL STUDY

Multiple tachyarrhythmia therapy systems including implantable cardioverter defibrillators (ICD) and ICD systems with Cardiac Resynchronization Therapy (CRT-D) featuring the SureScan Technology are labeled as MR conditional. For purposes evaluating the relationship of MR exposure to tachyarrhythmia therapies, all MR conditional labeled tachyarrhythmia therapy systems are considered interchangeable and contribute equally to the primary objective. The contributing systems are listed in Table 1 and 2 of the January 13th, 2016 revision of the protocol.

Study Design

MR conditional tachyarrhythmia therapy systems enrolled in the Medtronic CareLink® Network (CL) will be used to prospectively assess spontaneous Ventricular Fibrillation (VF) episode detection following MRI exposure. It is estimated that the annual incidence of patients who experience at least one true spontaneous VF episode is 1% or less. Published historical studies had also indicated that there is no significant difference in incidence of tachyarrhythmia comparing patients with or without CRT. Therefore, the likelihood of achieving a meaningful number of true VF episodes in patients following an MRI scan is very low. Given this low incidence rate, CL offers the only possible data source with the volume of MR conditional tachyarrhythmia therapy systems to potentially identify a correlation between VF detection delays and MR exposure.

(b) (4)

[redacted]

Enrollment and Duration

The study population is sourced from all patients implanted with an MR conditional tachyarrhythmia therapy system, followed in the Medtronic CL network with de-identified data accessibility. The overall surveillance scope and duration are dependent on a number of variables including:

- Number of MR conditional tachyarrhythmia therapy system implants.
- Number of MR conditional tachyarrhythmia therapy system implants that enroll in CL.
- Number of CL enrolled patients who regularly transmit device data.
- Annual MRI rate and the prevalence of true VF episodes.

The following assumptions were used to define the surveillance scope and duration:

(b) (4)

[redacted]

(b) (4)

[redacted]

Primary Objectives

- To characterize the proportion of episodes with ≥ 5 seconds VF detection delay in the MR conditional tachyarrhythmia therapy systems following MRI exposure.
- Data regarding the number of patients presumed to have had 2 or more scans will be provided.
- Pre-MRI and post-MRI[4] LV lead PCT measurements obtained through CareLink will be summarized for MR CRT-D patients. Summary statistics will be presented separately for pre-MRI and post-MRI PCT measurements. Based upon the estimates within Table 4, it is anticipated that PCT measurements from approximately 2,444 patients with a MRI will be presented.

CONCLUSION

The firm has shown a reasonable assurance of safety and effectiveness for their devices when exposed to MRI scanner environments falling within the labeled bounds established by the firm. Furthermore, the firm has provided an acceptable Post Approval Study protocol. Consequently, the lead reviewer recommends approval of the supplement.

OAI Firm & Corporate-wide Warning List was checked January 27, 2016 and the document was found to be clear.