AI4CMR v1.0 Software

User Manual

AI4MedImaging

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SW Version V1.0

Manufactured by

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U.S. Federal law restricts this device to sale by or on the order of a physician.

510(k) Number K220624

UDI-DI 05600250059022

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Table of Contents

1. Glossary: Symbols, Conventions and Abbreviations 4
1.1 Symbols 4
1.2 Conventions 4
1.3 Abbreviations 4

2. Terms and Conditions 6
2.1 Regulatory Status 6
2.2 Indications for Use 6
2.3 Intended users 6
2.4 Conditions for use 7
2.5 Contraindications 8
2.6 Limitations 8
2.7 Warnings and precautions 9
2.8 Intended patient population 10
2.9 Applicable medical conditions 10
2.10 Safety Instructions 10

3. Getting Started 12
3.1 System requirements 12
3.2 Setup 12
3.3 User Training 14
3.4 Software overview 14
3.4.1 General operating steps 16
3.4.2 Summary of outputs validation 18
3.4.3 Plugin 19

4. User account handling 25
4.1 Authentication 25
4.2 User information handling 26
4.3 Password handling 26
4.4 Open sessions 27
4.5 Logging info 27

5. Technical Support 29

1. Glossary: Symbols, Conventions and Abbreviations

1.1 Symbols

Symbol	Description
	Manufacturer: Indicates the manufacturer of the medical device.
	Rx only: Indicates that Federal law restricts this device to sale by or on the order of a physician.

1.2 Conventions

EDV – End-Diastolic Volume [ml]

ESV – End-Systolic Volume [ml]

SV – Stroke Volume [ml]

EF – Ejection Fraction [%]

Mass – Myocardial Mass [g]

CO – Cardiac Output [L/min]

EDV/BSA – End-Diastole Volume/Body Surface Area [ml/m²]

ESV/BSA - End-Systole Volume/Body Surface Area [ml/m²]

SV/BSA – Systole Volume/Body Surface Area [ml/m²]

Mass/BSA – Myocardial Mass/Body Surface Area [g/m²]

CI – Cardiac Index [L/(min m²)]

BSA - Body Surface Area [m²]

1.3 Abbreviations

ED – End-Diastole

ES – End-Systole

MRI – Magnetic Resonance Imaging

CMR – Cardiac Magnetic Resonance

DICOM – Digital Imaging and Communications in Medicine

HTTP – Hypertext Transfer Protocol

SA – Short-axis

LA – Long-axis

LV – Left Ventricle

RV – Right Ventricle

ICC - Interclass Correlation Coefficient

2. Terms and Conditions

This User Manual shall be accompanied by the specific plugin User Manual.
The plugin User Manual describes in more detail the features and steps necessary to interact with the AI4CMR v1.0 service. For clarification purposes only, we present an example of a possible sequence of steps to interact with AI4CMR v1.0.

2.1 Regulatory Status

AI4CMR v1.0 is FDA cleared with 510(k) Number K220624.

Users are required to investigate the regulatory requirements pertinent to their country or location prior to using AI4CMR v1.0.
It is the user's responsibility to obey these rules, statutes, and regulations.

2.2 Indications for Use

AI4CMR v1.0 software is designed to report cardiac function measurements (ventricle volumes, ejection fraction, indices etc.) from 1.5T and 3T magnetic resonance (MR) scanners. AI4CMR v1.0 uses artificial intelligence to automatically segment and quantify the different cardiac measurements. Its results are not intended to be used on a stand-alone basis for clinical decision-making.

The user incorporating AI4CMR v1.0 into their DICOM application of choice is responsible for implementing a user interface.

AI4CMR v1.0 is a support tool that provides relevant clinical data as a resource to the clinician and is not intended to be a source of medical advice or to determine or recommend a course of action or treatment for a patient.

2.3 Intended users

AI4CMR v1.0 is a medical device and shall be used by qualified medical professionals, experienced in examining and evaluating magnetic resonance images.

2.4 Conditions for use

AI4CMR v1.0 is a cloud-hosted service. The system shall be used in association with a third-party DICOM Viewer, which provides the interface between AI4CMR v1.0 and the intended users: Medical professionals, Software Developers, and Others.

AI4CMR v1.0 is implemented as a plug-in to the DICOM viewer by the user and automatically processes and analyses cardiac MR images received by the DICOM viewer to quantify relevant cardiac function metrics and makes the information available to the user at the user's discretion.

Patients will not be in direct contact with AI4CMR v1.0. The CMR images acquired for the patient are fed from the MRI Scanner or PACS (Picture Archiving and Communication System) to the third-party DICOM Viewer.

This system context and interfaces to third-party systems are represented in the diagram of Figure 1~~Figure 1~~. The AI4CMR v1.0 system boundaries, are defined by the box "AI4CMR v1.0".

The integration between AI4CMR v1.0 and the DICOM Viewer is established using plugins that implement a standard communication protocol.

The communication between AI4CMR v1.0 and the third-party system is initiated by the third-party system which posts a request to the AI4CMR v1.0 in a networked environment. AI4CMR v1.0 will validate and process the request and return a response via the same medium.

The patient data is anonymized by the third-party before being sent to AI4CMR v1.0.

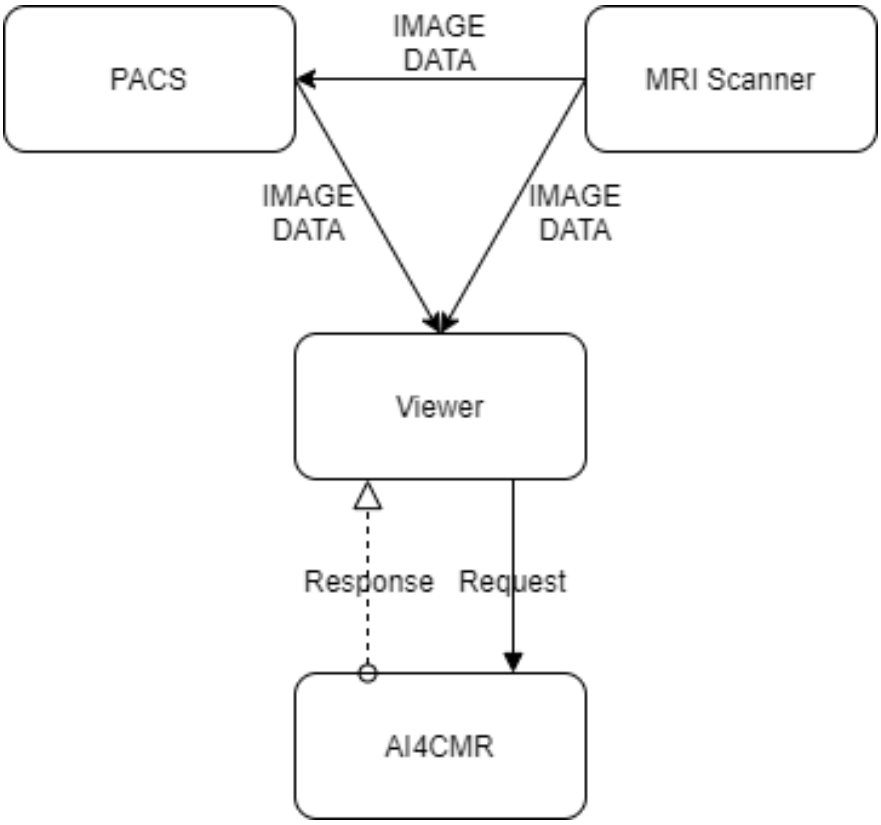

Figure 1. High-level representation of the interoperability between AI4CMR v1.0 and the third-party systems and services.

2.5 Contraindications

AI4CMR v1.0 is contraindicated to be used for post-processing of all image modalities other than cine CMR.

2.6 Limitations

AI4CMR v1.0 analysis is limited to cine CMR acquisitions.

Other studies such as Late Gadolinium Enhancement or Perfusion are not covered.

AI4CMR v1.0's performance has been tested in three MRI scanner vendors: Siemens, GE Healthcare Systems and Phillips Medical Systems. For new MRI scanner vendors, a message will be returned to the User stating that the vendor is not valid.

AI4CMR v1.0's performance has been validated for a range of image characteristics. Cases with image characteristics that are outside the boundaries of the verified performance of the algorithms will be rejected.

AI4CMR v1.0 was designed to work with isotropic images (i.e. images where the pixel spacing is equal in the X and Y directions, see section 3.4.1 for more information). Very seldom, CMR cases can differ in their X and Y pixel spacing by a minimum margin, mostly due to numeric approximations, resulting in the case being identified as anisotropic and being rejected by AI4CMR v1.0. This limitation can be easily mitigated from the plugin side by checking and truncating the pixel spacing values to 4 decimal places. This step solves the limitation while preserving the pixel spacing validation.

2.7 Warnings and precautions

- The intended use and performance of AI4CMR v1.0 may be impacted if the communication protocol with the DICOM Viewer is not adequately implemented.
- AI4CMR v1.0 must be used by qualified medical professionals only, experienced in examining and evaluating magnetic resonance images as a support tool that provides relevant clinical information.
- AI4CMR v1.0 shall not be used to view or analyze images of any part of the body except the cardiac images acquired from a CMR scanner.
- Quantitative analysis is dependent on the quality and correctness of the image source data acquisition.
- The patient data must be anonymized by the third-party plugin before sending it to AI4CMR v1.0.
- The patient data displayed is initially derived from the DICOM information, if available. Editing these values may affect the calculations in all modules. It is the User's responsibility to verify this data before releasing the final results.
- The User should keep a UPS system that provides emergency power when the input power source or mains power fails.
- It is the plugin maintenance team's responsibility to execute the installation procedure to validate the communication between the User and AI4CMR v1.0.
- It is AI4MedImaging's responsibility to update/do maintenance periodically to reduce the probability of AI4CMR v1.0 SW defects.
- At the installation time, a copy of the digital user manual must be copied to the User's network, under the domain of the User's IT Manager.
- In the event of loss of access credentials please follow the procedure in section 4. User account handling.
- Users should read this manual before using AI4CMR v1.0.

2.8 Intended patient population

The software analyses images of patients that were examined by CMR imaging.

Age The use is not recommended for children (age < 18yo) since the clinical evaluation studies targeted a mostly adult population.

Weight No limitations

Height No limitations

2.9 Applicable medical conditions

AI4CMR v1.0 is an image analysis software for the post-processing of CMR images, used for the assessment of the following cardiac diseases:

- Cardiac failure
- Ischemic heart disease
- Valvular heart disease
- Cardiomyopathy
- Hypertensive cardiac disease
- Other pathologies that need assessment of cardiac function and morphology

2.10 Safety Instructions

Software AI4CMR v1.0 is hosted in the cloud. The intended users interact remotely with the software via a standard communication protocol implemented between AI4CMR v1.0 and the DICOM Viewer.

The equipment communicating with AI4CMR v1.0 shall:

- Be connected to a secure network;
- Have an access control system, to ensure that only accredited users can access the device and the AI4CMR v1.0 service.

AI4CMR v1.0 requires that the passwords are different from the username and have at least:

- Eight (8) characters;
- One (1) digit;
- One (1) uppercase;
- One (1) lowercase;
- One (1) special character.

It is highly recommended the usage of anti-virus software in all computers interacting with the AI4CMR v1.0 to protect against cyber-attacks. Periodic backups are also recommended to make sure that no patient data is lost in an unforeseen event.

3. Getting Started

3.1 System requirements

AI4CMR v1.0 software runs as a Docker image on the cloud.
The minimum requirements for the ethernet connection are:

- High bandwidth network (50Mbits/s minimum and 100Mbits/s recommended).

3.2 Setup

For customer registration, the customer environment shall be informed to AI4MedImaging: MRI scanner vendor, PACS vendor and version, Viewer vendor and version and third-party plugin ID and version.

A *client_id* and temporary user authentication credentials will be assigned by AI4MedImaging to the customer.

The third-party plugin shall be installed and configured as per its User Manual.

To validate the set-up, the following validation protocol shall be followed:

1. Three clinical cases (hereinafter called gold samples GS1; GS2 and GS3) are delivered to the customer by AI4MedImaging. The samples shall be submitted to AI4CMR v1.0 through the third-party plugin.

   GS1 case is a valid case with all the mandatory and optional data;
   GS2 case is a valid case with all the mandatory data;
   GS3 case is a non-valid case with missing mandatory data.

2. The results displayed by the third-party plugin for each of the golden samples shall be compared with the following expected results:

GS1:

LV Report		
EDV	EDV index	CI
111.58	74.11	3.18
ESV	ESV index	ED frame
36.84	24.47	1
SV	SV index	ES frame
74.74	49.64	12

Mass	Mass index	BSA
78.03	51.83	1.51
EF	CO	
66.98	4.78	

RV Report		
EDV	EDV index	CI
110.74	73.56	3.10
ESV	ESV index	ED frame
37.72	25.06	29
SV	SV index	ES frame
73.02	48.50	12
EF	CO	BSA
65.94	4.67	1.51

GS2:
A warning shall be displayed stating CO, CI and other indexed volume metrics were not computed since heart rate, height and weight were not given.

LV Report		
EDV	EDV index	CI
209.53	-	-
ESV	ESV index	ED frame
105.66	-	25
SV	SV index	ES frame
103.87	-	9
Mass	Mass index	BSA
139.71	-	-
EF	CO	
49.57	-	

RV Report		
EDV	EDV index	CI
191.65	-	-
ESV	ESV index	ED frame
85.05	-	24
SV	SV index	ES frame
106.61	-	9
EF	CO	BSA
55.62	-	-

GS3:
The submission shall be disabled. A warning shall be displayed stating there are missing required fields.

3. The customer's IT Manager must send the validation report to AI4MedImaging's Field Support via email. The report must include:
   - A signed statement by the IT Manager confirming if the validation protocol was successful or if it failed.
   - Screenshots of the results obtained for the 3 golden samples.

4. AI4MedImaging's Field Support must confirm reception and sign the report. If the validation protocol is successful, AI4MedImaging will provide the final user credentials to the customer. Otherwise, further support must be offered for problem resolution in articulation with the third-party plugin vendor.

3.3 User Training

After the setup is validated, the users will partake in individual or group training given by AI4MedImaging through the Microsoft Teams platform. The users must be trained before using AI4CMR v1.0.

Additional individual/group training or Demos can be requested and scheduled by contacting our Technical Support (Section 5).

3.4 Software overview

The AI4CMR v1.0 operating sequence of events is summarized in Figure 2~~Figure 2~~. The green colored boxes include the operations executed on the external DICOM Viewer plugin, to initiate AI4CMR v1.0 processing (blue boxes).

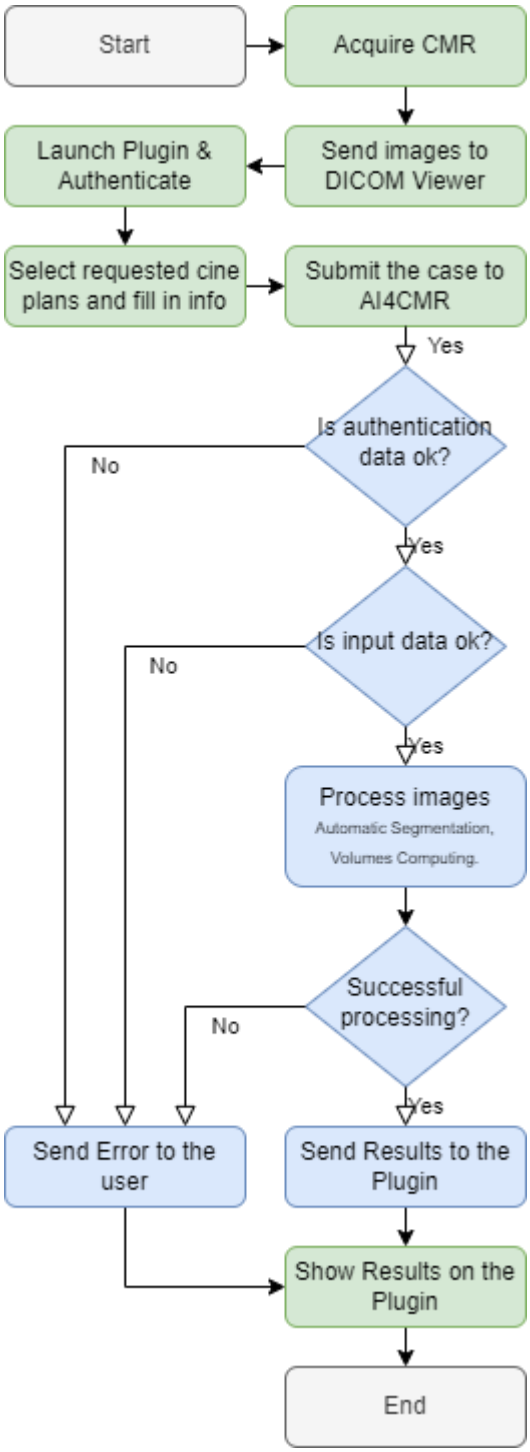

Figure 2. Flowchart of the operating sequence. Green steps are out of AI4CMR v1.0's control; blue steps are controlled by AI4CMR v1.0.

3.4.1 General operating steps

The general operating steps to use AI4CMR v1.0 are summarized in the following table:

Operating step	System context
1. The Cardiac Magnetic Resonance is acquired according to standardized protocols	MRI Scanner
2. The images are sent to the third-party software	DICOM Viewer
3. The user launches the dedicated plugin on the third-party software and inserts the user credentials	Plugin
4. The user selects the correct cine sequence planes and other requested patient data	Plugin
5. The user submits the request form to the AI4CMR v1.0 cloud service	Plugin
6. The request is subject to authentication	AI4CMR v1.0
7. The data on the request is checked for sanity and completion	AI4CMR v1.0
8. The patient data is processed by several AI-based image processing modules (myocardium automatic segmentation, ventricle volumes computation)	AI4CMR v1.0
9. The results and log messages (errors, warnings, …) are collected and returned to the plugin via the communication API	AI4CMR v1.0
10. The user sees the output of AI4CMR v1.0 on the dedicated plugin	Plugin

A CMR case to be submitted to AI4CMR v1.0 shall consist of:

1. Required:
    - DICOM cine SA with metadata:
        - Image Patient Position;

        - Image Patient Orientation;
        - Pixel Spacing;
        - Slice Thickness;
        - Rows;
        - Columns.
    - Patient metadata:
        - Age (on acquisition date);
    - Sex.
2. Optional:
    - Height, weight, heart rate.

The outputs of AI4CMR v1.0 consist of:

- Left Ventricle endo and epicardium contours (coordinates)
- Right Ventricle endocardium contours (coordinates)
- Left Ventricle volumes-derived metrics:
    - EDV – End-Diastolic Volume [ml]
    - ESV – End-Systolic Volume [ml]
    - SV – Stroke Volume [ml]
    - EF – Ejection Fraction [%]
    - Mass – Myocardial Mass [g]
    - CO – Cardiac Output [L/min]
    - EDV/BSA – End-Diastole Volume/Body Surface Area [ml/m^2]
    - ESV/BSA - End-Systole Volume/Body Surface Area [ml/m^2]
    - SV/BSA – Systole Volume/Body Surface Area [ml/m^2]
    - Mass/BSA – Myocardial Mass/Body Surface Area [g/m^2]
    - CI – Cardiac Index [L/(min m^2)]
    - BSA - Body Surface Area [m^2]
- Right Ventricle volumes-derived metrics:
    - EDV – End-Diastolic Volume [ml]
    - ESV – End-Systolic Volume [ml]
    - SV – Stroke Volume [ml]
    - EF – Ejection Fraction [%]
    - CO – Cardiac Output [L/min]

- EDV/BSA – End-Diastole Volume/Body Surface Area [ml/m²]
- ESV/BSA - End-Systole Volume/Body Surface Area [ml/m²]
- SV/BSA – Systole Volume/Body Surface Area [ml/m²]
- CI – Cardiac Index [L/(min m²)]
- BSA - Body Surface Area [m²]

See Section 3.4.2 for details on outputs validation.

3.4.2 Summary of outputs validation

The studies conducted under the clinical evaluation phases showed high agreement between AI4CMR v1.0 measurements and the human raters (experts) in a set of 146 patients:

- Correlation (ICC) in the measurement of LV EDV is 0.99, LV ESV is 0.99, LV EF is 0.87 and Mass is 0.94.
- Correlation (ICC) in the measurement of RV EDV is 0.96, RV ESV is 0.95 and RV EF is 0.81.
- The other volume metrics are arithmetically derived from the previous.
- The accuracy and precision of the measurement of the volume are given by the bias (mean difference) and the standard deviation.

AI4CMR v1.0 software vs Experts*

Volume parameter	Bias ± SD
LV EDV (ml)	8.7 ± 17.3
LV ESV (ml)	-2.9 ± 17.5
LV EF (%)	3.9 ± 5.7
Mass (g)	2.5 ± 18.0
RV EDV (ml)	8.4 ± 15.6
RV ESV (ml)	-9.1 ± 13.8
RV EF (%)	7.8 ± 7.3

(*) The experts used an FDA cleared device, which computes the volumes based on their manual segmentations.

No uncertainty/error information is shown in the software together with the LV and RV measurements.

3.4.3 Plugin

AI4CMR v1.0 is intended to be integrated with a third-party DICOM Viewer. The integration is established via a communication protocol implemented by a plugin. AI4CMR v1.0 does not have a Graphical User Interface. The end-user will interact with AI4CMR v1.0 via the Plugin's interface.

The Plugin User Manual which accompanies the current manual describes in more detail the features and steps necessary to interact with the AI4CMR v1.0 service.
The Plugin consists of a user interface to help the User create the request form. Different viewers can have different user experiences, but the main idea should be the same.

For clarification purposes, this section provides merely indicative (not binding) examples of what the user experience may be like with a third-party Plugin for AI4CMR v1.0.

Login

The first step to using the AI4CMR v1.0 is to successfully authenticate with the service. To do that, the User shall provide a username and password, Figure 3~~Figure 3~~:

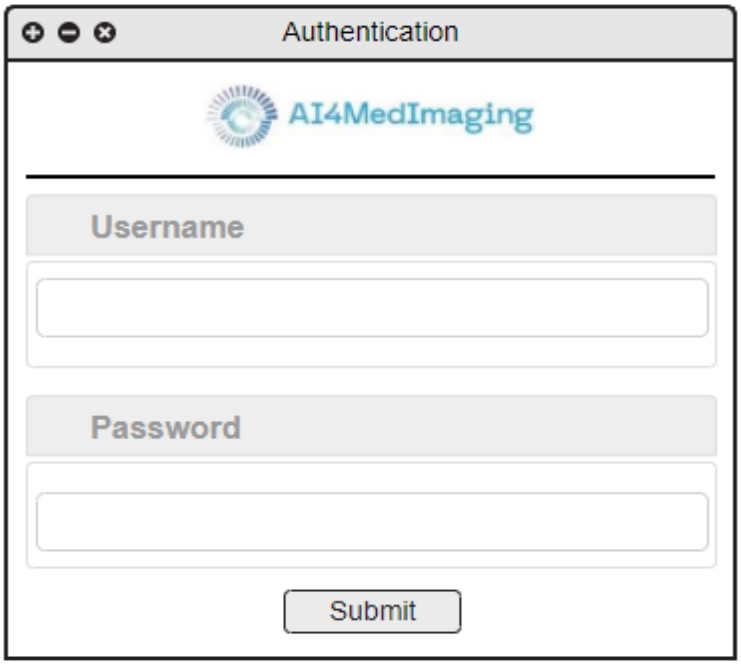

Figure 3. Example of a plugin login window.

Form filling

The plugin provides a way for the User to fill in the necessary information to perform a request, as presented in Figure 4~~Figure 4~~.

The User shall identify the short-axis cine sequence (SA) and add it to the Plugin (using drag and drop, for example). The SA sequence is mandatory and should always be provided.

The acceptance range of SA cine sequences to be inputted is between 9 and 16 sequences ([9,16]) as shown in the table[1] below:

Ranges	Number of Slices
Error	]- ∞, 8[
Warning	[8, 9[
Acceptance	[9, 16]
Warning	]16, 19]
Error	]19, +∞[

Patient metadata shall be filled in by the User if the Plugin does not automatically fill it based on the DICOM information:

- Mandatory:
  - Patient ID
  - Age
  - Sex
- Optional:
  - Heart rate (if not sent to AI4CMR v1.0: CO and CI will not be computed)
  - Height (if not sent to AI4CMR v1.0: no BSA nor indexed metrics (EDV/BSA, ESV/BSA, SV/BSA, Mass/BSA,CI) will be computed)
  - Weight (if not sent to AI4CMR v1.0: no BSA nor indexed metrics (EDV/BSA, ESV/BSA, SV/BSA, Mass/BSA, CI) will be computed)

[1] The values are the result of a study conducted based on a significative sample of CMR cases.

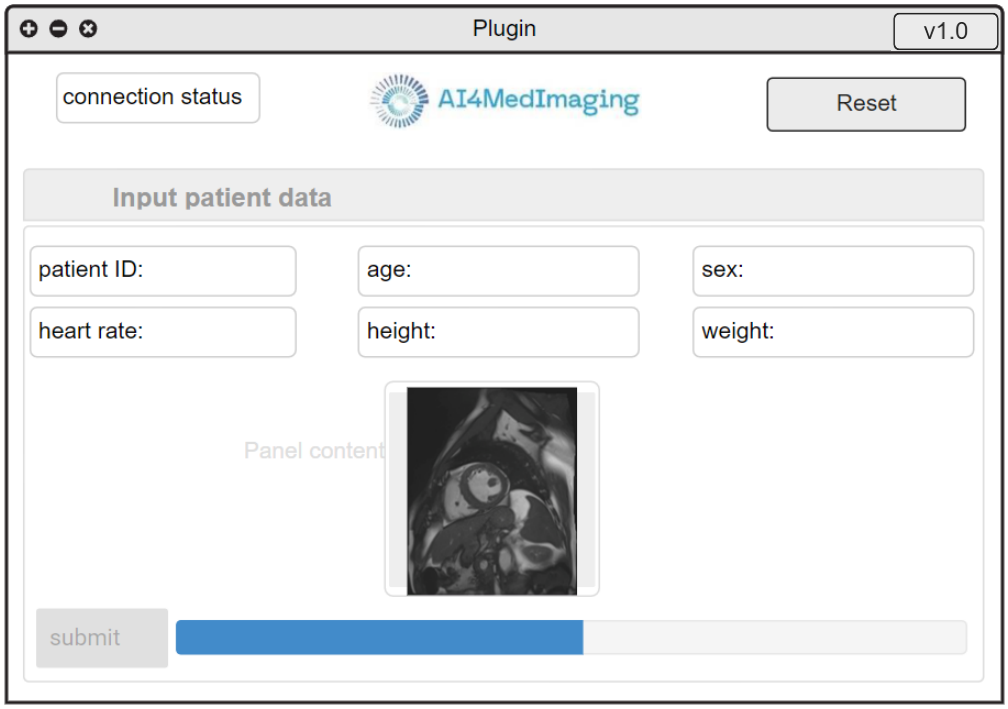

Figure 4. Example of a plugin form filling window.

Results presentation

After successful processing, the plugin presents the results.

One example of a possible user interface for results reporting is presented in the bottom half of Figure 5~~Figure 5~~ (LV report) and Figure 6~~Figure 6~~ (RV Report).

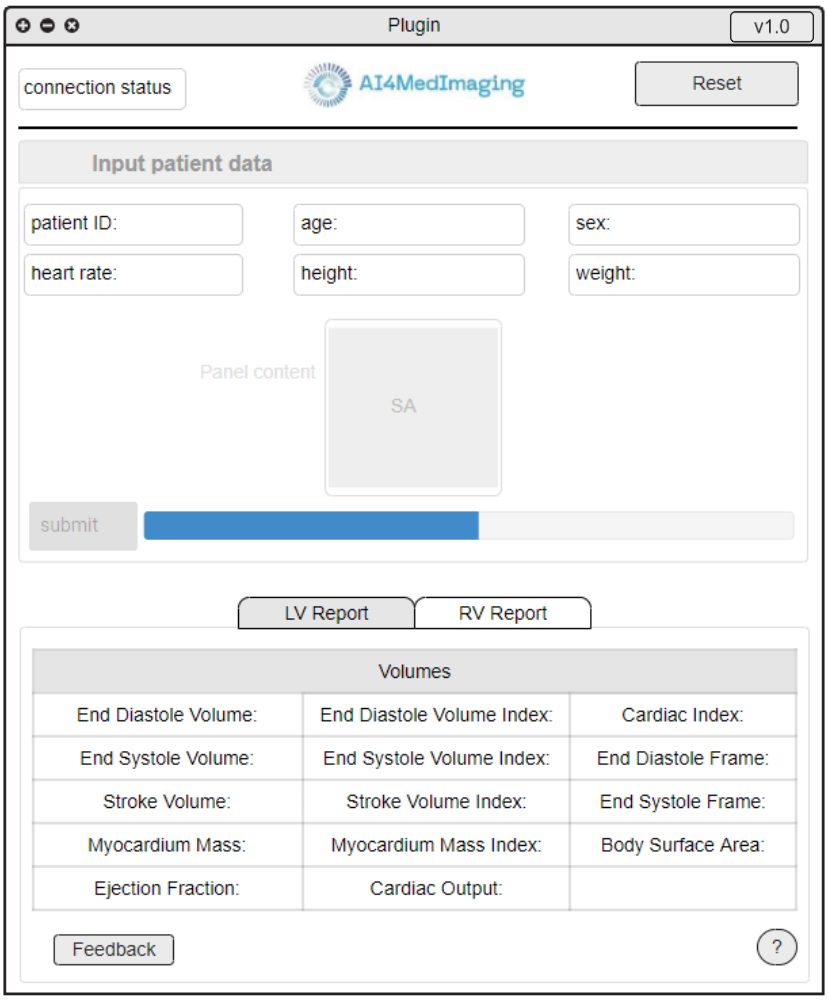

Figure 5. Example of a plugin form filling and results in the presentation window – LV Report.

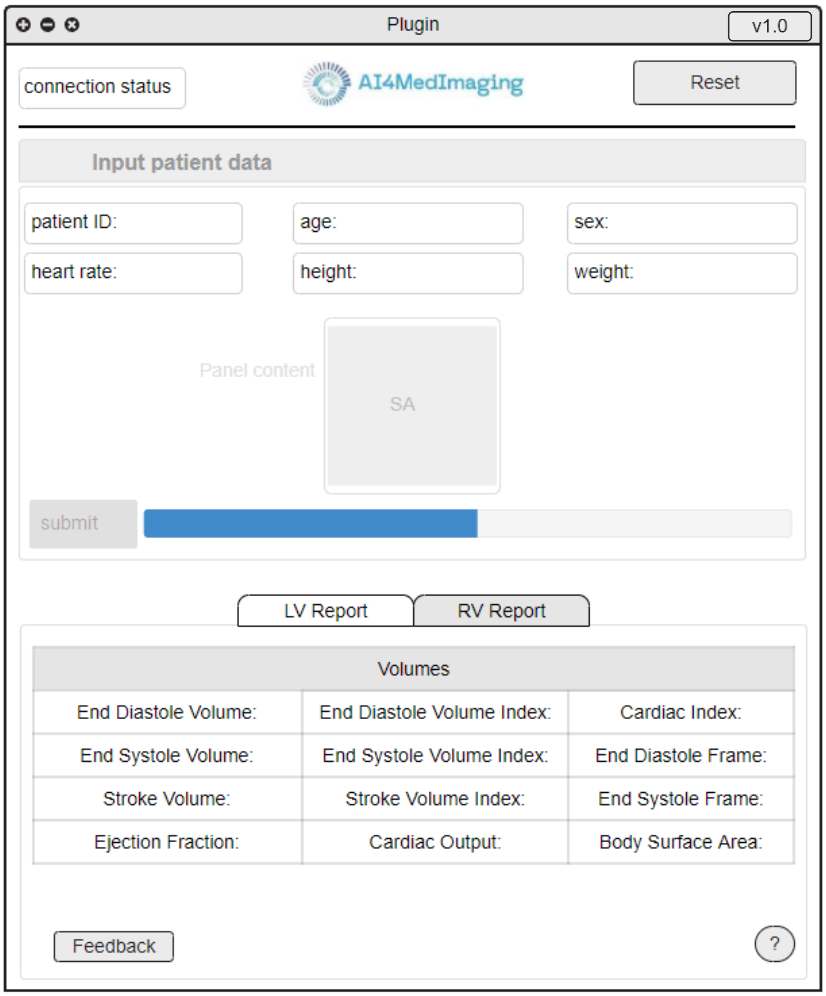

Figure 6. Example of a plugin form filling and results in the presentation window – RV Report.

After a failed processing, the plugin presents an error message, so that the User can adapt the request or report a possible problem.

Additional fields

Connection status

This field is used to indicate that the AI4CMR v1.0 service is available. If not, the User can force a connection status update by clicking on the status button.

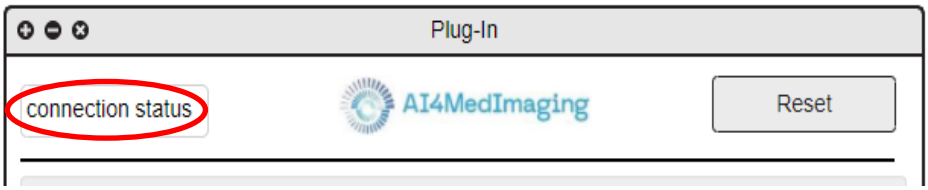

Figure 7. Connection status example.

Reset button

The reset button is used to clean all the info from the current request and make it easier for the User to start a new request without cleaning each field individually.

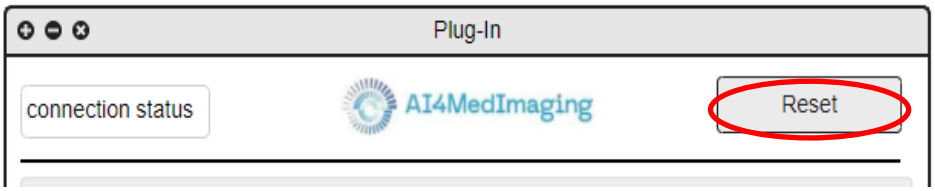

Figure 8. Reset button example.

Info button

This button presents information regarding the plugin and AI4CMR v1.0 service, such as email, certifications, versions, device labelling and so on.

Figure 9. Info button example.

Feedback button

The User can access plugin support by clicking on this button, which redirects him to feedback email software.

Figure 10. Feedback button example.

4. User account handling

The AI4CMR v1.0 provides a user account handling page, that allows each user to change their personal information and credentials. To access this functionality, the user should use the following link via the Google Chrome browser (minimum recommended version: 97) or the Safari browser (minimum recommended version: 14.1):

- https://auth.ai4medimaging.com/auth/realms/srerealm/account

4.1 Authentication

To access the account, the user should provide the assigned username or email and password.
Note: the authentication/login window depends on the third-party plugin integration.

Figure 11. User account login page.

After successful authentication the user handling page will be presented, **Figure 12**.

4.2 User information handling

After logging in, on the separator “Account” the user can change the email, first name and last name by filling the respective field and clicking in “Save”. If these values already exist, they will be presented in the respective field.

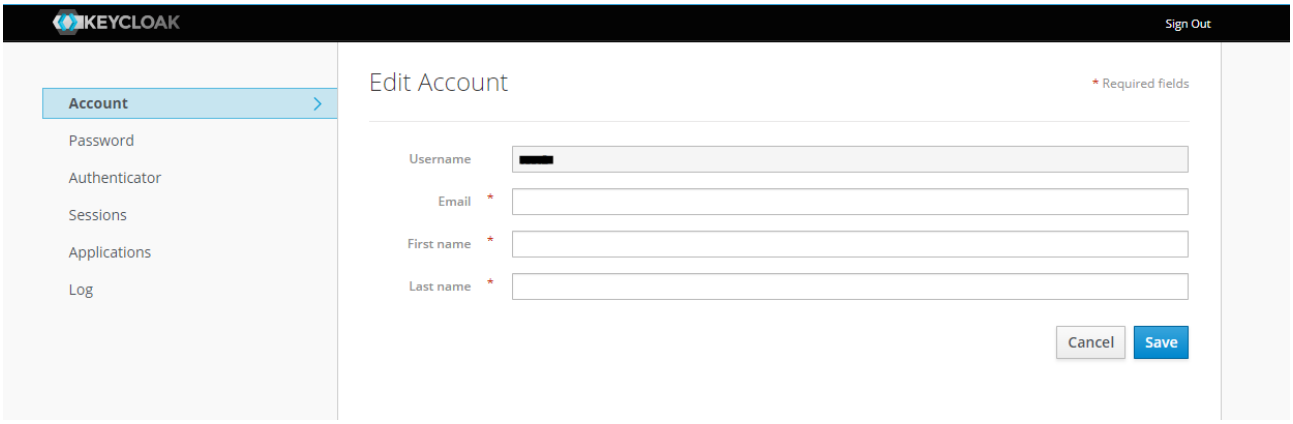

Figure 12. User account personal information edit page.

4.3 Password handling

To change the password, the user should log in first and change to the “Password” separator, provide the current password on the “Password” field and the new password on the “New Password” and “Confirmation” fields. After clicking in “Save” the password will be updated.

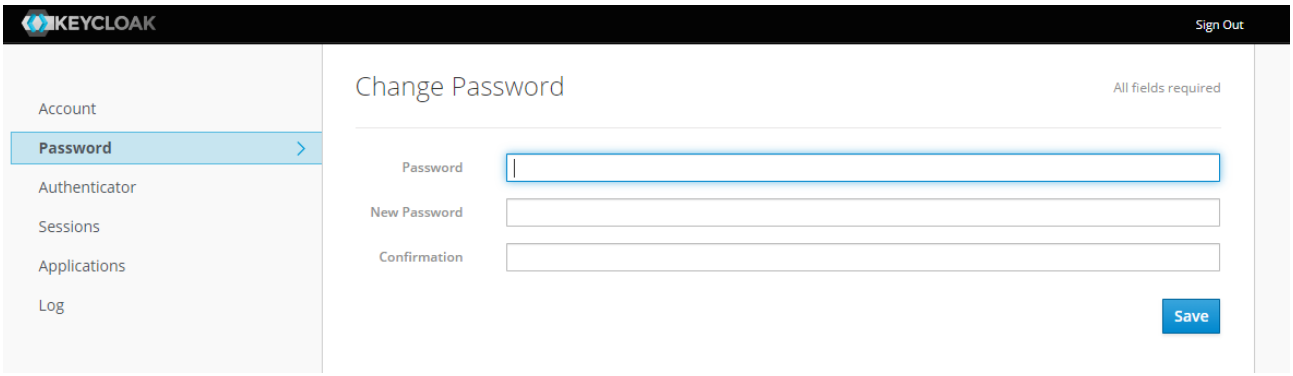

Figure 13. User account password edit page.

In case of password loss or account compromise, the IT Manager of the User’s Institution should contact the AI4MedImaging Technical Support (see section 5 for details).

4.4 Open sessions

The user has the option to monitor all open sessions associated with his account. That information is accessible in the “Sessions” separator. If any of the sessions open is considered suspect, the user has the option to close it using the “Log out all sessions” button.

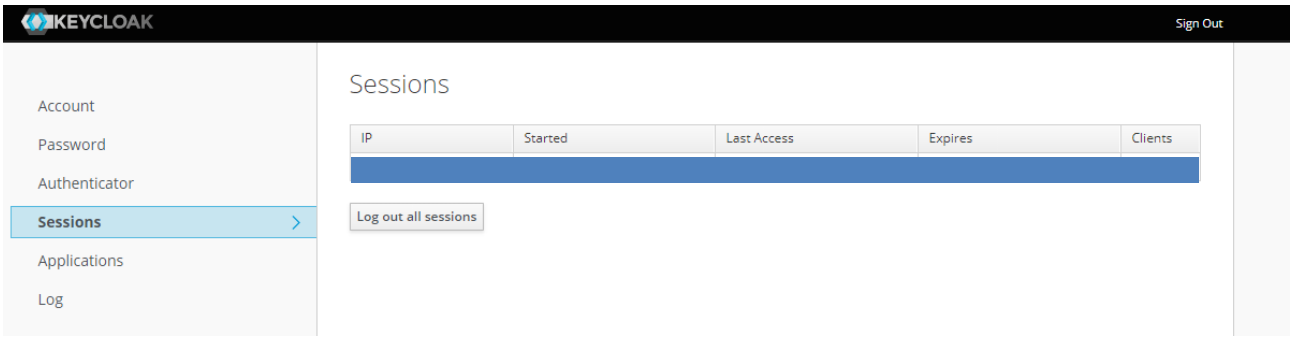

Figure 14. User account open sessions page.

4.5 Logging info

In addition to the open sessions, the user has the option to see all logging events that happen using his account. This information can be accessed on the “Log” separator.

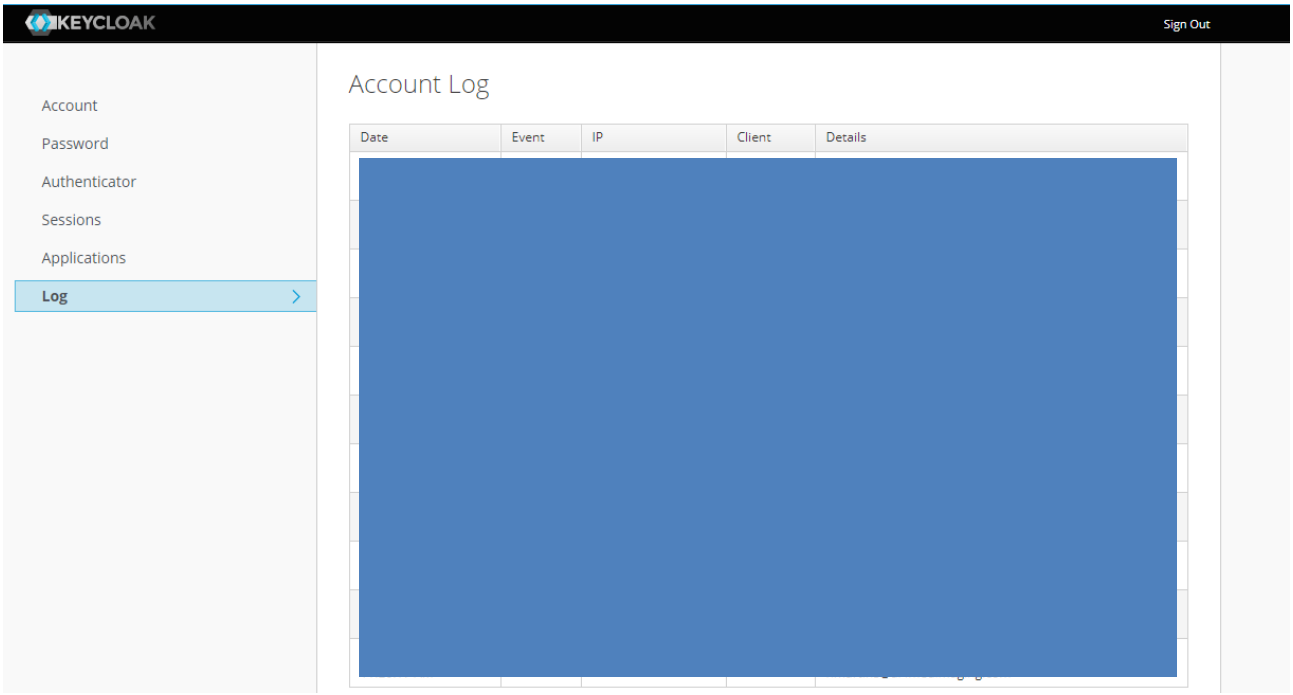

Figure 15. User account access log page.

5. Technical Support

For technical questions, to report a problem, or to request individual/group training or demos, please contact our team by e-mail or website.

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