

36 **Step-by-Step Guide to MAV-clic: Framework for the Health Care**
37 **Data Analysis**
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39 **Zeeshan Ahmed, PhD¹; Minjung Kim, PhD²; Bruce T. Liang, M.D., F.A.C.C³**
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41 ¹Department of Genetics and Genome Sciences, School of Medicine, University of
42 Connecticut Health Center, Farmington, CT, USA; ²The Pat and Jim Calhoun
43 Cardiology Center, School of Medicine, University of Connecticut Health Center,
44 Farmington, CT, USA. ³Ray Neag Distinguished Professor of Cardiovascular Biology
45 and Medicine, School of Medicine, University of Connecticut Health Center,
46 Farmington, CT, USA.

47

48 **Abstract**

49 Healthcare data includes information about patient life style, medical history, visits to the
50 practice, lab tests, imaging test, diagnoses, medications, surgical procedures, genomics profile,
51 consulted providers and claims. Adequate and analytic access to the health care data has
52 potential to revolutionize the field of medicine by improving the quality and transition of care,
53 and developing better understanding of biological mechanisms and modelling complex
54 biological interactions by integrating and analyzing knowledge in a holistic manner. To fulfill
55 the growing interests in implementing the health information system, MAV-clic is developed
56 to satisfy the requirements of data owners as well as data users in the healthcare system. As
57 the multi-database management system, it can benefit for the data owners to manage huge
58 database from multiple sources in a centralized manner. The data having different contents,
59 formats, styles, sizes, structures can be extracted and transformed into the normalized format
60 and stored into the MAV-clic system with High performance computing technology. The well-
61 organized data management features allow for data users to analyze the complex, disparate
62 healthcare data. Analytics process in MAV-clic can help building the cohort in terms of
63 demographic information, and time information as well as generating evidence using analytics
64 of the patient's information along with diagnoses, medications, laboratory results. MAV-clic
65 also offers the customized functions, which can explore the quality measures of the hospital
66 using the EHR database, visualize the patterns of the analyzed results, and report the summary
67 in an automated and timely manner. In this manuscript we describe the potential of MAV-clic
68 by explaining its features for clinical, users, measures and database of database management,
69 analysis, visualization, sharing and reporting.

70 **Keywords:**

71 Analysis, Database, Data Mining, HIPAA, Patient Generated Health Data

72

73 MAV-clic

74

75 Trying achieving the goals for the provision of better care and better health of population at
76 lower costs together with better work-life for clinicians and staff at UConn Health, in this
77 manuscript we present MAV-clic (Management, Analysis and Visualization of Clinical Big Data).

78 MAV-clic is supported by the SNE-PTN (Southern New England Practice Transformation
79 Network), one of 29 networks across the country, selected by Centers for Medicare and
80 Medicaid Services (CMS), as part of the Transforming Clinical Practices Initiative. The audience
81 of SNE-PTN and MAV-clic is not limited to doctors from all specialties, Podiatrists, Optometric,
82 Oral Surgeons, Dentists, Chiropractors, Physician Assistants, Nurse Practitioners, Clinical Nurse
83 Specialists, Clinical Social Workers, Clinical Psychologists, Registered Dietitians, Nutrition
84 Professionals Physical Therapists, Occupational Therapists and Qualified Speech-Language
85 Therapists. As, aims include use of health care data to improve quality and transition of care,
86 obtain actionable care gap based information about patients and develop communication and
87 coordination across:

- 88 • Hospitals,
- 89 • Specialists,
- 90 • Behavioral health,
- 91 • Oral health,
- 92 • Community based providers
- 93 • Sub-acute care,
- 94 • Nurse,
- 95 • Quality Inspectors,
- 96 • Management,
- 97 • Researchers,
- 98 • Analysts.

99 MAV-clic is a new HIPAA compliant framework for the health care data analysis at the UConn
100 Health, CT, USA. It implements health care and user's data security, which includes:

- 101 1) Application and Data Criticality,
- 102 2) Risk Management and Analysis,
- 103 3) Information System Activity Review,
- 104 4) Contingency Plan,
- 105 5) Device and Media Controls,
- 106 6) Access Controls.

107 MAV-clic is a new large scaled, user-friendly, interactive, cross-platform, encrypted, multi-
108 roles based, automated, customized and centralized multi-database management framework
109 for health care data management, analysis and visualization. It is based on Butterfly model
110 and product line architecture; therefore all major modules are capable of performing
111 individual key roles as well as integrating each other. It is developed using JAVA programming
112 language and tested at Microsoft Windows 10 and macOS Sierra (Version 10.12.6) operation
113 systems.

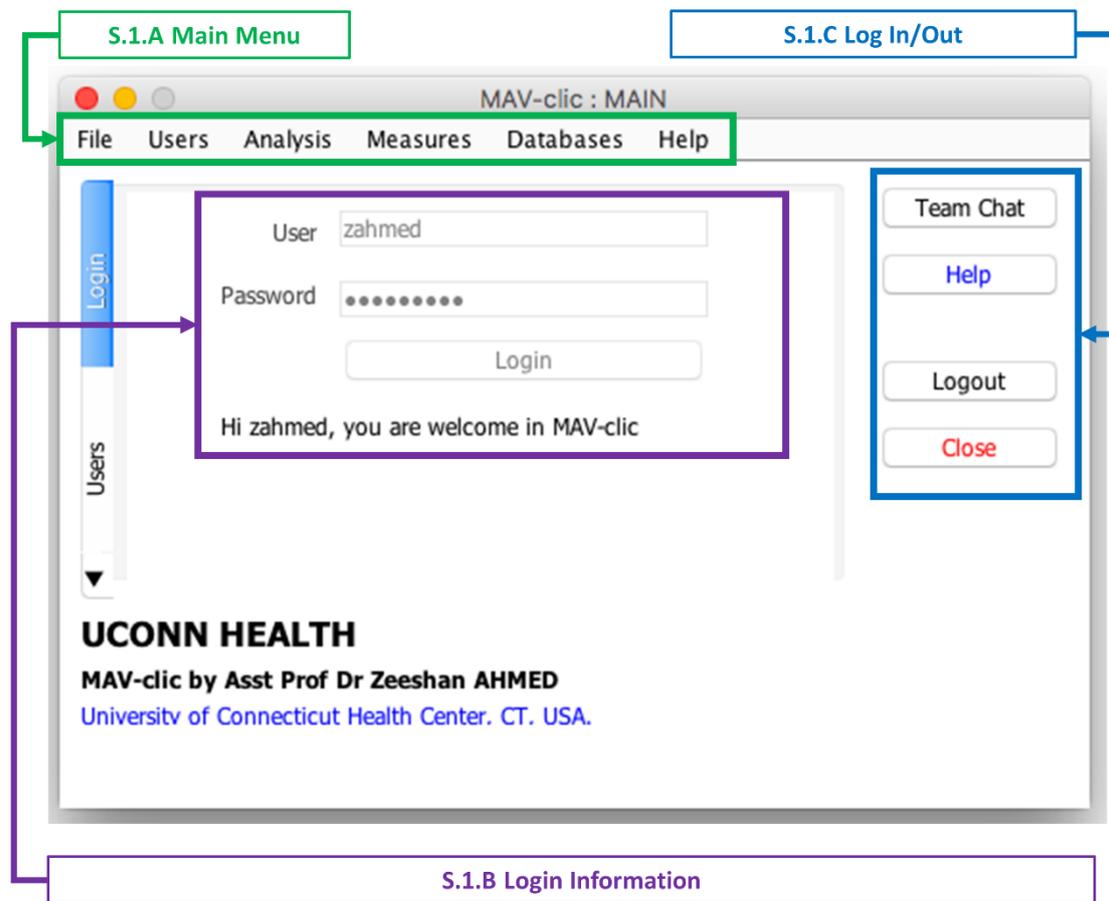
114 The graphical user interface of MAV-clic is divided in to following six modules: Main, Users,
 115 Analysis, Measures, Databases and ETL (Extract, Transform and Load). In this manuscript, we
 116 guide users in learning about MAV-clic by describing all the features of these all modules.

117 **MAV-clic Main**

118

119 MAV-clic Main is the primary graphical user interface of the MAV-clic. Main offers six tabs
 120 (Login, Users, Analysis, Measures, Database and ETL) can be observed in the left panel and
 121 each tab makes its own role in terms of management, analysis and visualization of the clinical
 122 data stored in the EHR system (S.Figure.1).

123



124

125 **S.Figure.1.** Main Interface to login and logout the MAV-clic

126

No.	Feature	Description
S.1.A	Main Menu	Main top-down menu consists of six components as follows: <ul style="list-style-type: none"> • File <ul style="list-style-type: none"> • Exit • Users <ul style="list-style-type: none"> • Institutes

		<ul style="list-style-type: none"> • Employees • Roles • Admin • Analysis <ul style="list-style-type: none"> • MAV-clic Eye • MAV-clic Measurement Analyzer • Measures <ul style="list-style-type: none"> • Measures • Version • Denominator • Numerator • Reports • Databases <ul style="list-style-type: none"> • Databases • Tables • Help <ul style="list-style-type: none"> • Contact
S.1.B	Login Information	The user enters user name and password to login to MAV-clic.
S.1.C	Log In/Out	<p>After log-in, the user has four options to choose.</p> <ul style="list-style-type: none"> • Team Chat • Help • Logout • Close

127 **S.Table.1.** Main Interface to login and logout the MAV-clic

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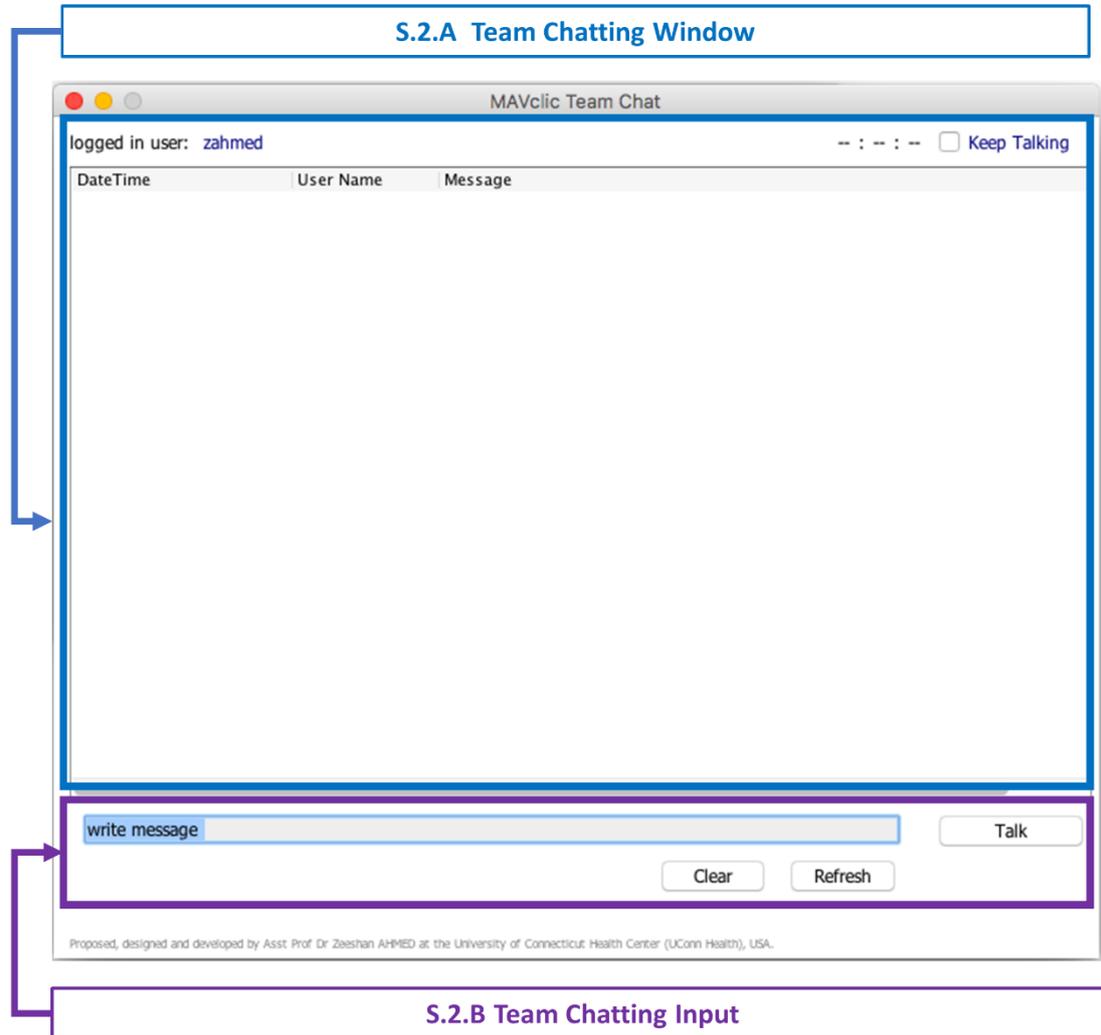
129 “Login” offers HIPAA compliant users authentication process. When a user logs into the MAV-
 130 clic system, a user must provide combinations of a user name (created by the MAV-clic
 131 administrator) and password (contains at least six characters long, include at least one number,
 132 include at least one symbol, must not contain the user ID, must be different from previous
 133 passwords, required to be changed at least once with in every 90 days). At successful login, it
 134 notifies user about password expiration 30 days before. “Login” tab also offer following
 135 options:

- 136
1. Logout from session
 - 137 2. Get administrator’s contact information for help (For assistance and troubleshooting
 138 please write at: zahmed@uchc.edu OR please call at: 860-679-2643)
 - 139 3. Team Chat (a module to connect all logged in users to exchange messages)
 - 140 4. Close application (including all open relevant modules).

141 All the features of Main are presented in S.Figure.1 and explained in TableS.1.

142 **MAV-clic Team Chat:**

143 After a logon, user can participate in conversations with other team members by pushing the
 144 “Team Chat” button (seen in S.1.C). S.Figure2 presents all the information made in the team
 145 chatting window.



146
 147 **S.Figure.2.** Team Chatting Window

148

No.	Feature	Description
S.2.A	Team Chatting Window	Displays the conversation <ul style="list-style-type: none"> “Keep Talking” Button: Check the option button to activate a “Keep Talking” function. If the button is checked, the conversation time will be recorded.
S.2.B	Team Chatting Input	Write the message <ul style="list-style-type: none"> “Talk” Button: Send the message. “Clear” Button: Clear all the conversation texts in the window. “Refresh” Button: Restore the cleared message in the window

149 **S.Table.2.** Team Chatting Window

User Data Management with MAV-clic

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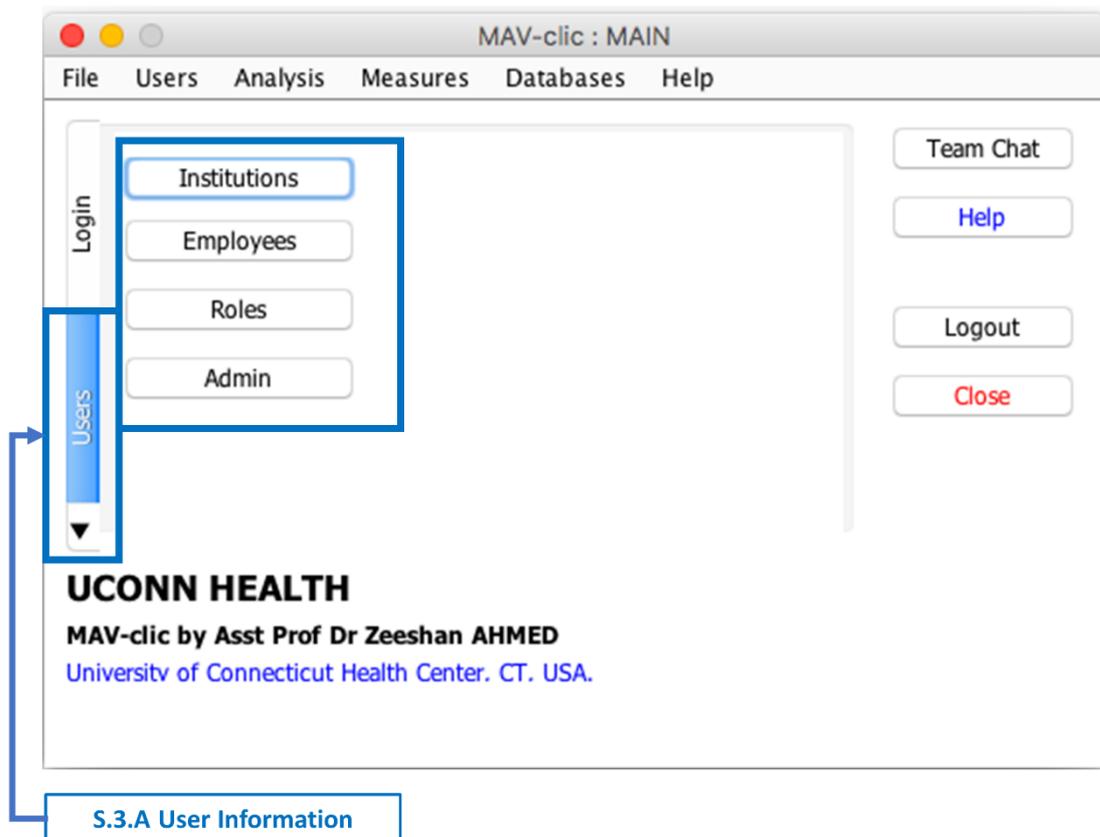
151

152 “Users” module helps in managing the data about all institutions (direct or collaborators) and
 153 employees playing different roles. It also helps in creating user accounts for all employees
 154 interacting with MAV-clic by setting access permissions and give updates for the logged events
 155 (operations performed by users).

156 Each user account has its own collection of settings in terms of the institution, role in the
 157 institution, and personal information (name, email, and office location). Users tab helps to
 158 create and manage the users’ information. In the institutions (S.Figure.4), and Roles (S.Figure.5)
 159 sections, all the information of institutions and roles are created. The created information is
 160 used to complete the employee information as seen in S.Figure6.

161 The “Admin” section can help system manger to manage the user login information using the
 162 following two tabs: User login management (S.Figure.7) & User login history (S.Figure.8). In
 163 the user login management tab, the system manager can create the user login information
 164 and assign the permissions in using the system. In the login history information, the history
 165 information can help the system manager can monitor users activity. The information can be
 166 used to analyze the performance of the system as well as to know which users have been
 167 inactive for a while.

168



169

170 **S.Figure.3.** “Users” Tab in the MAV-clic

171

No.	Feature	Description
S.3.A	User Information	In the “Users” tab, you can manage the user profile using following buttons: <ul style="list-style-type: none"> • Institutions • Employees • Roles • Admin

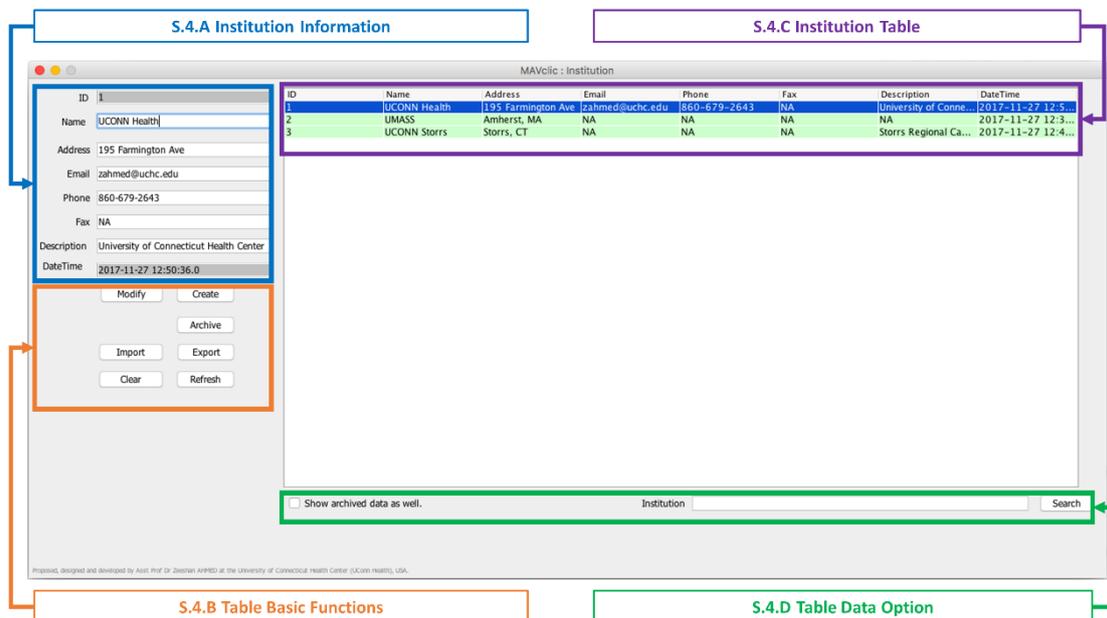
172 **S.Table.3.** “Users” Tab in the MAV-clic

173

174 **Institutions:**

175 This is sub-module of Users. It offers features to collect and maintain information about
 176 institutions. The features are presented in S.Figure.4 and explained in S.Table.4.

177



178

179 **S.Figure.4.** Institution Information in the “Users” Menu

180

No.	Feature	Description
S.4.A	Institution Information	Create the institution information. <ul style="list-style-type: none"> • Name, • Address, • Email • Phone • Fax. • Description
S.4.B	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data from Microsoft Excel spreadsheet. • Clear: To clear text fields.

		<ul style="list-style-type: none"> Refresh: To refresh and new updates (if exists) data.
S.4.C	Institution Table	Displays the institution table.
S.4.D	Table Data Option	<ul style="list-style-type: none"> “Show archived data as well”: Check “Show archived data as well” option to retrieve the archived data. Institution: Enter the existing institution information to search and retrieve the related information from the table (S.4.C).

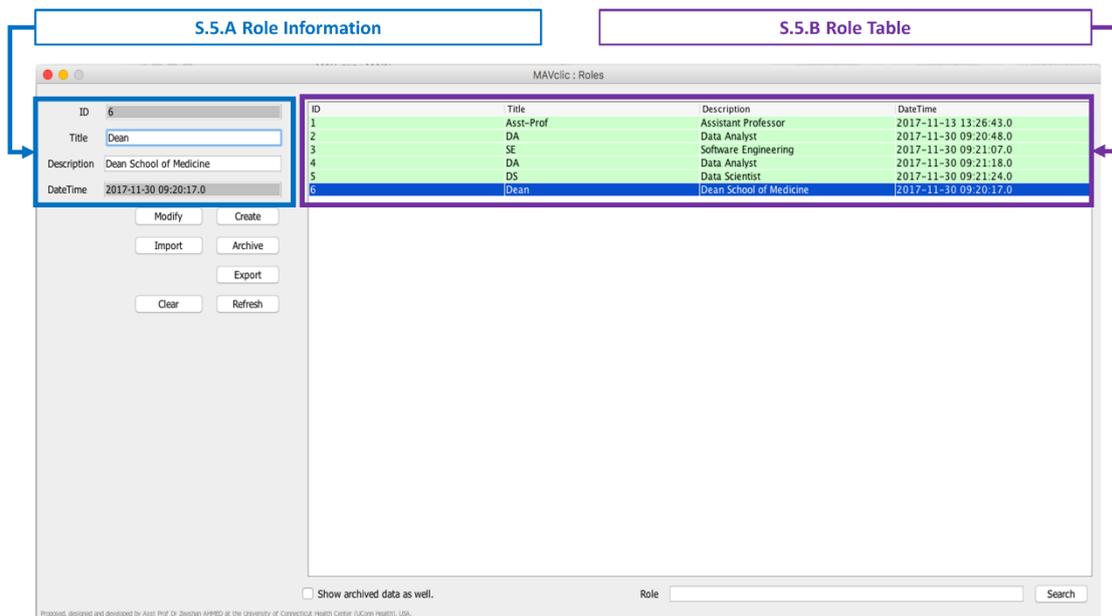
181 **S.Table.4.** Institution Information in the “Users” Menu.

182

183 **Roles:**

184 This is sub-module of Users. It offers features to collect and maintain information about roles
 185 of employees. The features are presented in S.Figure.5 and explained in S.Table.5.

186



187

188 **S.Figure.5.** Role Information in the “Users” Menu

189

No.	Feature	Description
S.5.A	Role Information	Create the roles (positions) of the users in the institution. i.e.) data scientist, medical doctor, statistician, etc. Fields: <ul style="list-style-type: none"> Title Description
S.5.B	Role Table	Displays the user’s role information.
	Basic Functions	<ul style="list-style-type: none"> Create: To create the new entry. Modify: To modify existing, selected data. Archive: To archive existing, selected data. Export: To export data in Microsoft Excel spreadsheet. Import: To import data from Microsoft Excel spreadsheet. Clear: To clear text fields.

		<ul style="list-style-type: none"> • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the role information users entered in a search text field.
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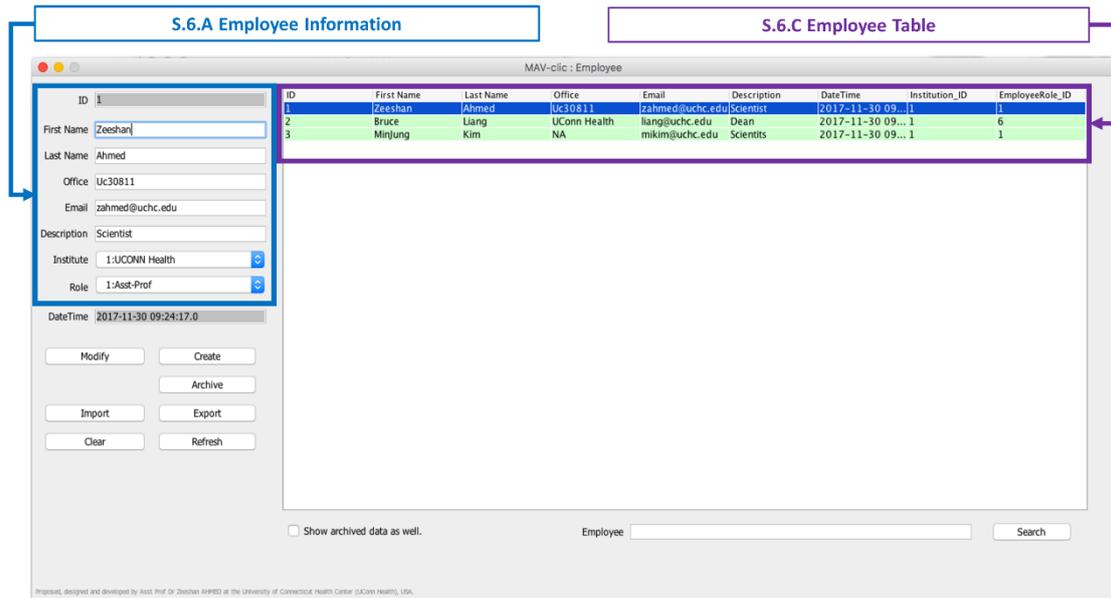
190 **S.Table.5.** Role Information in the “Users” Menu

191

192 **Employees:**

193 This is sub-module of Users. It offers features to collect and maintain information about
 194 employees. It’s all features are presented in S.Figure.6 and explained in S.Table.6.

195



196

197 **S.Figure.6.** Employee Information in the “Users” Menu

198

No.	Feature	Description
S.6.A	Employee Information	Create the user information. Once the institution and roles information are created, you can select user’s institution and role using drop-down menu. Fields: <ul style="list-style-type: none"> • First Name • Last Name • Office • Email • Description • Institute • Role
S.6.B	Employee Table	Displays the user’s information
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data from Microsoft Excel spreadsheet.

		<ul style="list-style-type: none"> • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the employee information users entered in a search text field.
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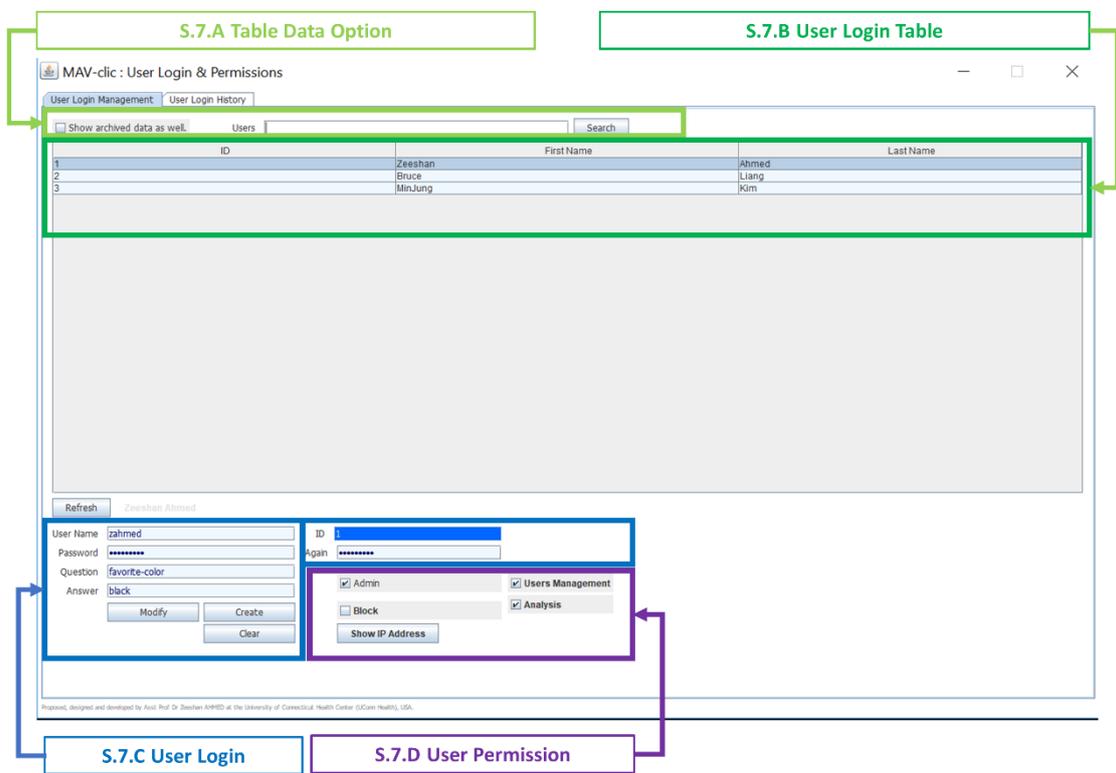
199 **S.Table.6.** Employee Information in the “Users” Menu

200

201 **Admin:**

202 This is one of the most important sub-modules of Users. It offers features to create user
 203 accounts by selecting already created employees (S.Figure.6), set/update password and set
 204 permissions to access sub-modules of MAV-clic. It also offers features to get information about
 205 all logged events. The features are presented in S.Figure.7 and 8, and explained in S.Table.7
 206 and 8.

207



208

209 **S.Figure.7.** User Login Management in the “Users” Menu

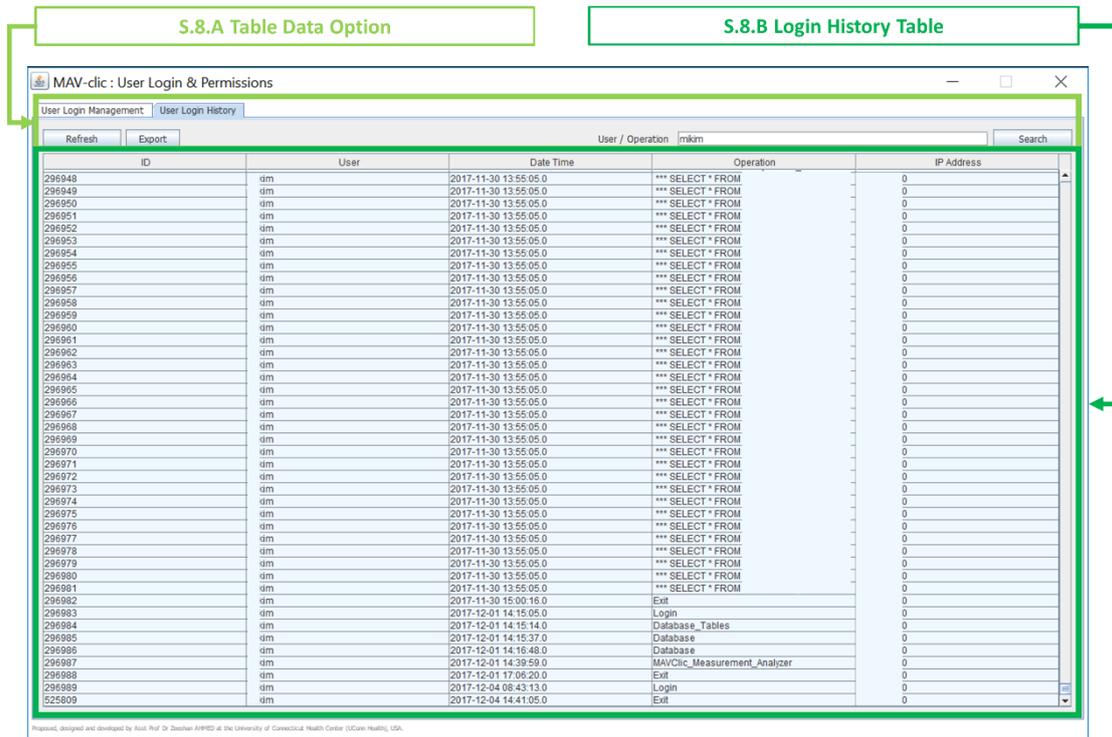
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No.	Feature	Description
S.7.A	Table Data option	<ul style="list-style-type: none"> • “Show archived data as well”: Check the option to retrieve the archived data. • “Users”: Enter a term to search and retrieve the related information from the table (S.7.B)
S.7.B	User Login Table	Displays user login information in a table format.
S.7.C	User Login	Create user login information. <ul style="list-style-type: none"> • Username: must be different from users/employee’s first and last name.

		<ul style="list-style-type: none"> • Password: should be at least six characters long, include at least one number, include at least one symbol (_&!%^<>*=-;~), must not contain the user ID, must be different from previous passwords, required to be changed at least once with in every 90 days. • Question: user proposed question, which can be used to verify user in case of losing or forgetting password. • Answer: user proposed answer to set question.
S.7.D	User Permission	<p>Specify the tasks and features user can perform</p> <ul style="list-style-type: none"> • Admin: Check the option to get administrative privileges. • User Management: Check the option to manage the user information (institution, employees, and roles) and measures information (measures, measures versions, measure version denominator, and measure version numerator). • Analysis: Check the option to use “Analysis” menu. • Block: If this option checked, the selected person restrict to use main menus. • Show IP Address: Displays a unique identifying IP address.
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Clear: To clear text fields.

211 **S.Table.7.** User Login Management in the “Users” Menu

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213

214 **S.Figure.8.** User Login History in the “Users” Menu

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No.	Feature	Description
S.8.A	Table Data option	<ul style="list-style-type: none"> • “Refresh”: Refresh the searched information and show it in the table (S.8.B).

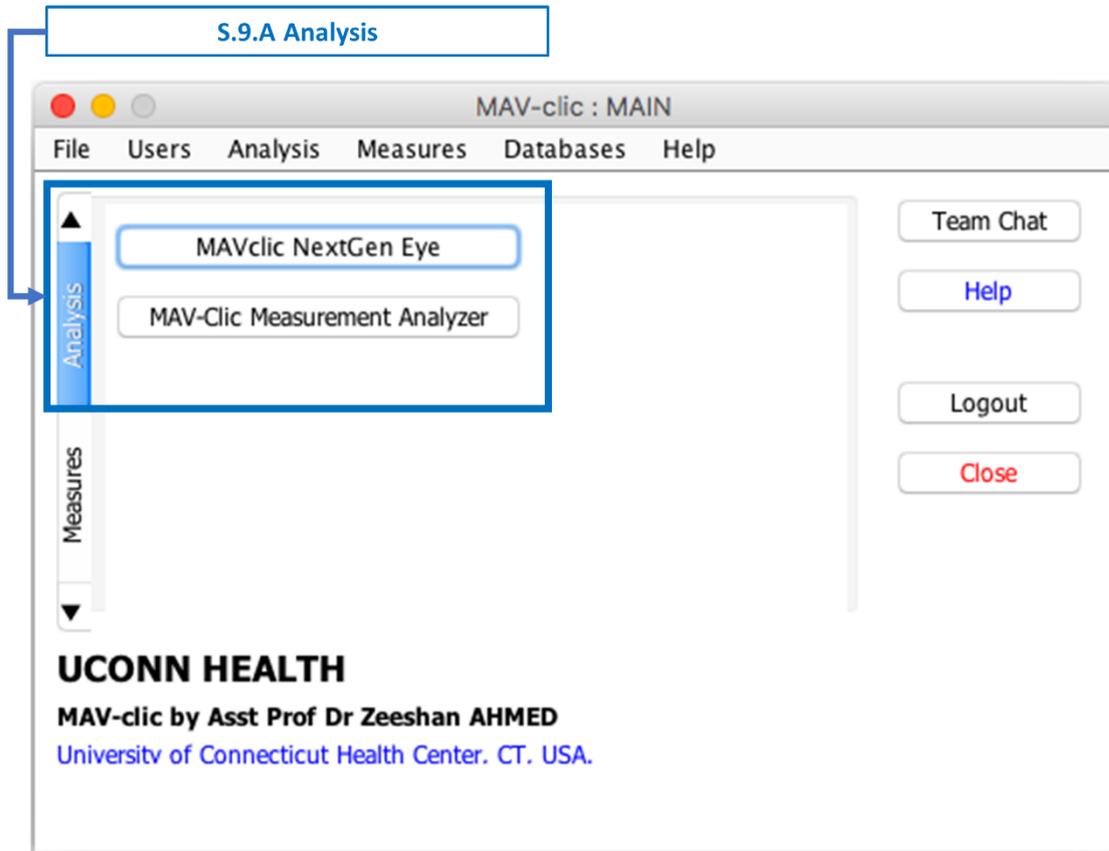
		<ul style="list-style-type: none"> • “Export”: Export the user login information from Microsoft Excel spreadsheet (.xlsx). • “Users/ Operation”: Enter user/operation term to search and retrieve related information from the table (S.8.B).
S.8.B	Login History Table	Displays summary table of all logins, sorted from the oldest to the newest.
	Table Basic Functions	<ul style="list-style-type: none"> • Search: To search data based in entered keyword in search text field.

216 **S.Table.8.** User Login History in the “Users” Menu.

217

218 **Analyzing and Visualizing the Clinical Data**

219 The Analysis tab (S.Figure.9 and S.Table.9) offers two buttons: MAV-clic NextGen Eye, and
 220 MAV-clic Measurement Analyzer. The major functions in the MAV-clic NextGen Eye is to look
 221 into the clinical data based on the customized selections in term of personal and regional
 222 information, medication, and lab results in a single database while the main role of MAV-clic
 223 Measurement Analyzer is to calculate the quality measure using clinical data stored in multiple
 224 EHR databases.



225
 226 **S.Figure.9.** “Analysis” Tab in the MAV-clic

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No.	Feature	Description
S.9.A	Analysis	In the “Analysis” tab, you can choose one of followings: <ul style="list-style-type: none"> Measures NextGen Eye: Select “MAV-clic NextGen Eye” button to look over the patient information sorted out based on the selected criteria. MAV-clic Measurement Analyzer: Select “MAV-clic Measurement Analyzer” button to build the cohort, evaluate quality measures, and make a report.

228 **S.Table.9.** “Analysis” Tab in the MAV-clic

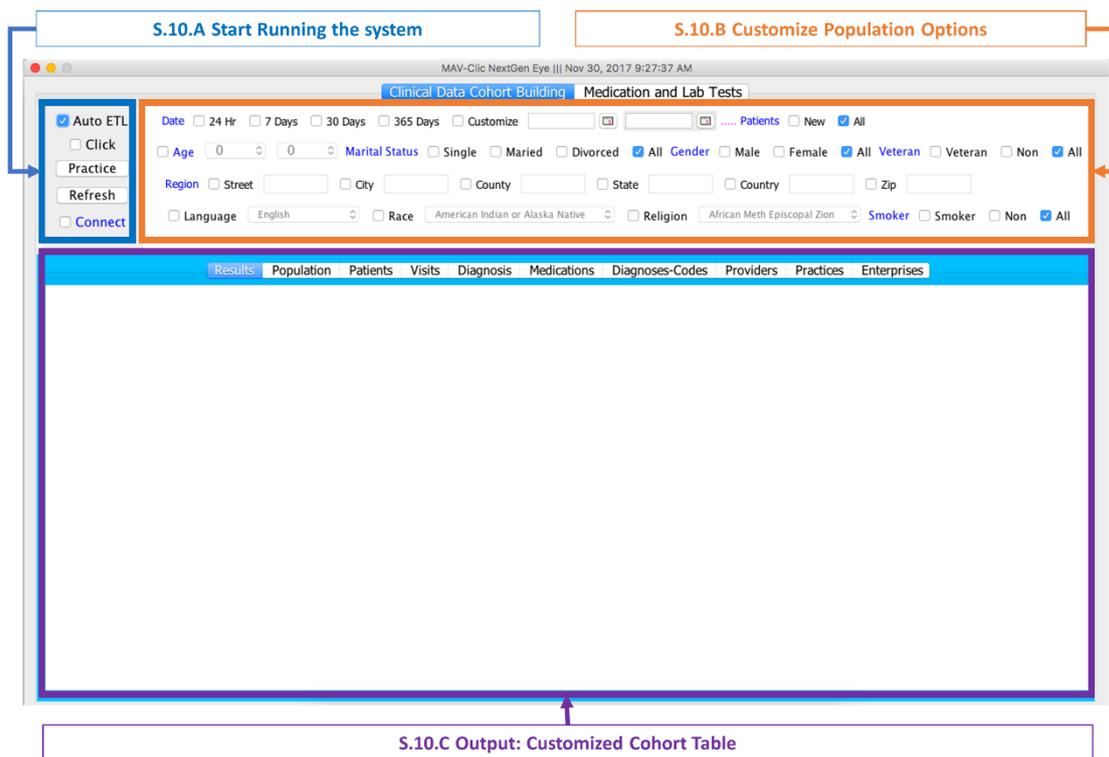
229

230 **MAV-clic NextGen Eye:**

231 This is the sub-module of Analysis which allows user to connect to the NextGen relational
 232 database and to analyze the patients’ clinical information in a viewpoint of the healthcare

233 providers. . It is further divided in to two additional sub-modules, 1) Clinical Data Cohort
 234 building (S.Figure10), and 2) Medication and Lab Test (S.Figure11).

235 Before starting analysis, user is required to firstly, connect (S. Figure. 10A) to the NextGen
 236 relational database by checking “Connect” (blue color text), and at successful connection it
 237 will turn in to “Disconnect” (red color text). Then in case user would like to automatically draw
 238 ontological relationships between extracted patients based data (e.g. total pollution →
 239 patients → visits → diagnoses → provided medications → providers who treated patients →
 240 practice → enterprise), it’s required to check option “Auto ETL”. Lastly, user can practice based
 241 information by pressing button “Practice” and can perform new analysis by pressing button
 242 “Refresh”.



243

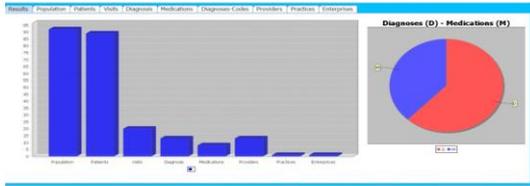
244 **S.Figure.10.** Clinical Data Cohort Building in MAV-clic NextGen Eye

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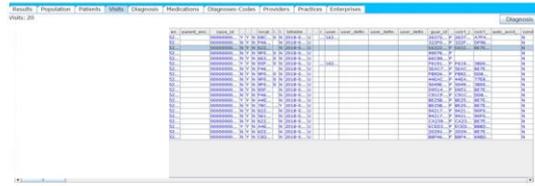
No.	Feature	Description
S.10.A	Start Running the system	<ul style="list-style-type: none"> Auto ETL: If this option is checked, ETL processes will be executed following the sequence of “Population> Patients > Visit> Diagnosis”. If it is not checked, the system will perform the analysis based on user’s input. The user should manually select the sequence to obtain the analysis results. Click: Checking the option, users can select a particular patient of interest and track the patient information from the tabs in the “Output” section (S.10.C). Practice: Displays all the provider information stored in the MAV-clic. Refresh: Refreshes the result based on the changes made in options (S.10.B). Connect: if this option is checked, MAV-clic connects with the database.

<p>S.10.B</p>	<p>Customize Population Option</p>	<p>Customize the population of interest with ten different options. All options except Date are selected at default.</p> <ul style="list-style-type: none"> • Patients <ul style="list-style-type: none"> ○ Search among new patients only ○ Search among all patients (new and old) • Date, day and hours: <ul style="list-style-type: none"> ○ 24 Hour ○ 7 days ○ 365 days ○ Customize <ul style="list-style-type: none"> ▪ Start date ▪ End date • Age <ul style="list-style-type: none"> ○ Start age ○ End age • Marital Status <ul style="list-style-type: none"> ○ Single ○ Married ○ Divorced ○ All • Gender <ul style="list-style-type: none"> ○ Male ○ Female ○ All • Veteran <ul style="list-style-type: none"> ○ Veteran ○ Non ○ All • Smoker <ul style="list-style-type: none"> ○ Smoker ○ Non ○ All • Region <ul style="list-style-type: none"> ○ Street ○ City ○ County ○ State ○ Country ○ Zip • Language • Race • Religion
<p>S.10.C</p>	<p>Output: Customized Population</p>	<p>Provides population information sorted out based on the selected criteria. MAV-clic offers ten output tabs having different perspectives in the defined population.</p> <ul style="list-style-type: none"> • Results <ul style="list-style-type: none"> ○ Bar chart showing the frequencies from the results (population, patients, visits, diagnosis, medication, providers, practices, and enterprises) ○ Pie chart having the frequency ratio of diagnoses vs. medications • Population <ul style="list-style-type: none"> ○ All the people who entered in the EHR system ○ Fields <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID. ▪ Demographics: Name, Address, Race, Data of Birth etc. • Patients <ul style="list-style-type: none"> ○ All the patients who registered to receive the treatment

		<ul style="list-style-type: none"> ○ Field <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID. ▪ Time stamp information: Time information using EHR system ● Visits <ul style="list-style-type: none"> ○ All the patients who visit the health providers ○ Field <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID, Encounter Id, Provider ID, Location ID, Case ID ▪ Encounter time stamp information ▪ Payment information ● Diagnosis <ul style="list-style-type: none"> ○ All the diagnosis information which are made during the health provider visit ○ Fields <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID, Encounter Id, Provider ID, Location ID, Case ID, Diagnosis code library ID ▪ Diagnosis related time stamp information ▪ Diagnosis information: Diagnosis code, ICD-9 code, Diagnosis description etc. ● Medications <ul style="list-style-type: none"> ○ All the medication which are made during the health provider visit ○ Fields <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID, Encounter Id, Provider ID, Location ID, Case ID, NDC (National Drug Code) ID, Diagnosis Library ID ▪ Medication related time stamp information ▪ Medication information: Rx quantity, Rx refills, Rx unit, Rx comment etc. ● Diagnosis-Codes <ul style="list-style-type: none"> ○ All the diagnosis information stored in the database ○ Fields <ul style="list-style-type: none"> ▪ Diagnosis code library ID ▪ Diagnosis code ▪ ICD-9 code ▪ Diagnosis description ● Providers <ul style="list-style-type: none"> ○ All the healthcare providers who treat patients ○ Fields <ul style="list-style-type: none"> ▪ ID information: Provider ID ▪ Contact Information: Name, Address, Telephone number, Email, Fax etc. ● Practices <ul style="list-style-type: none"> ○ All the healthcare practices that patients use ○ Fields <ul style="list-style-type: none"> ▪ ID information: Enterprise ID, Practice ID ▪ Contact Information: Name, Address, Telephone number, Email, Fax etc. ● Enterprises <ul style="list-style-type: none"> ○ All the healthcare enterprises that are composed of healthcare practices ○ Fields <ul style="list-style-type: none"> ▪ ID information: Enterprise ID ▪ Enterprise related time stamp information
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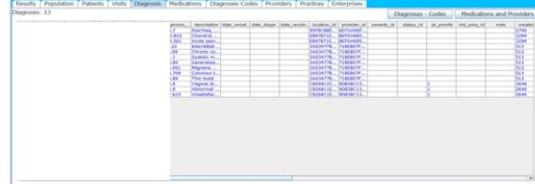
S.Figure.10.1 Results Tab in the Cohort Table



S.Figure.10.4 Visits Tab in the Cohort Table



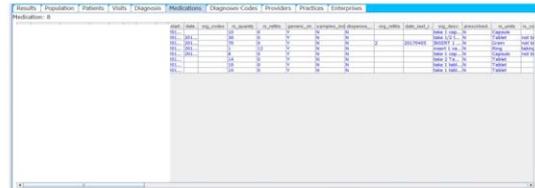
S.Figure.10.2 Population Tab in the Cohort Table



S.Figure.10.5 Diagnosis Tab in the Cohort Table

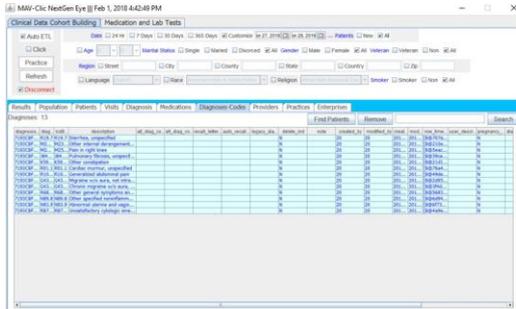


S.Figure.10.3 Patients Tab in the Cohort Table

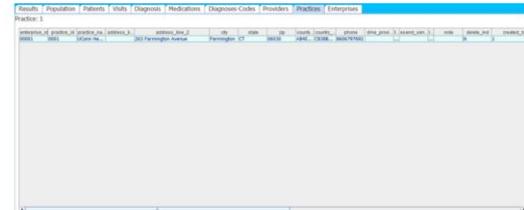


S.Figure.10.6 Medications Tab in the Cohort Table

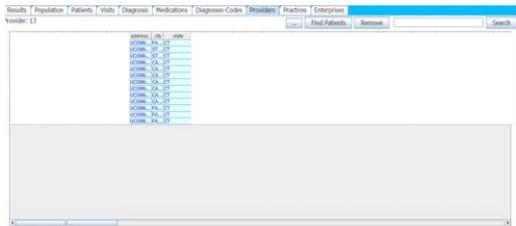
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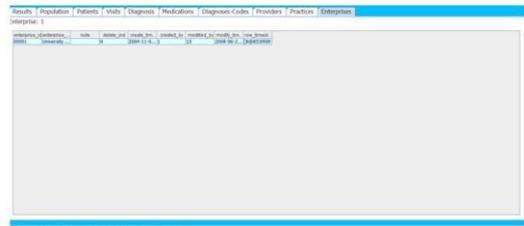
S.Figure.10.7 Diagnoses-Codes Tab in the Cohort Table



S.Figure.10.9 Practices Tab in the Cohort Table

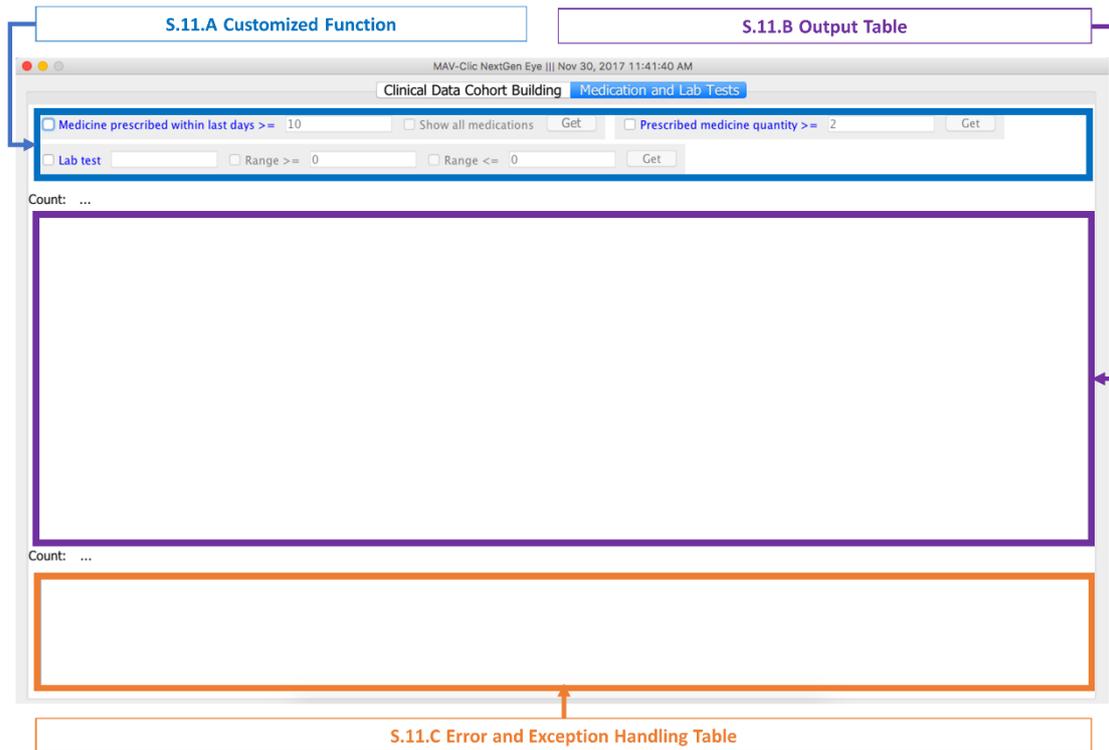


S.Figure.10.8 Providers Tab in the Cohort Table



S.Figure.10.10 Enterprises Tab in the Cohort Table

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S.Figure.11. Medication and Lab Tests in MAV-clic NextGen Eye

No.	Feature	Description
S.11.A	Customized Function	Customize the population with medication and lab test options. <ul style="list-style-type: none"> • Medicine prescribed within last days <ul style="list-style-type: none"> ○ Medicine prescribed within last days: Check the option and input the number of the days to obtain the patients' medication information ○ Show all medications: Check the option to obtain all the medication information. • Prescribed medicine quantity: Check the option and input the number of medicine quantity to get the patients' medication information • Lab Test <ul style="list-style-type: none"> ○ Check the "Lab test" option and input the name of lab test to obtain the patients' lab test information ○ Check the "Range >=" and/or "Range <=" option(s) to define the lowest and/or highest values of the lab test.
S.11.B	Output Table	Displays the patient information table
S.11.C	Error and Exceptional Handling Table	Displays the patient information table when the result is not-recommended format or is out of range in the lab test.

S.Table.11. Medication and Lab Tests in MAV-clic NextGen Eye

258

259 Users can customize the cohort conditions in terms of the personal information, regional
 260 information (as seen in S.Figure10.B) from the registered patient population. It is capable of
 261 tracking one specific patient in terms of visit to the practices, diagnoses, medication, and
 262 consulted providers. Once the cohort is built from the Clinical Data Cohort Building

263 (S.Figure.10), analyzers can look into details in terms of medications and lab test results as
264 seen in the S.Figure.11.

265 MAV-clic Measurement Analyzer:

266 MAV-clic Measurement Analyzer is composed of three analysis and visualization submodules
267 of 1) Clinical Data Analysis, 2) Measurement Analysis, and 3) Report Generation. In Clinical
268 Data Analysis (S.Figure12), users can build group of patients by choosing the demographic and
269 time points information same as the Clinical Data Cohort Building (S.Figure10) and by assigning
270 the diagnosis of interest codes to the quality measure information.

271 Similar to the MAV-clic NextGen Eye, there are two preliminary steps prior to designing the
272 initial patient population of interest. The first step is to check the “Connect” button in order
273 to connect to the relational database. The second step is to check “Auto ETL” button to track
274 the ontological relationships from the registered patient population in the database
275 automatically. After selecting the design elements for group of patients, users can run the MAV-
276 clic system by pressing the “Practice” button at the first analysis, and by pressing the “Refresh”
277 button after the second analysis.

278 In calculating the quality measures, it is required to build the population at risk. The population
279 at risk can be defined as diagnosis information. In the diagnosis-code tab (S.Figure12.8), users
280 can 1) filter out the diagnosis codes of interest, 2) connect the codes with the measure, and
281 measure versions, and 3) save the link in the server. The saved link information can narrow
282 down the patient population satisfying the conditions of initial population which is the first
283 step of evaluating the quality measures. The clinical information who are selected for quality
284 measure evaluation can be downloaded with Microsoft Excel Spreadsheet (.xlsx).

285 Also, the population at risk can be defined by the medications use. The medications of interest
286 can be searched in the medication tab in the cohort table (S.Figure12.7). Based on the selected
287 lists of medication, the patients can be found by clicking a “Find Patients” button. Also, clinical
288 information sorted out can be downloaded with Microsoft Excel Spreadsheet (.xlsx).

289

		<ul style="list-style-type: none"> ○ Single ○ Married ○ Divorced ○ All ● Gender <ul style="list-style-type: none"> ○ Male ○ Female ○ All ● Veteran <ul style="list-style-type: none"> ○ Vetran ○ Non ○ All ● Smoker <ul style="list-style-type: none"> ○ Smoker ○ Non ○ All ● Region <ul style="list-style-type: none"> ○ Street ○ City ○ County ○ State ○ Country ○ Zip ● Language ● Race ● Religion
S.12.C	Output: Customized Cohort Table	<p>Provides patient population information sorted out based on the selected criteria. MAV-clic provides ten output tabs having different perspectives in the defined population. In each tab, the patient information can be saved as Microsoft Excel spreadsheet (.xlsx).</p> <ul style="list-style-type: none"> ● Summary: Unique numbers calculated in the systems <ul style="list-style-type: none"> ○ Unique number of patients ○ Unique number of patients visited ○ Unique number of visits ○ Unique number of patients prescribed medications ○ Unique number of prescribed medications ○ Unique number of providers ○ Unique number of diagnosis codes ○ Unique number of icd9cm codes ○ Unique number of practices where medications prescribed ● Results <ul style="list-style-type: none"> ○ Bar chart showing the frequencies from the results (population, patients, visits, diagnosis, medication, providers, practices, and enterprises) ○ Pie chart having the frequency ratio of diagnoses vs. medications ● Population <ul style="list-style-type: none"> ○ All the people who entered in the EHR system ○ Fields <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID. ▪ Demographics: Name, Address, Race, Data of Birth etc. ● Patients <ul style="list-style-type: none"> ○ All the patients who registered to receive the treatment ○ Field <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID. ▪ Time stamp information: Time information using EHR system

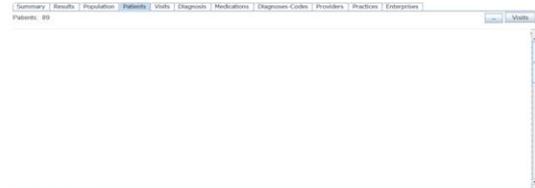
		<ul style="list-style-type: none"> • Visits <ul style="list-style-type: none"> ○ All the patients who visit the health providers ○ Field <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID, Encounter Id, Provider ID, Location ID, Case ID ▪ Encounter time stamp information ▪ Payment information • Diagnosis <ul style="list-style-type: none"> ○ All the diagnosis information which are made during the health provider visit ○ Diagnosis Search Function <ul style="list-style-type: none"> ▪ Diagnosis name search ▪ ICD-9 Code Search ○ Fields <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID, Encounter Id, Provider ID, Location ID, Case ID, Diagnosis code library ID ▪ Diagnosis related time stamp information ▪ Diagnosis information: Diagnosis code, ICD-9 code, Diagnosis description etc. • Medications <ul style="list-style-type: none"> ○ All the medication which are made during the health provider visit ○ Medication Search Function <ul style="list-style-type: none"> ▪ Medication name search ▪ NDC Code Search ○ Fields <ul style="list-style-type: none"> ▪ ID information: Person (Patient) ID, Practice ID, Enterprise ID, Encounter Id, Provider ID, Location ID, Case ID, NDC (National Drug Code) ID, Diagnosis Library ID ▪ Medication related time stamp information ▪ Medication information: Rx quantity, Rx refills, Rx unit, Rx comment etc. • Diagnosis-Codes <ul style="list-style-type: none"> ○ All the diagnosis information stored in the database ○ Users can filter out the diagnosis codes of interest, save the codes in the relevant measures, and measure version, and save them in the database. This work enables to find out initial patient population for the quality measures. ○ Fields <ul style="list-style-type: none"> ▪ Diagnosis code library ID ▪ Diagnosis code ▪ ICD-9 code ▪ Diagnosis description • Providers <ul style="list-style-type: none"> ○ All the healthcare providers who treat patients ○ Fields <ul style="list-style-type: none"> ▪ ID information: Provider ID ▪ Contact Information: Name, Address, Telephone number, Email, Fax etc. • Practices <ul style="list-style-type: none"> ○ All the healthcare practices that patients use ○ Practice Search Function <ul style="list-style-type: none"> ▪ Practice location search ▪ Practice Specialty search ○ Fields <ul style="list-style-type: none"> ▪ ID information: Enterprise ID, Practice ID ▪ Contact Information: Name, Address, Telephone number, Email, Fax etc. • Enterprises
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	<ul style="list-style-type: none"> ○ All the healthcare enterprises that are composed of healthcare practices ○ Fields <ul style="list-style-type: none"> ▪ ID information: Enterprise ID ▪ Enterprise related time stamp information

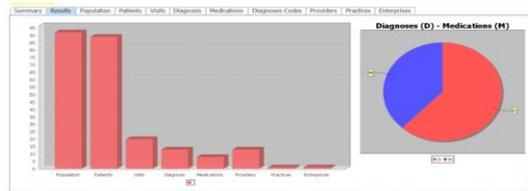
293 **S.Table.12.** Clinical Data Analysis in MAV-clic Measurement Analyzer
 294



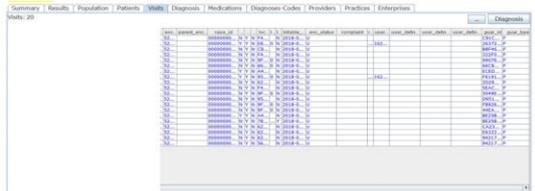
S.Figure.12.1 Summary Tab in the Cohort Table



S.Figure.12.4 Patients Tab in the Cohort Table



S.Figure.12.2 Results Tab in the Cohort Table



S.Figure.12.5 Visits Tab in the Cohort Table

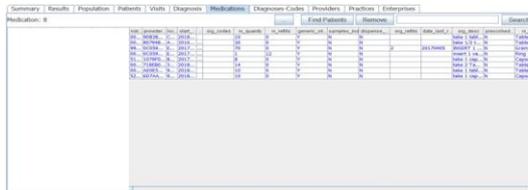


S.Figure.12.3 Population Tab in the Cohort Table

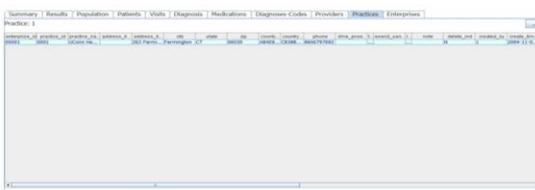


S.Figure.12.6 Diagnosis Tab in the Cohort Table

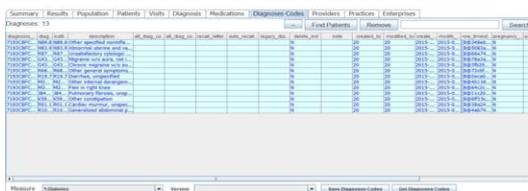
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S.Figure.12.7 Medications Tab in the Cohort Table



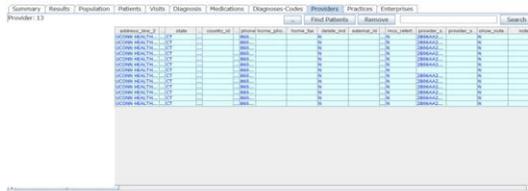
S.Figure.12.10 Practices Tab in the Cohort Table



S.Figure.12.8 Diagnoses-Codes Tab in the Cohort Table



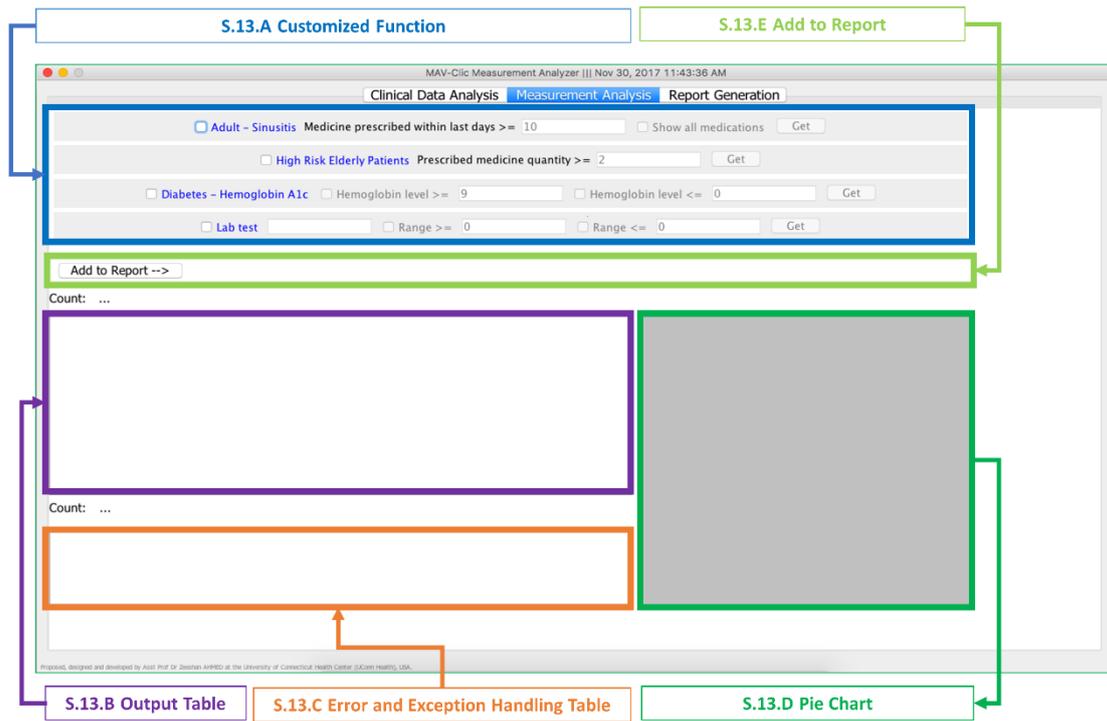
S.Figure.12.11 Enterprises Tab in the Cohort Table



S.Figure.12.9 Providers Tab in the Cohort Table

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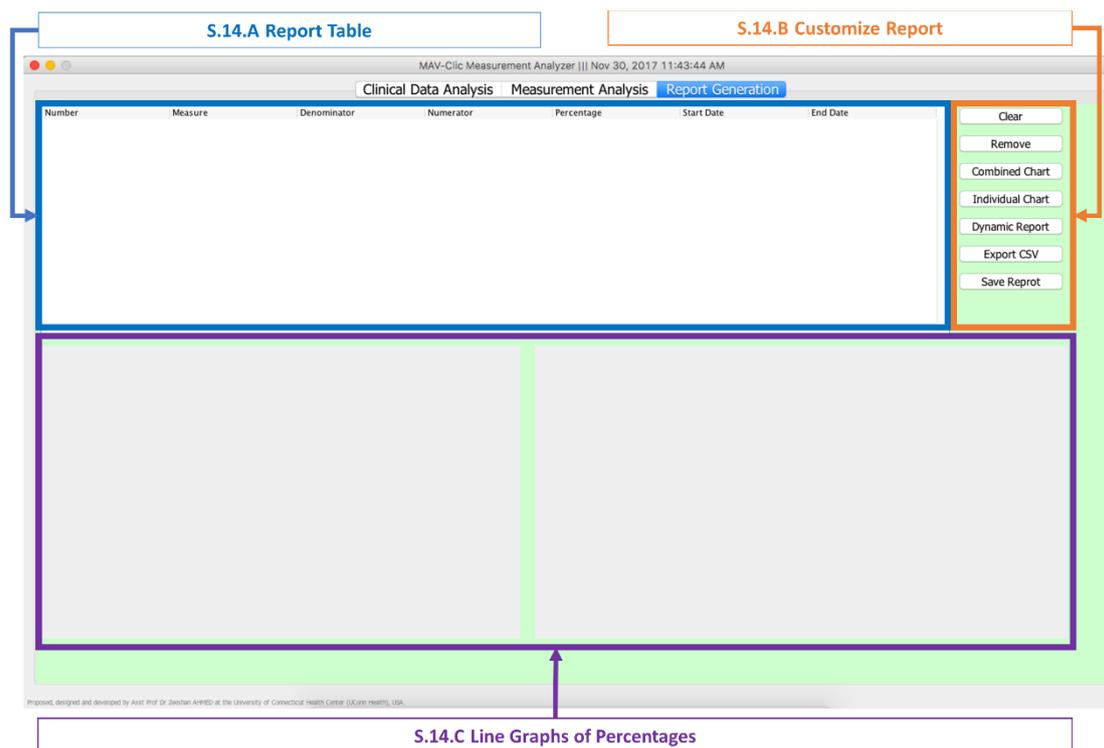
300

S. Figure.13. Measurement Analysis in MAV-clic Measurement Analyzer

No.	Feature	Description
S.13.A	Customized Function	<p>Customize the population with medication and lab test options. Default of the initial patient population is the patients defined at the “Clinical Data Analysis” Menu.</p> <ul style="list-style-type: none"> • Adult –Sinusitis <ul style="list-style-type: none"> ○ Check the option and input the number of the days to obtain the patients’ medication information • High Risk Elderly Patients <ul style="list-style-type: none"> ○ Check the option and input the number of prescribed medicine quantity to obtain the patients’ medication information • Diabetes-Hemoglobin A1c <ul style="list-style-type: none"> ○ Check the “Diabetes-Hemoglobin A1c” option to obtain patient’s hemoglobin information. ○ “Hemoglobin level >=“and/or “Hemoglobin level <=“: Check the options and input the lowest and/or highest values of the hemoglobin level. • Medicine prescribed within last days <ul style="list-style-type: none"> ○ Medicine prescribed within last days: Check the option and input the number of the days to obtain the patients’ medication information ○ Show all medications: Check the option to obtain all the medication information. • Lab Test <ul style="list-style-type: none"> ○ Check the “Lab test” option and input the name of lab test to obtain patients’ the lab test information ○ “Range >=“and/or “Range <=“: Check the option to define the lowest and/or highest values of the lab test.
S.13.B	Output Table	Displays the patient information table.

S.13.C	Error and Exception Handling Table	Displays the patient information table when the result is not-recommended format or is out of range in the lab test.
S.13.D	Pie Chart	Displays the numerical proportion of the selected patient information (S.13.B).
S.13.E	Add to Report	Click the button to move the patient information to the “Report Generation” tab.

301 **S.Table.13.** Measurement Analysis in MAV-clc Measurement Analyzer
 302



303 **S.Figure.14.** Report Generation in MAV-clc Measurement Analyzer
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 305

No.	Feature	Description
S.14.A	Report Table	<p>Displays the summary information which was made in the “Measurement Analysis” tab. The report table contains 7 components as follows:</p> <ul style="list-style-type: none"> • Number • Measure • Denominator: Number of Initial patient population (S.12.C) • Numerator: Number of cohort defined with medication and lab test options (S.13.B). • Percentage: Numerator/Denominator *100 • Start Date • End Date
S.14.B	Customize Report	<p>Customize the report table (S.14.A) with seven different options.</p> <ul style="list-style-type: none"> • Clear: Clear all the information in the report table (S.14.A). • Remove: Remove the selected information in the report table (S.14.A). • Combined Chart

		<ul style="list-style-type: none"> • Individual Chart • Dynamic Report: Export the report table information (S.14.A) and combined line graph (S.14.C) to Jasper Report print (.jrprint). • Export CSV: Export the report table information (S.14.A) to Microsoft Excel spreadsheet (.xlsx). • Save Report: Save the report table information (S.14.A) in the “Measures Reports” (S.20.B).
S.14.C	Line Graphs of Percentages	<p>Displays line graphs having series of percentage data pointes</p> <ul style="list-style-type: none"> • Left Window: Combined chart having all the quality measures in a chronological sequence. • Right Window: Multiple individual chart having a relevant quality measure in a chronological sequence.

306 **S.Table.14.** Report Generation in MAV-clic Measurement Analyzer

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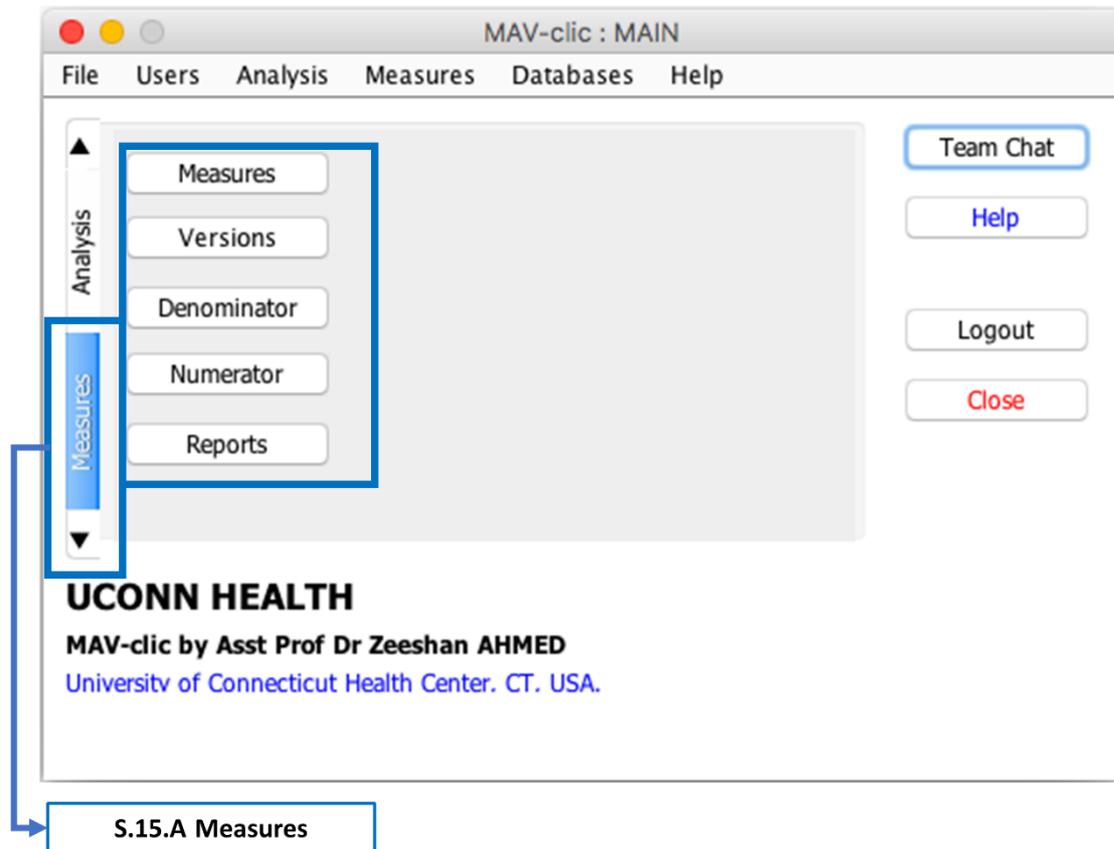
308 Once the initial population is built from the Clinical Data Analysis, users can find out the
 309 patients who received specific laboratory tests and medications in the Measurement Analysis
 310 (S.Figure13). The selected patients in the Clinical Data Analysis and Measurement Analysis are
 311 counted and used as denominator, and numerator of quality measures. In Report Generation
 312 (S.Figure14), the collected information from the previous two modules can be used to
 313 calculate the quality measures, to visualize into the chart, and to make a report.

314

315 **Measure Information Management with MAV-clic**

316

317 Most of quality measures can be represented as the proportion or the percentage which can
 318 be calculated with the denominator and the numerator. The denominator counts on the
 319 patients treated by healthcare provider during a defined time period. The numerator
 320 represent the number of patients who is in the denominator as well as who received the
 321 diagnostic lab tests or medications. The Measure tab (in S.Figure15) presents four buttons to
 322 choose measure elements. Each button leads users to manage the measure relevant
 323 information in terms of measure (S.Figure16), measure version (S.Figure17), denominator
 324 (S.Figure18), and numerator (S.Figure19). The calculated information with the denominator
 325 and numerator in each measure version is listed in the Measure Report (S.Figure20).



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327 **S.Figure.15.** “Measures” Tab in the MAV-clic

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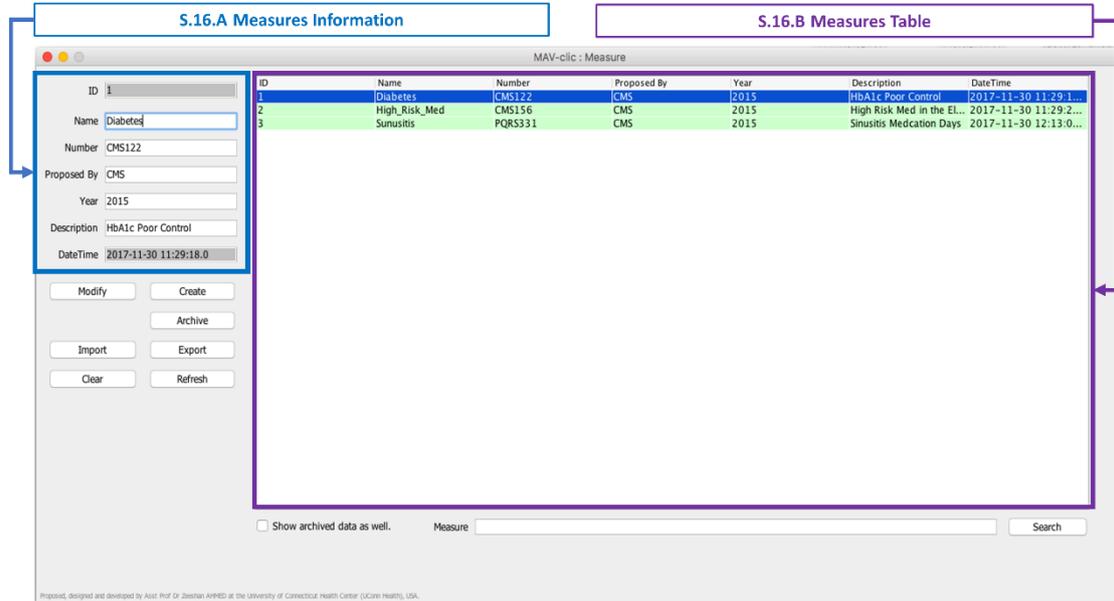
No.	Feature	Description
S.15.A	Measures	In the “Measure” tab, you can set up the measures. Measures consist of five components as follows: <ul style="list-style-type: none"> • Measures • Versions • Denominator • Numerator • Reports

329 **S.Table.15.** “Measures” Tab in the MAV-clic

330 **Measure:**

331 This is sub-module of Measures. It offers features to collect and maintain information
 332 about measures (e.g. name, number, proposed by, year and additional
 333 description).The features are presented in S.Figure.16 and explained in S.Table.16.

334



335

336 **S.Figure.16.** Measure Information in the “Measures” Tab

337

No.	Feature	Description
S.16.A	Measures information	Create the “Measure” information. Input quality measure name, number, year, and the organization information. Fields: <ul style="list-style-type: none"> • Name • Number • Proposed by • Year • Description
S.16.B	Measure Table	Displays the measures’ information.
	Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data from Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the measure information users entered in a search text field.

338 **S.Table.16.** Measure Information in the “Measures” Tab

339

Versions:

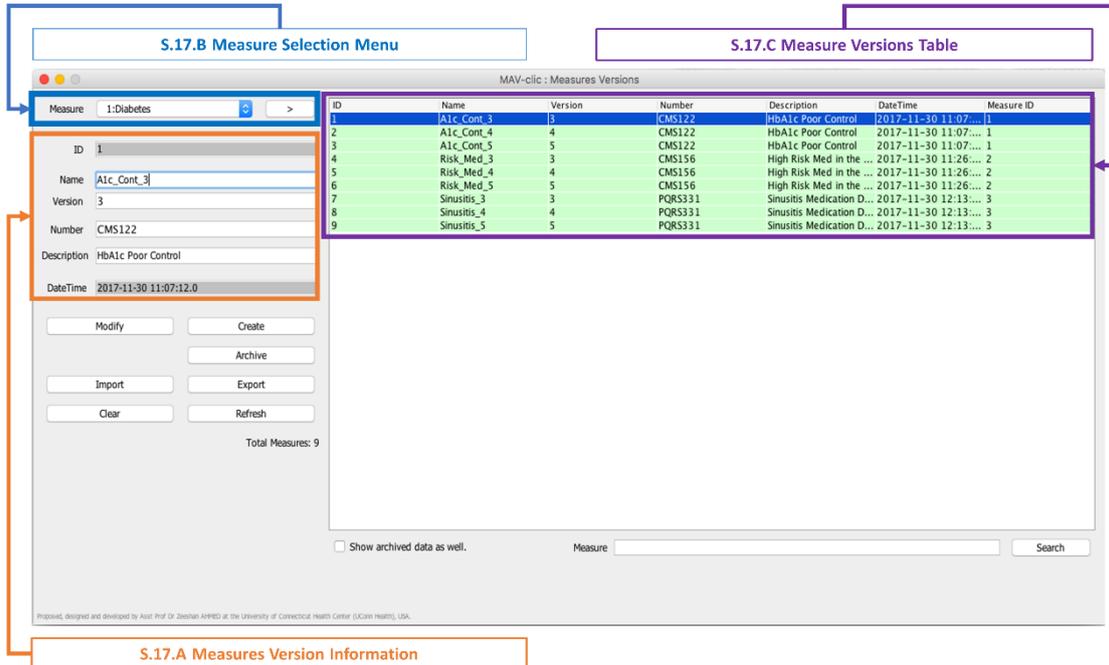
340

This is sub-module of Measures. It offers features to collect and maintain information about the versions of measures. The features are presented in S.Figure.17 and explained in S.Table.17.

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S.Figure.17. Measure Version Information in the “Measures” Tab

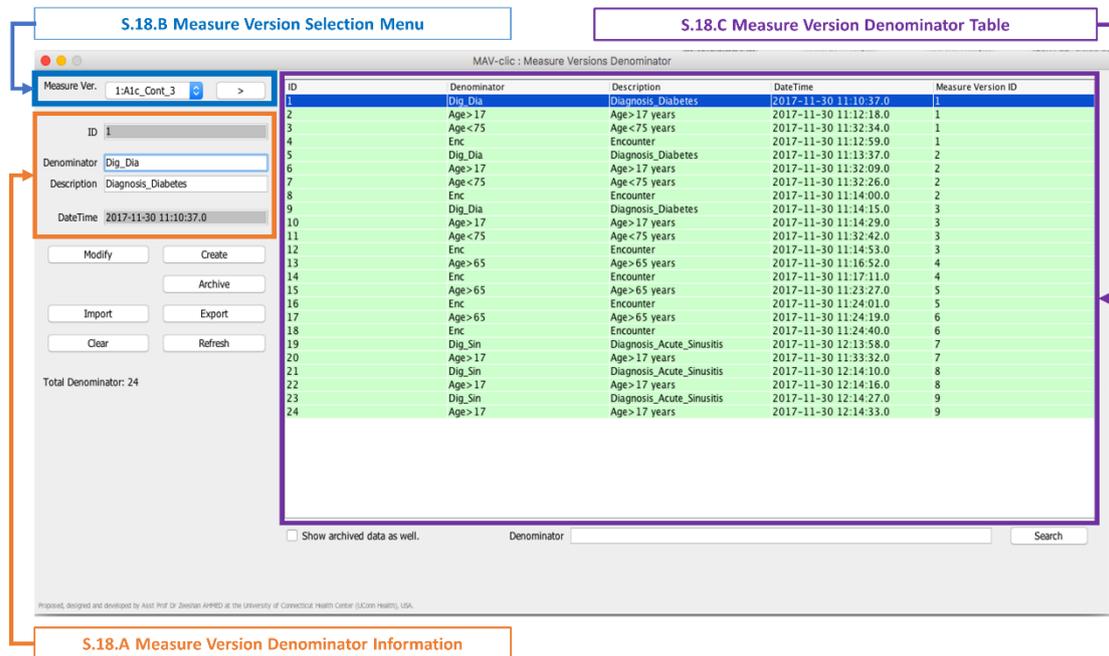
No.	Feature	Description
S.17.A	Measure Version information	Create the “Measure version” of the quality measures in the “Measures”. Fields: <ul style="list-style-type: none"> • Name • Version • Number • Description
S.17.B	Measure Selection Men	Once the “Measures” information is created, users can select the one of measures using drop down menu. Enter the submit button “>” next to the “Measures” drop down menu to see the sorted result in the measure version table (S.17.C).
S.17.C	Measure Version Table	Displays the measures’ information.
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data in Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the measure information users entered in a search text field.

346

S.Table.17. Measure Version Information in the “Measures” Tab

347 **Measure Versions Denominator:**

348 This is sub-module of Measures. It offers features to collect and maintain information
 349 about Measure Version Denominator. The features are presented in S.Figure.18 and
 350 explained in S.Table.18.



351

352 **S.Figure.18.** Measure Version Denominator in the “Measures” Tab

353

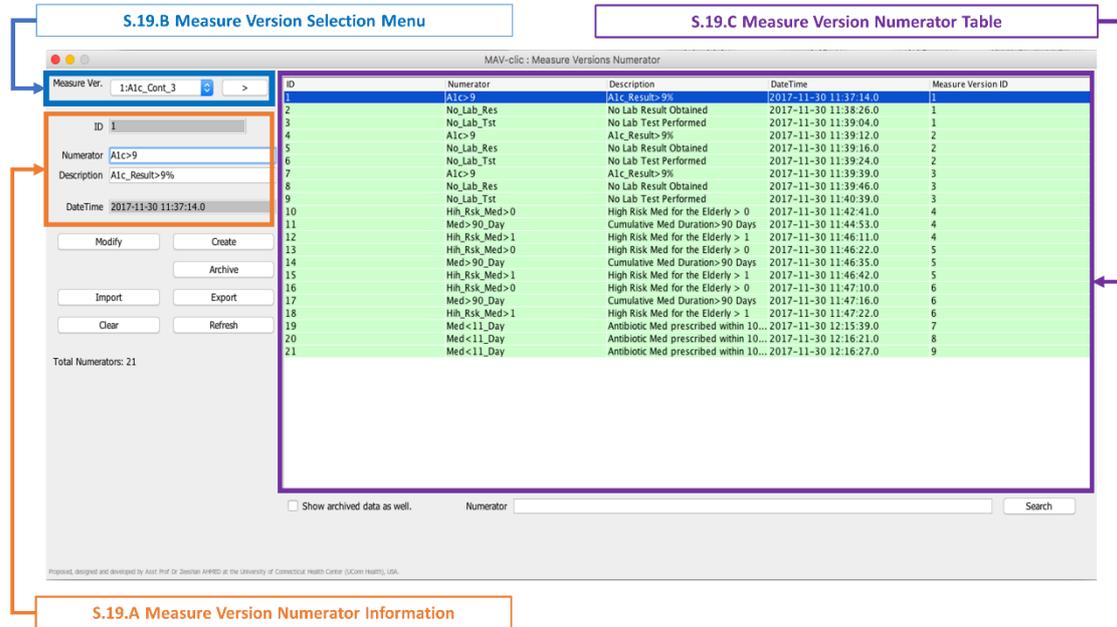
No.	Feature	Description
S.18.A	Measure Version Denominator information	Create the “Measure Version Denominator” of the quality measures in the “Measure Version”. Fields: <ul style="list-style-type: none"> • Denominator • Description
S.18.B	Measure Version Selection Menu	Once the measures & the measure versions information created, users can select the one of the measure versions using drop down menu. Enter the submit button “>” next to the “Measure Version” drop down menu to see the sorted result in the measure version denominator table (S.18.C).
S.18.C	Measure Version Denominator Table	Displays the measures’ denominator information.
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data from Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the relevant data to the denominator information users entered in a search text field.

354 **S.Table.18.** Measure Version Denominator in the “Measures” Tab

355 **Measure Versions Numerator:**

356 This is sub-module of Measures. It offers features to collect and maintain information
 357 about Measure Version Numerator. The features are presented in S.Figure.19 and
 358 explained in S.Table.19.

359



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361 **S.Figure.19.** Measure Version Numerator in the “Measures” Tab

362

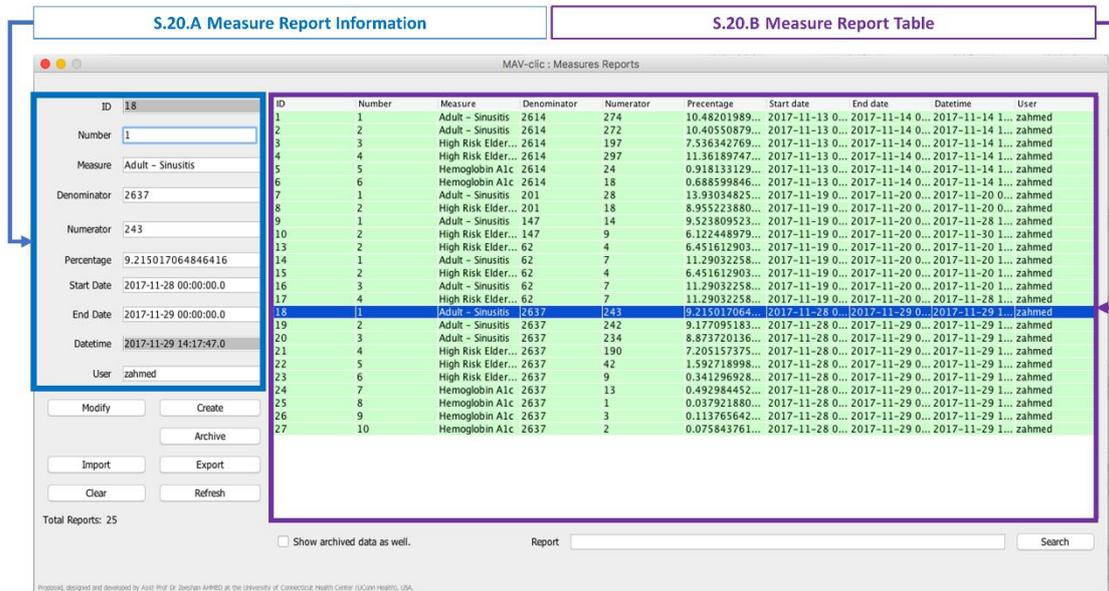
No.	Feature	Description
S.19.A	Measure Version Numerator information	Create the “Measure Version Numerator” of the quality measures in the “Measure Version”. <ul style="list-style-type: none"> • Fields:Numerator • Description
S.19.B	Measure Version Selection Menu	Once the measures & the measure versions information created, users can select the one of the measure versions using drop down menu. Enter the submit button “>” next to the “Measure Version” drop down menu to see the sorted result in the measure version numerator table (S.19.C).
S.19.C	Measure Version Numerator Table	Displays the measures’ Numerator information.
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data in Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related to the numerator information users enter in a search text field.

363 **S.Table.19.** Measure Version Numerator in the “Measures” Tab

364 **Reports:**

365 This is sub-module of Measures. It offers features to collect and maintain information
 366 about created Reports using MAV-clic Measurement Analyzer (S.Figure.14 and
 367 S.Table.14). The features are presented in S.Figure.20 and explained in S.Table.20.

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369

370 **S.Figure.20.** Measure Reports in the “Measures” Tab

No.	Feature	Description
S.20.A	Measure Report Information	Create “Measure Report” information. Input measure name, numeric values of denominator, numerator, and percentage level. Fields: <ul style="list-style-type: none"> • Number • Measure • Denominator • Numerator • Percentage • Start Date • End Date • User
S.20.B	Measure Report Table	Displays the list of report that is made in the “Measure Report Information” (S.20.A) and “Report Generation” (S.14.B).
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data in Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the report information users enter in a search text field.

371 **S.Table.20.** Measure Reports in the “Measures” Tab

Database Management with MAV-clic

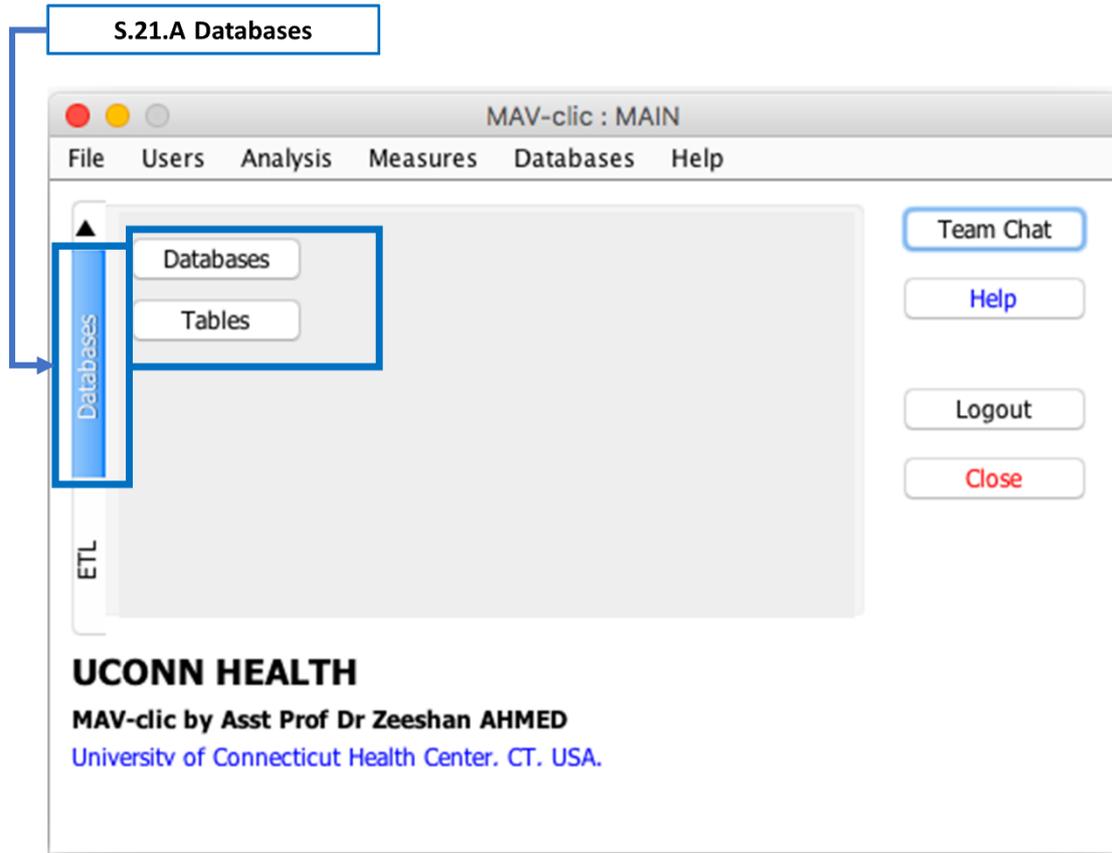
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A table is collection of EHR data in a structured format in a database. Similar to the general database system, a given table can only belong to a single database, and the collected tables can be one database. Based on the structure, Database tab allows users to navigate, create, modify and archive databases and tables at the S.Figure.22 and S.Figure23. It presents the way to manage and interact with databases and tables.

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380

381 **S.Figure.21.** “Databases” Tab in the MAV-clic

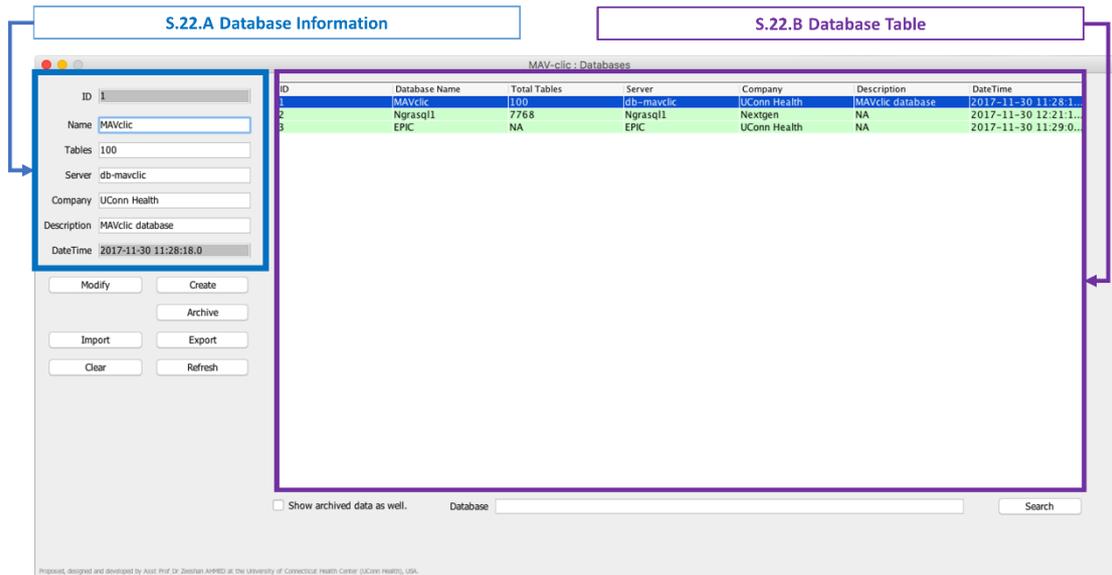
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No.	Feature	Description
S.21.A	Databases	In the “Databases” tab, users can set up the databases, tables.

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S.Table.21. “Databases” Tab in the MAV-clic

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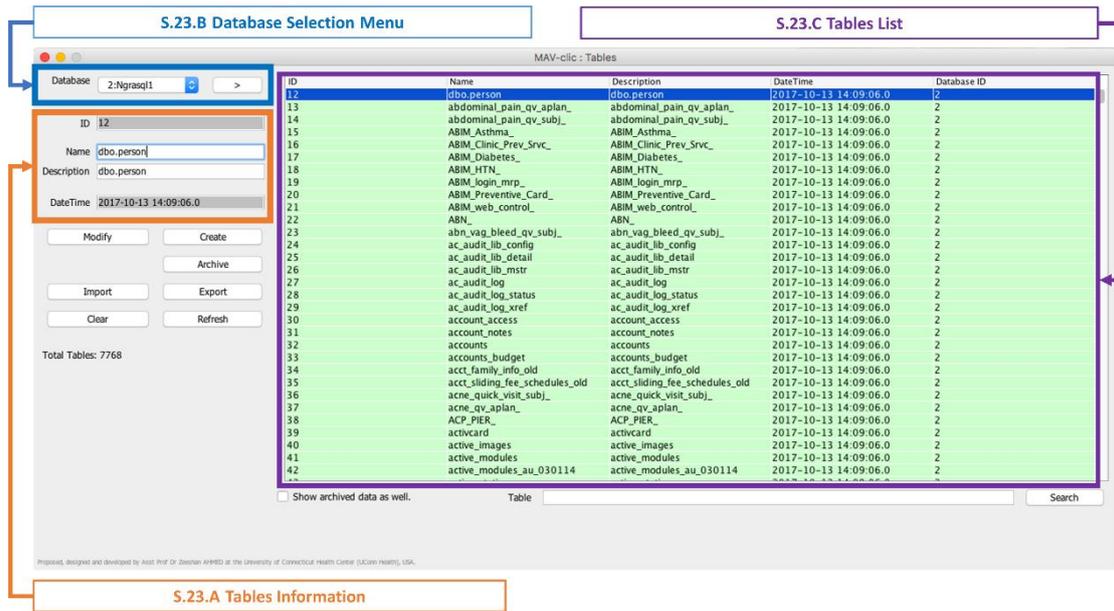
386 **S.Figure.22.** Database Information in the “Databases” Tab

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No.	Feature	Description
S.22.A	Database Information	<p>Create “Databases” information. Input database name, number of tables, server name.</p> <p>Fields:</p> <ul style="list-style-type: none"> • Number • Tables • Server • Company • Description
S.22.B	Database Table	Displays the database information
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data in Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the database information users entered in a search text field.

388 **S.Table.22.** Database Information in the “Databases” Tab

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391 **S.Figure.23.** Table Information in the “Databases” Tab

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No.	Feature	Description
S.23.A	Tables Information	Create the “Tables” information. Fields: <ul style="list-style-type: none"> • Name • Description
S.23.B	Database Selection Menu	<ul style="list-style-type: none"> • Once the database information created, users can select the one of database using drop down menu. • Enter the submit button “>” next to the “Database” drop down menu to see the filtered result in the table (S.23.C).
S.23.C	Tables List	Displays the “Tables” information in the Database.
	Table Basic Functions	<ul style="list-style-type: none"> • Create: To create the new entry. • Modify: To modify existing, selected data. • Archive: To archive existing, selected data. • Export: To export data in Microsoft Excel spreadsheet. • Import: To import data in Microsoft Excel spreadsheet. • Clear: To clear text fields. • Refresh: To refresh and new updates (if exists) data. • Search: To search and retrieve the related data to the table information users entered in a search text field.

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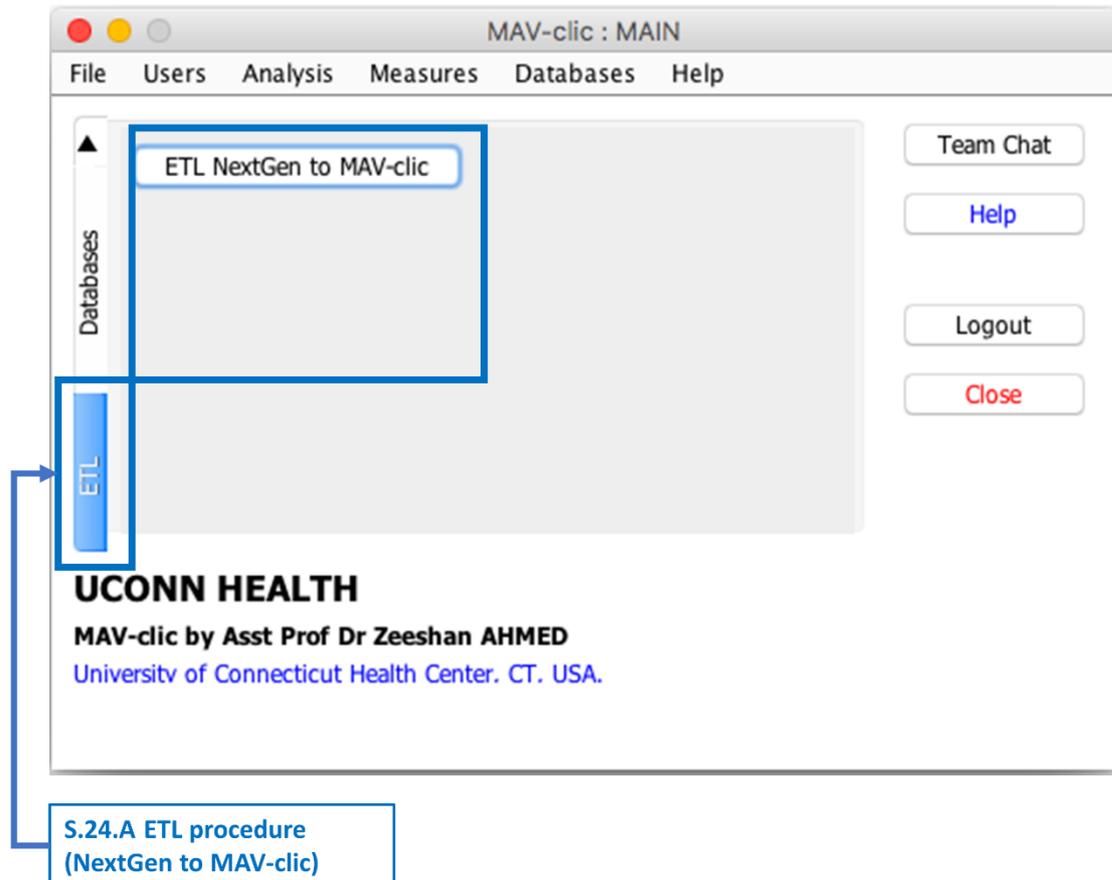
S.Table.23. Table Information in the “Databases” Tab

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ETL Management with MAV-clic

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EHR data collect enormous of data. EHR covers all the medical data which is collected during an inpatient hospitalization, an outpatient clinic visit, an emergency room visit etc. Each visit can produce dozens of tables along with diagnosis, medication, laboratory results, imaging results, payment information etc. Integration with entire EHR data in the system that focuses on analyzing clinical data is not cost effective in terms of money and time.



S.24.A ETL procedure (NextGen to MAV-clic)

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S.Figure.24. “ETL” Tab in the MAV-clic

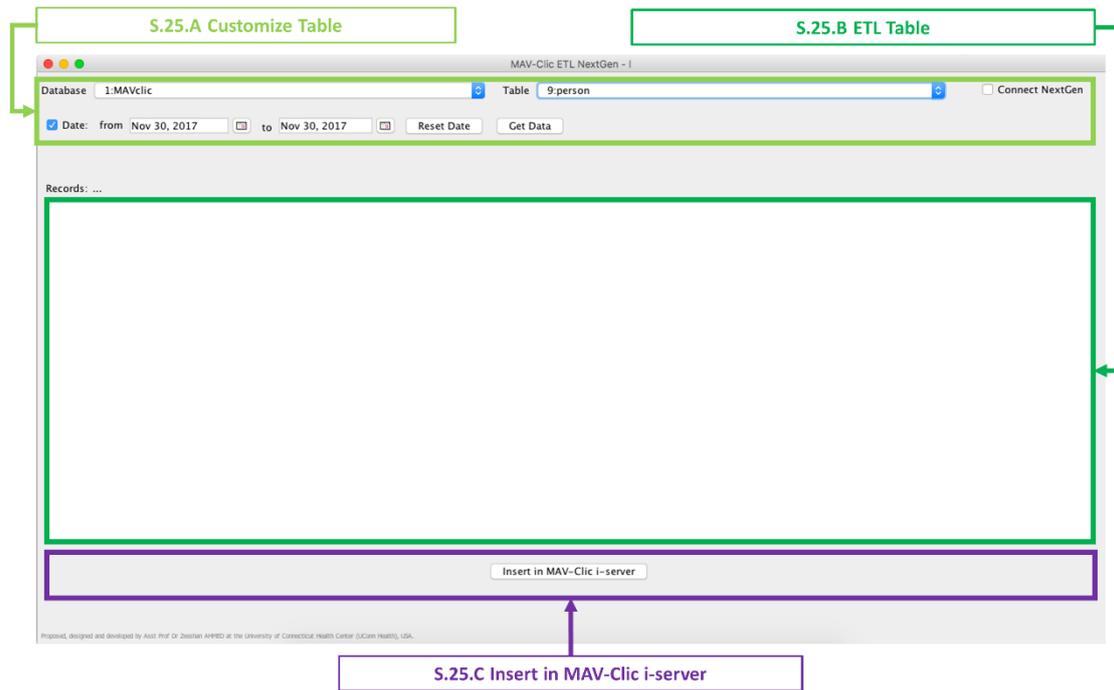
No.	Feature	Description
S.24.A	ETL Procedure (NextGen to MAV-clic)	In “ETL” tab, users can move the table in NextGen database to MAV-clic <i>i</i> -server.

406
407

S.Table.24. “ETL” Tab in the MAV-clic

408 Therefore, it is important to determine the clinical data of interest and to proceed the
409 extraction, transformation, and loading (ETL) functions in order to save the data in the MAV-
410 clic *i*-server. S.Figure25 presents the way to define the database, table and to move the
411 selected table to the MAV-clic *i* server with the ETL procedures. The loaded table to the MAV-
412 clic *i*-server can be used to evaluate the clinical research and quality measures.

413



414

415 **S.Figure.25.** MAV-clic ETL Procedure: NextGen to MAV-clic *i*-server

416

No.	Feature	Description
S.25.A	Customize Table	Find a table user want to extract by selecting the following options. <ul style="list-style-type: none"> • Database: Select one of databases using drop-down menu. • Table: Select one of tables using drop-down menu. • Connect NextGen: Check the option to connect the NextGen (EHR) database. • Date: Customize the range of date. • Reset Date: Reset the options. • Get Data: Run the system.
S.25.B	ETL Table	Displays the table information.
S.25.C	Insert in MAV-clic <i>i</i> -server	Enter this button to upload the ETL table (S.25.B) to the MAV-clic <i>i</i> -server.

417

S.Table.25. MAV-clic ETL Procedure: NextGen to MAV-clic *i*-server

418

419 Installation and Configuration

420 MAV-clic is programmed in Java programming language, built and tested at both Mac-OS-X
421 and Windows platform. To successfully run (JAR file), it requires Java Version 8 with Update
422 131 (build 1.8.0_131-b11) can be downloaded from www.java.com. Additional information
423 and updates are available at: <https://github.com/drzeeshanahmed/MAV-clic/wiki>. For further
424 assistance, it is advised to contact MK and ZA.

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431 Authors and contributions

432 Dr Ahmed perceived the idea and did all work on the software and infrastructure design and
433 implementation and related aspects of MAV-clic. Dr Ahmed and Dr Kim did analysis and
434 performance evaluation of MAV-clic. Dr Liang guided study.

435 **Zeeshan Ahmed, Ph.D.**, is an Assistant Professor and Assistant Director Bioinformatics:
436 *Medical Dean's Precision Medicine Program*, at the Genetics and Genome Sciences, Institute
437 for Systems Genomics, School of Medicine, University of Connecticut Health Center. Dr
438 Ahmed's research focuses on dealing practical issues associated to the clinical, diagnostic,
439 longitudinal, metabolomics, proteomics, histology, pathology, oncology, genomics,
440 transcriptomics and epigenomics big data management, processing, analysis, visualization and
441 integration for precision medicine.

442 **Minjung Kim, Ph.D.**, is an Assistant Professor at The Pat and Jim Calhoun Cardiology Center,
443 School of Medicine, University of Connecticut Health Center. Dr. Kim's research interests lie in
444 healthcare system development, specifically applying statistical engineering methodologies to
445 improve the clinical information system, syndromic surveillance, chronic disease care
446 management and clinical decision support system.

447 **Bruce T. Liang, M.D., F.A.C.C.**, is the Dean, UConn School of Medicine, University of
448 Connecticut Health Center. Dr. Liang is the Director, Pat and Jim Calhoun Cardiology Center,
449 and Ray Neag Distinguished Professor of Cardiovascular Biology and Medicine. Dr. Liang is a
450 the fellow of the American College of Cardiology, the American Heart Association and the
451 Council on Clinical Cardiology and Basic Cardiovascular Sciences. He is also a member of the
452 American Society for Clinical Investigation.

