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Pediatric Blood Calculator

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Expert System based calculator for infant blood draw for critical tests

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Abstract: This paper outlines an expert system based solution for calculating the optimal amount of blood draw from infants to carry out critical tests requested by the attending clinicians. The solution is a hand-held device with a user-friendly interface that allows a meaningful two-way conversation between the clinician and the pathology office. Based on the tests being requested, the calculator determines the minimum amount of blood required in the different vials based on a smart expert system. This removes the uncertainty that is prevalent today in the amount of blood required to do all the tests, since in some cases there is not enough blood for all the requested tests by the attending clinicians. The expert-based solution would be a stand-alone hand-held device, but have the ability to interface with the hospital electronic record systems to ensure all compliances and easy transference of the information.

Introduction

Blood sampling is critical in tracking the condition of a patient. In modern medicine it is common for patients to be subjected to continuous blood examination until they are discharged. Repeat phlebotomy does come with inherent risks. Iatrogenic anemia, complications and costs of blood transfusion, and adverse patient outcomes can all be rooted in repeated blood sampling. This problem is particularly significant in infants, children, elderly, or immunocompromised patients.[7] It has been shown in studies on elderly patients that nosocomial anemia lead to increased risk of respiratory failure. [5] The reason infants and children are at a higher risk of complication is due to the limited amount of blood that can be drawn. The limited amount of blood that can be drawn from pediatric patients in turn limits the number of tests that can be performed by a clinician, hence every drop of blood counts when sampling blood from children.

Phlebotomist perform a critical role for hospitals. They determine the rationale for laboratory testing based on symptoms and how best to use blood sampling to monitor body system function and diagnosing disorders. Performing their duties requires managing the roughly 5 liters of blood that are in the human body while conducting tests. [9]

Iatrogenic anemia is caused by repeated blood draws in hospitals. Challenges with iatrogenic anemia are prevalent in intensive care units (ICU), as different physicians consult the patient and order tests guidelines can become overlooked. Studies show that 70% of patients in the ICU after two days develop anemia. The number of anemic patients jumps to 90% after three days in the ICU. Adults can lose 340-660mL of blood per week from running tests to monitor patient conditions.[17]

For infants, the effects of iatrogenic anemia are much more severe. Preterm neonatal infants can loss up to one third of their blood volume from frequent blood sampling within the first week.[8] At Akron Children's Hospital a child weighing five pounds or less can give a maximum of 4.8ml blood over a 24-hour period.[11] Although children receiving blood draws can undergo blood transfusion, there are additional costs that may be physical and/or financial. In this study the primary focus will be optimizing blood sampling for infants and children.

A way of curbing iatrogenic anemia is performing blood transfusions, however there are hazards. Randomized studies have suggested that high blood transfusions in infants lead to increase infant mortality and major bleeding.[2] Increased red blood cell transfusion in low birth weight infants is associated with a higher risk of mortality. High red blood cell transfusions in low birth weight infants are also correlated with Retinopathy of Prematurity ROP, necrotizing enterocolitis NEC, and Bronchopulmonary dysplasia BPD. Blood transfusions are not only costly but in adult patients can lead to pulmonary injuries like edema.[16]

Expert Systems are a branch of AI whose foundation relies on simulating human reasoning through a myriad of if-then statements. The development of expert systems started in the 1950s. In 1956 Marvin Minsky and John McCarthy hosted the Dartmouth Summer Research Project on Artificial Intelligence. Experts from around the world convened on how to make computers operate like the human brain.[3] One of the first inventions was created by innovators Newell, Shaw, and Simon who wanted to create a general problem-solving algorithm that handled tasks by imitating human reasoning. These systems would mimic how humans by developing a plan, solve problems according to plan, then revise the plan with past data.[4] Early developments include the MIT project ELIZA in the 1960s. ELIZA was a natural language processing tool that simulated human conversation. Many of these systems relied on rule based expert systems that used a series of if-then statements and expert knowledge to reach a conclusion. IBM's 1997 success Deep Blue is an expert system that beat the world champion Gary Kasparov and displayed how robust expert systems could out-perform humans on specific tasks.[3]

Expert Systems consist of three major components, the knowledge base, an inference engine, and a user interface. The knowledge base is the real world facts and rules the expert systems uses to piece together an answer containing a series of if-then statements. The inference engine derives new information from the rules given in the knowledge base. [14] The inference engine can work on forward or backward chaining. Forward chaining uses initial data from the user and follows a chain rule to determine potential results. Backward chaining takes a claim and verifies whether the claim meets all the rule requirements. The user interface is how the experts interact with the algorithm to feed in information and obtain meaningful results.[6]

Researchers have used expert systems in medicine to tackle a host of different challenges. Expert Systems have been integrated into medicine as a way of helping medical professionals make decisions, determine diagnoses, and as an alternative if specialized medical help is not available. Examples of Expert systems in medicine are algorithms used to identify ocular diseases and fuzzy rule-based programs that can detect early stage coronary artery disease.[10] Expert Systems must meet rigorous standards to be properly used in medicine. Improper diagnosis from flawed systems can lead to complications, medical errors, or mortality. However, if expert systems prove to be more accurate and reliable then their human counterparts, there is the potential to decrease medical errors and improve standard of care.[15]

Expert Systems poses a plethora of benefits when advancing medical diagnostic systems but there are some disadvantages. Draw backs to expert systems include the ability to handle uncertainty and validation. Some solutions to tackle this issue within medical diagnosis systems have been Bayesian Networks which utilize a graphical model to illustrate variables and the connections between variables. A lab from the University of Bucharest used a combination of ontology model and Bayesian Networks to help diagnosis heart disease.[19] Validation of expert systems can also become a challenge as models can present conclusions based on rules given but error detection of conclusions must still be provided. To validate the quality of results, expert systems will use expert oversite from professionals in the field of study to determine if the results are valid. Disadvantages with this technique of validation is that experts will tend to input very specific cases that they have worked with. Although this approach checks the expert system it does not verify all cases the system will be used for. In our expert system we will work closely with lab experts from Akron Children's Hospital and Roche to access the data of the system.[20]

The expert system in this study will be used to optimize a list of tests ordered by physicians for pediatric patients. The algorithm used uses forward chaining to select specific tube test combinations based on clinician data from Akron Children's Hospital. The user interface is a Raspberry Pi 3 B+ connected to a seven-inch touchscreen for input. The study will compare the output of the of the Expert System to the past data.

Problem Outline

Pediatric patients have a limited amount of blood they can give to run tests. Problems with drawing blood include being unable to run all tests, iatrogenic anemia, wasted tubes, increased cost, and medical error. When physicians and specialists want to run tests to obtain a comprehensive understanding of the patient's condition running all tests, although ideal, would be dangerous. Physicians typically use a series of charts, personal knowledge, and additional software tools to determine how much blood in what tubes are to be chosen. The information is not condensed and automated into a single location.

When doctors at Akron Children's Hospital order tests they use a combination of predetermined lists called Smart Sets and individually picked tests. A Smart Set is list of tests to identify a specific problem with the patient, an example of a Smart Set is Endocrinology Ambulatory Oral Tolerance Test which is used to help diagnose diabetes. This smart set is comprised of 18 tests and can require 44.5ml of blood with the current standards. An infant or pediatric patient under 5 years of age could weigh between 5lb to 40lb and can have a maximum blood draw of only 4.8ml to 36.4ml respectively in a 24-hour period.[11] Physicians can order multiple sets at a time or additional tests on top of initial sets. As a result, every drop of blood counts.

To be able to run all or at least as many tests as possible blood must be used efficiently. Currently blood is wasted by taking ideal volume for tests and spreading samples across multiple tubes. The process drains more blood leading to less tests and a more fatigued patient. In some cases, doctors cannot receive all the desired information to make their best diagnosis. Patients with more blood drawn are at risk of anemia, increased risk of infection, and can have inferior patient outcomes. Infant mortality is often linked to iatrogenic anemia from too much testing. If insufficient information is gained from a series of Smart Sets earlier in the day, then additional tests might be required at a later time. Therefore, even if doctors can perform all the sought after tests there exists a goal to reduce the overall amount of blood taken from the patient.

The problem is not unique to pediatric patients. Elderly patient or individuals spending long periods of time in the ICU can fall victim to anemia caused by blood sampling. As patients stay in the hospital for prolong periods of time monitoring their condition becomes taxing on their overall blood supply. State of the art medical tracking is stifled as blood is continuously being removed. Transfusions can help aid the problem but have their draw backs. Blood transfusions are costly and can become source of infection, resulting in less favorable patient outcomes, and increased medical expenses.

Phlebotomists, pediatricians, technicians, specialists, and nurses must all be in synchronous communication to ensure unnecessary blood is not drawn and unneeded tests are not ordered. Although the process is typically smooth, errors do occur. As different physicians seek data about the patient through testing, they may not uphold blood sampling standards. Errors such as being unsure if enough blood was drawn to perform additional tests, nonessential surgeries for atrial blood, and over draw do occur. A central solution does not exist that optimizes patient blood use to reduce medical errors.

Problem Solution

Hardware

The device is comprised of 3 major components, a Raspberry Pi 3 Model B+, 7in touch screen, and plastic case. The Raspberry Pi 3 Model B+ uses a Cortex-A53 64-bit processer and 1 GB of LPDDR2 SDRAM. The image of the software is stored on a 32GB SD card. The platform offers many types of wireless communication to include 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, and BLE which will be used for communication between devices.[13] The extended 40-pin GPIO header will be used to connect the Raspberry Pi 3 Model B+ display port to the 7in Touch Screen. The 7in touch screen has a resolution of 800 x 480 pixels and 10 finger capacitive touch.[12] The Raspberry Pi and 7in touchscreen are housed in a protective plastic case. All physical components can be seen in figure H1 and wiring can be seen in figure H2.

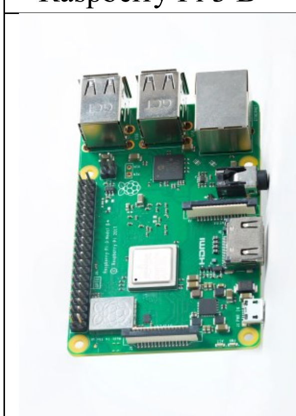
Raspberry Pi 3 B+	7in Touch Screen	Case
		

Figure H1

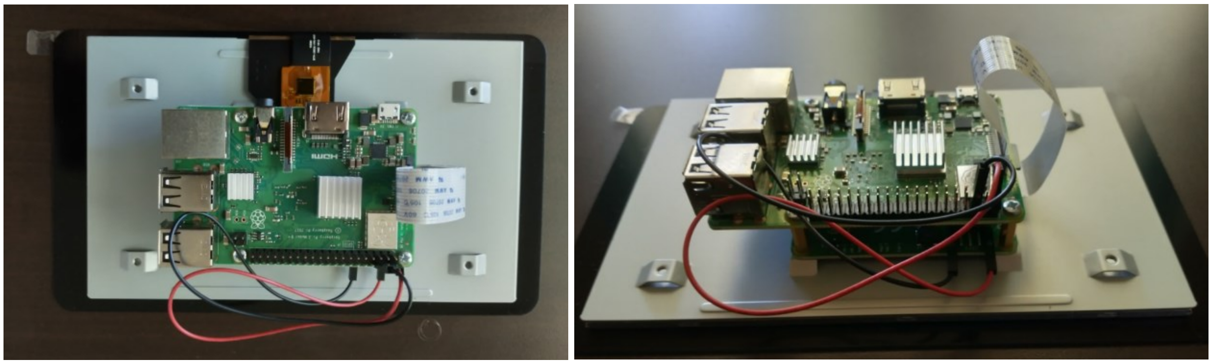


Figure H2

Software

The operating system used will be Raspbian, which is the standard Linux based desktop operating system for the Raspberry Pi. The programming language used will be Python 3.7. Python libraries used for the system include xlrd for extracting and reading excel files and the Tkinter Library will be used to make the tablet user interface. Microsoft Excel will be used to store the data for individual Smart Sets.

Maximum Blood Calculation - BloodV function.

Akron Children's' Hospital uses a blood draw policy to determine the maximum amount of blood that can be taken from a patient within a 24hour period based on their weight and respiratory status. The patient must have a hematocrit of above 7 to be able to draw blood if they have no respiratory compromise and above a 10 with respiratory compromise to be able to draw blood. The table used to determine maximum blood was plotted in Microsoft Excel, the correlation is linear with an R = 0.99. The function was plotted with Max Volume in ml = 1.99*(Weight in kg) + 0.244. The linear correlation and Blood V flowchart can be seen in figure S1 and figure S2 respectively.

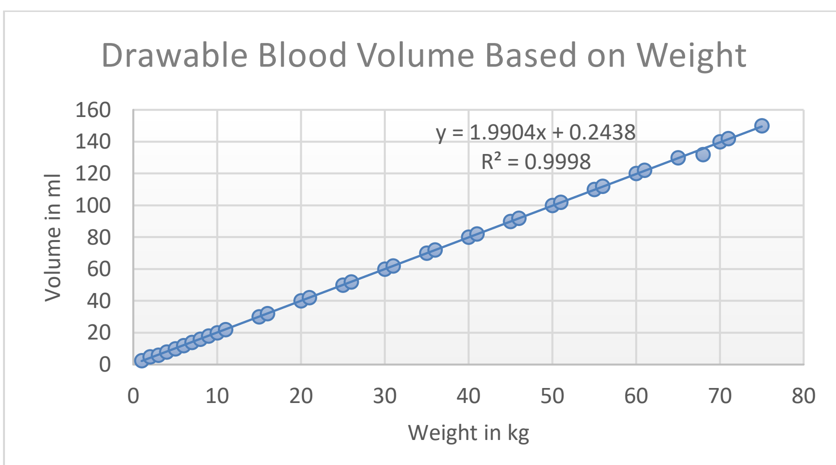


Figure S1

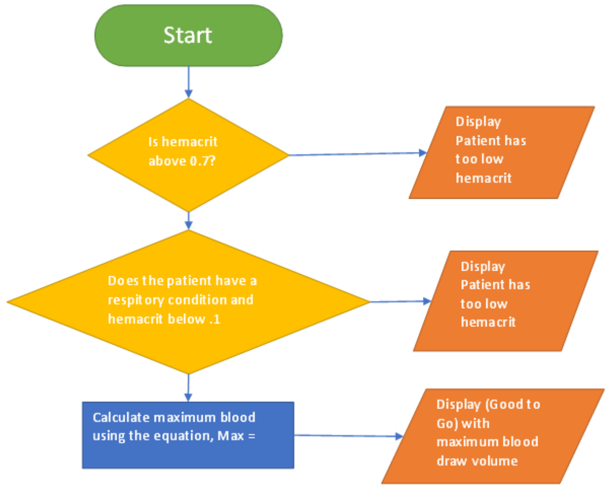


Figure S2

Expert System

The expert system will be used to optimize blood use by determining tube types and volumes based on input from physicians and specialists. The expert system will use forward chaining, to create lists of tests per tube. The forward chain operates by taking input about the patient and following a list of rules until the desired outcome is achieved. The test data the inference engine will use is stored in Excel files in the Raspberry Pi. The physician will start by selecting their specialty, and this will enable the inference engine to know which files to choose from. The Python script then uses the xlrd library to extract and read the information on the files.

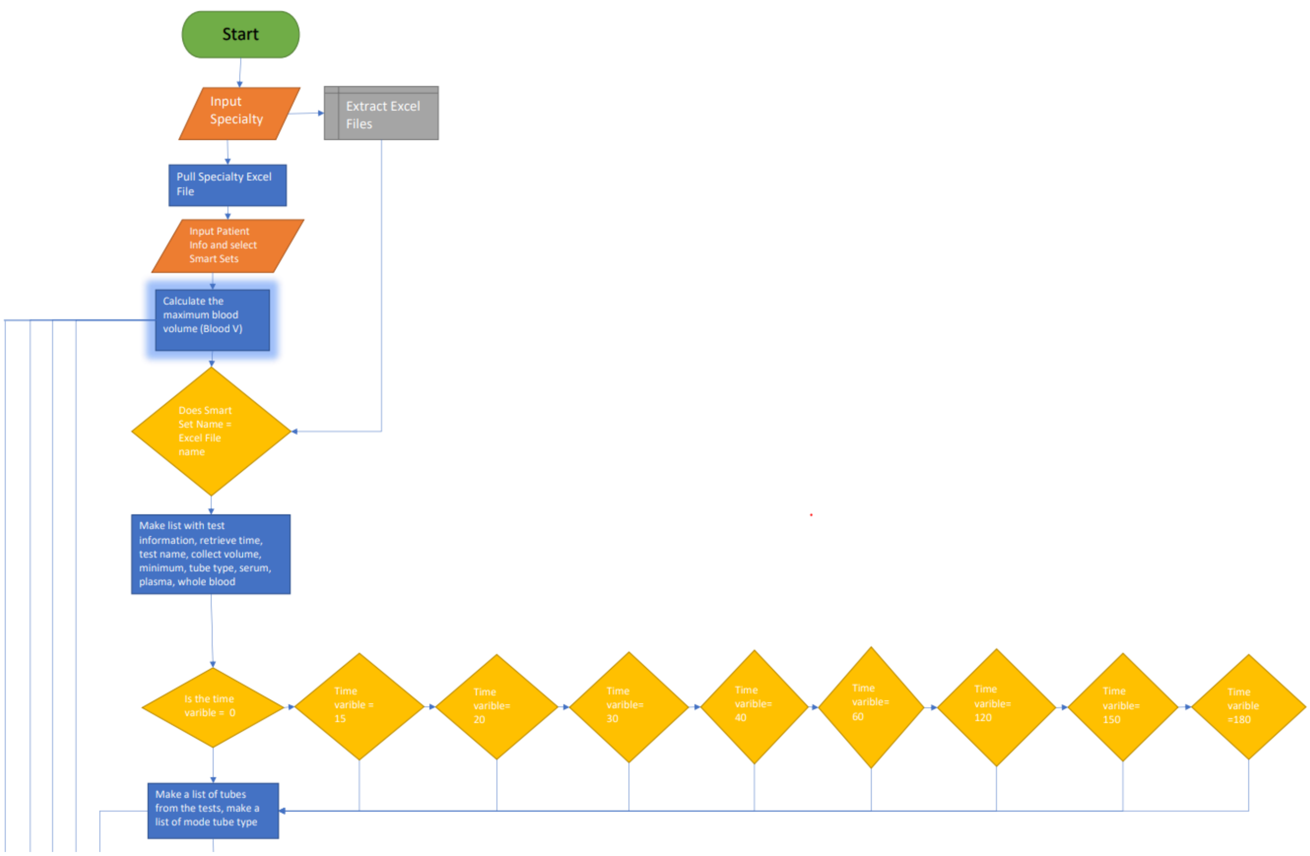
The knowledge base rules are, If time variable is = X then place in list, If tube anti-coagulant status is true then do not use Serum or Red Top tube, If tube uses whole blood then separate tube from list, If tube is equal to tube mode place in list, If blood volume used to too high then minimize blood volume. The inference engine takes these rules to generate a list with the best combination of tubes to perform tests.

The first step is separating the tubes by time variable. The time variable is when the provider takes the patients blood this can happen at time 0, 15min, 20min, 30min, 40min, 60min, 120min, 150min, 180min, and 24hour. Each of these time variables will get their own list of tubes. Then the software removes any tests that require whole blood and places them in a separate list. While blood tests are a special case, as such they are treated with a different equation. Next the software checks the anti-coagulant status. If the patient has coagulant then Serum and Red top tubes are avoided when choosing tube types.

The next step is determining the mode of the test tubes in the list. This way the software can iteratively choose the most common test tube in the list. When all tubes of the most common type are chosen and separated from the list then the software recalculates the mode and starts over until all tests are accounted for. The expert system has now created a list of tube and test combinations accounting for time, anti-coagulant status, whole blood, and most common tube types.

The last phase checks the total blood volume against the maximum blood volume specified by the Blood V function. If the blood volume is too high then the expert system will iteratively start making tests with absolute minimum values in the order of reducing dead volume, reducing analytical volume, and finally reducing to minimum dead volume and minimum analytical volume. By this point either a combination of tests tubes below the threshold will be reached or there will be a warning notifying the user with the absolute minimum volume combination and that the total blood volume exceeds the limit of maximum blood drawable. The structure of the inference engine is seen in figure S3.

Expert System Flow Chart



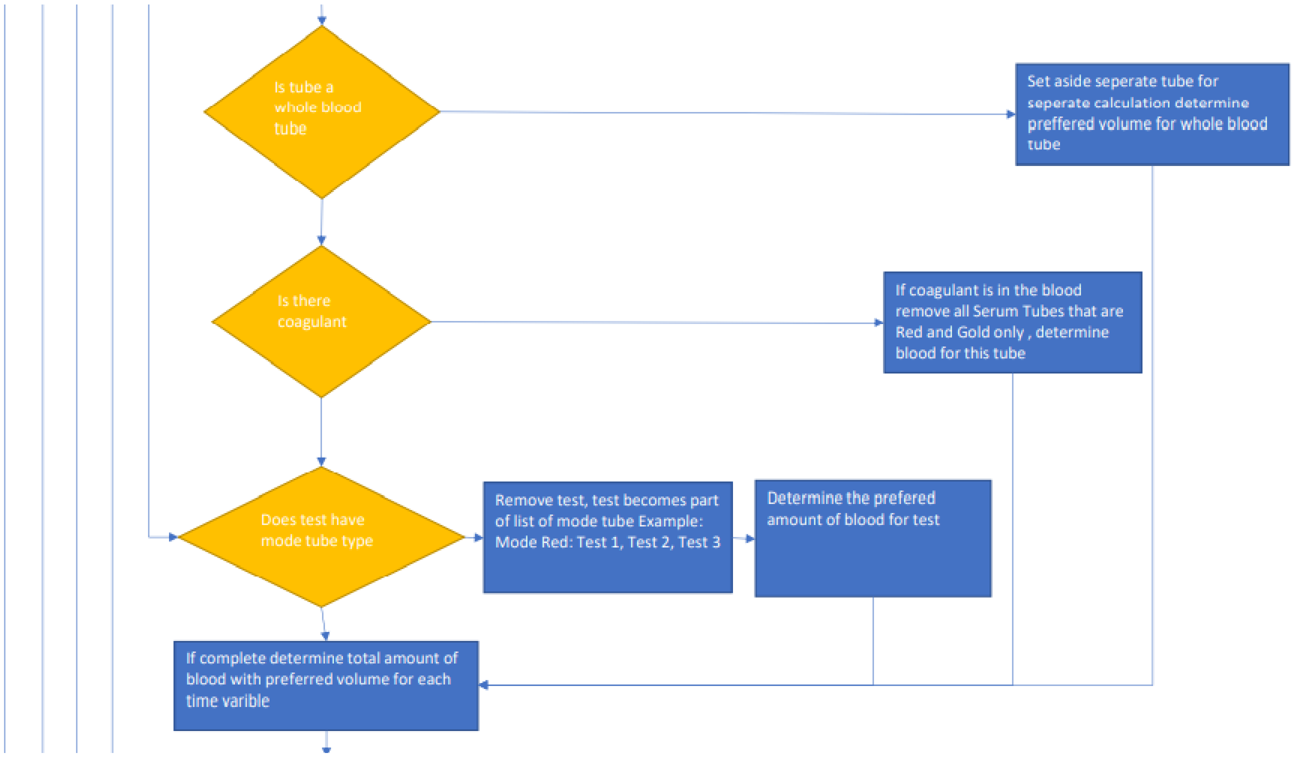

Is tube a whole blood tube
Set aside seperate tube for seperate calculation determine preffered volume for whole blood tube
Is there coagulant
If coagulant is in the blood remove all Serum Tubes that are Red and Gold only , determine blood for this tube
Does test have mode tube type
Remove test, test becomes part of list of mode tube Example: Mode Red: Test 1, Test 2, Test 3
Determine the prefered amount of blood for test
If complete determine total amount of blood with preferred volume for each time varible

Figure S3

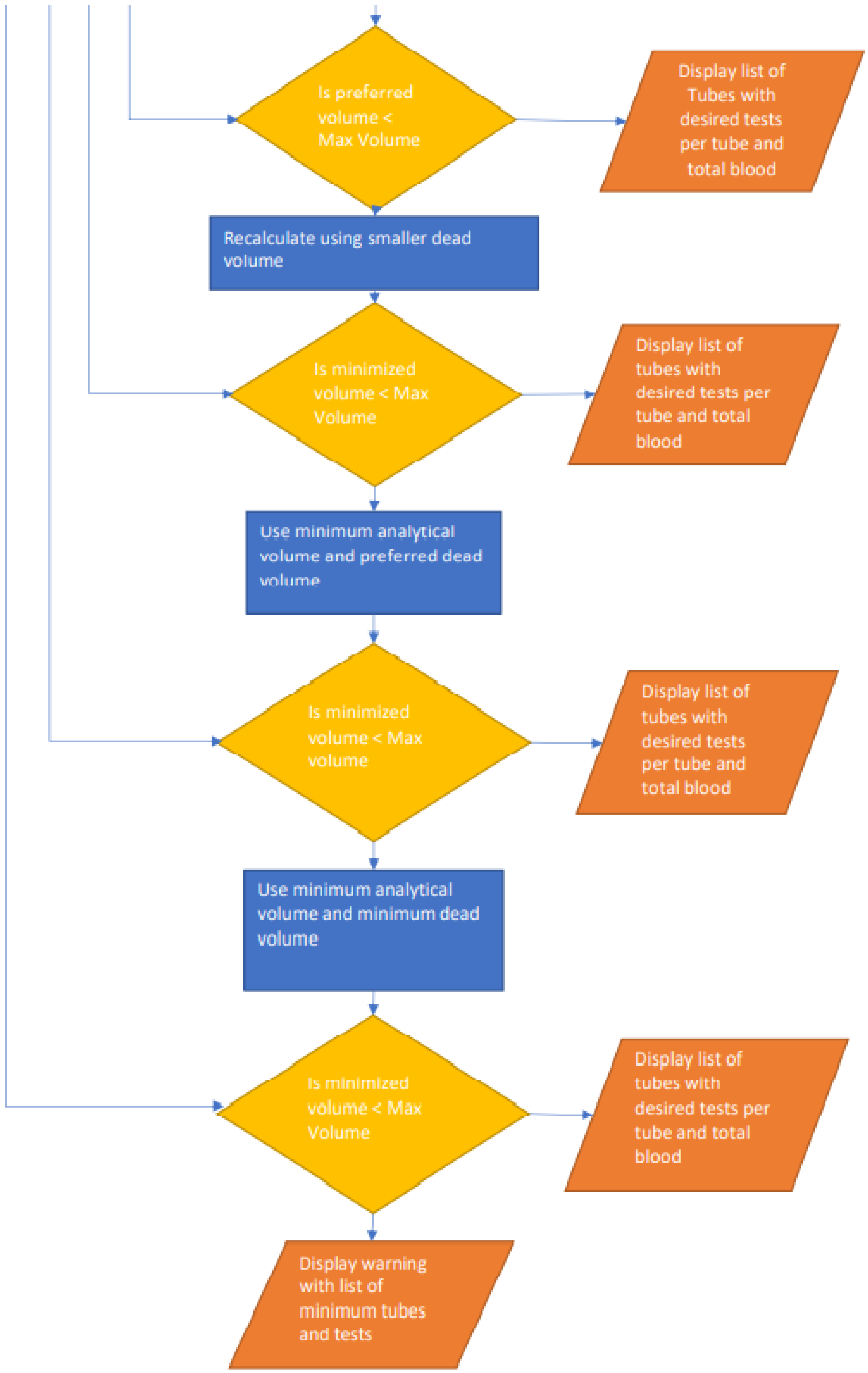
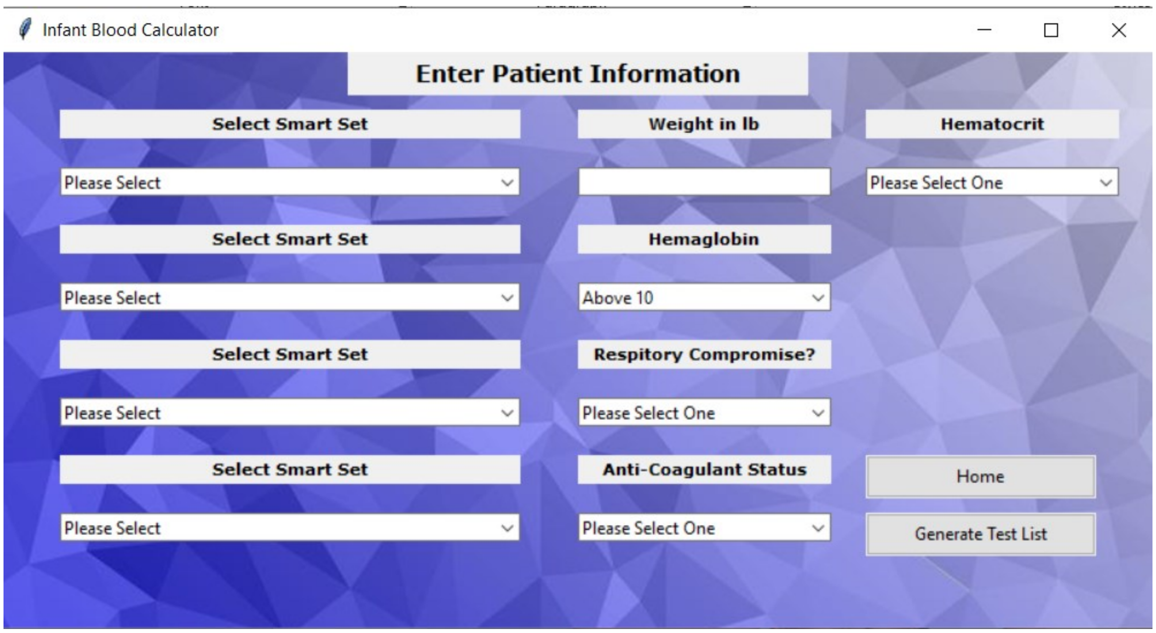

Is preferred volume < Max Volume
Display list of Tubes with desired tests per tube and total blood
Recalculate using smaller dead volume
Is minimized volume < Max Volume
Display list of tubes with desired tests per tube and total blood
Use minimum analytical volume and preferred dead volume
Is minimized volume < Max volume
Display list of tubes with desired tests per tube and total blood
Use minimum analytical volume and minimum dead volume
Is minimized volume < Max Volume
Display list of tubes with desired tests per tube and total blood
Display warning with list of minimum tubes and tests

Figure S3.2

Interface

The interface for the expert system is Python's open sourced Tkinter graphical user interface. Tkinter does not require licensing and is free to use for any purpose. The interface starts with the ability to request a test or check the status of old tests. When tests are requested the user is prompted to select their specialty with a drop down menu. After selecting the specialty, the medical professional is prompted to select a maximum of four smart sets, weight of patient in lb, Hemoglobin level, respiratory compromise, anti-coagulant status, and hematocrit level. After the appropriate information is put into the interface the user is able to check the list of tests they are ordering. If the user agrees with all the information, then they send the request to the lab.



Security Issue and Connectivity

The pediatric blood calculator will actively be working with confidential patient data. To ensure the safety of patient information the device will not connect to Wifi or the Hospital's Cloud Services. To communicate with other devices the system will use the Bluetooth 4.2 or BLE. This will only allow the device to communicate with paired near peer systems. Future encryption of patient details as well as connectivity to Epic software will be considered for future models.

FDA Approval

To use the pediatric blood calculator in hospitals the software would have to undertake the FDA approval process as well as maintain the certification. The process of obtaining FDA approval includes choosing a device classification, developing a prototype, submitting FDA verification forms, a formal review process, and ongoing compliance to updated standards.

Device Classification

Medical devices can fall into three categories, Class I, Class II, and Class III. Class I medical devices present very low direct risk to a patient. An example of a Class I device would be a stethoscope or bedpan. Premarket notifications and FDA clearance is not required before marketing a Class I device. Class II medical devices present a risk to patients that are higher than Class I but lower than Class III. Examples of Class II medical devices include pregnancy test kits and powered wheelchairs.

The pediatric blood calculator would very likely be under a Class II A medical device. The pediatric blood calculator looks at the tests ordered and optimizes how to the tests will be run to reduce the amount of blood needed for the tests. Although not necessarily life threatening on its own, the amount of blood used for the tests can affect test validity; if the tests do not have the correct amount of blood then incorrect test results can be generated. Test results are used to determine patient treatment and have a drastic effect on patient outcomes. The pediatric blood calculator is not a software that directly monitors the patient which would fall under Class II B certification. Class III devices are very high risk to the patient. Example of Class III devices include pacemakers and surgical robots. Class III devices undergo the most rigorous FDA scrutiny. Although the pediatric blood calculator is a physical handheld device, the expert system would be considered a standalone software and fall under software regulations.

FDA Verification

For the purposes of our study we will focus on software FDA verification. A historical example of software malfunctions causing patient harm has been the Therac-25. The Therac-25 was a software-controlled radiation device. Due to overconfidence in the medical software, patients were exposed to deadly levels of radiation. Today the FDA requires strict verification of software used in medicine. Basic considerations the FDA requires software engineers to provide are risk analysis, detailed list of software requirements, verification testing, and traceability.

Risk analysis is documentation that illustrates how software errors are mitigated. Engineers must also show a detailed list of requirements the software is intended to meet and how that was incorporated into the design of the final product. The FDA requires verification testing to ensure that the device does what it is intended to do based on the design criteria. Computer scientists must also present traceability, showing how the software minimizes error throughout the entirety of the design. Traceability tends to be the most time consuming of the FDA verification process.

FDA Approval and Review

After classification and verification the medical device can undergo 510(k) submission. Although some devices can be exempt from 510(k) submission, our device does not fall into this category. 510(k) is submitted premarket to show that the device is safe and effective for clinical use. To obtain 510(k) approval the engineers of the medical device must show how the device is an improvement over what currently exists and or how it compares to similar devices. In our case the standalone medical software would either be compared to EPIC software currently being used by hospitals or the paper and pencil methods currently being used by medical professionals. The pediatric blood calculator being a novel software would have to prove more efficient than the current flow used by medical professionals to obtain 510(k) approval. A device cannot go to market until this requirement is met.

FDA maintenance

After an organization has submitted all necessary documentation and has received approval by the FDA to market their device, they must still maintain their device over the course of the product's life. The FDA can require that the device be pulled from the market if the engineers do not comply with FDA regulation updates throughout the duration of product use.

Final Design

The Pediatric Blood Calculator is an expert system housed in a Raspberry Pi based tablet like device. The medical specialists selects their specialty, blood sampling tests, and inputs patient information. The software is designed to determine the maximum amount of blood the patient can give in a 24hour period and determine the ideal test tube combination for the Smart Sets selected. This study will compare the expert system output volume with the output volume chosen by medical professionals.

Test Results

Methods

To test the device code output, we simulated 20 fake patients and performed hand calculations to check if the code was working properly. The simulated group of patients was generated using data of Cincinnati Children's hospital seen below. Cincinnati Children's provides a chart outlining normal growth of pediatric patient generated by data from the Centers for Disease Control and Prevention (CDC). The patients ranged in ages from one to 10 and weights 70lb to 15lb with an average of 42.5lb. Hematocrit levels for the children ranged from 0.2 to 0.9 with an average of 0.5. Each simulated child over age six were given three random Endocrine Smart Sets. Patients under age six were given three or less smart sets at random. The output of maximum blood volume per child generated by the BloodV function will be checked by hand to verify if the code is correctly determining maximum draw. The Expert System Algorithm for each test tube dictionary output will have a hand calculation to match to check the performance and accuracy of the smart system.

Age	Height Females in Inches	Height Males in Inches	Weight Females in Pounds	Weight Males in Pounds
1	27 to 31	28 to 32	15 to 20	17 to 21
2	31.5 to 36	32 to 37	22 to 32	24 to 34
3	34.5 to 40	35.5 to 40.5	26 to 38	26 to 38
4	37 to 42.5	37.5 to 43	28 to 44	30 to 44
6	42 to 49	42 to 49	36 to 60	36 to 60
8	47 to 54	47 to 54	44 to 80	46 to 78
10	50 to 59	50.5 to 59	54 to 106	54 to 102
12	55 to 64	54 to 63.5	68 to 136	66 to 130
14	59 to 67.5	59 to 69.5	84 to 160	84 to 160
16	60 to 68	63 to 73	94 to 172	104 to 186
18	60 to 68.5	65 to 74	100 to 178	116 to 202

Chart Provided by Cincinnati Children

Output and Results

The output of the system can be found on the next series of pages. The expert system successfully yielded the python list of dictionaries as intended. The script was able to identify the mode tube used at each time set and then organize the tubes accordingly. Each dictionary output gives tube type, time of draw, and tests per tube. The expert system was also able to lower the blood volume if the patient was not a high enough weight to withdraw the specified amount of blood for all tests. The code was also able to tell if there was too little blood in a tube. When this occurs, the expert system will round the tube up to 2ml of blood. The area the expert system tended to struggle was with was Whole Blood tubes. In some cases, the expert system did not always successfully pull the whole blood tests from the general tests and was incorrectly counted among all the tests.

Since the Python script outputs a list of dictionaries, this enables the code to act as an application programming interface (API). As an API the function does not need to be embedded into the hand-held tablet to work but rather incorporated into the hospital's software directly in future iterations. This is an important design specification to meet as this allows the code to be more easily licensed for other hospitals. Since the output of the code can be contained in a single list, when data is being sent over Bluetooth the only thing the software will be sending is the array of dictionaries with all the desired information.

The study showed that even with optimal minimization of blood volume the smallest simulated patients were not always able to meet the demand for blood. If the dictionary states being on "Version 4" then all settings for blood volume are set to the lowest standard. If the maximum blood drawable is lower, then the total of version 4 then the simulated tests would not have been able to be conducted without external intervention like a blood transfusion. This result is seen in the one-year old patients near the bottom of the chart. The study stops at children of age one but newborn infants a couple of months old would not be able to meet these blood sampling demands. By successfully minimizing the blood needed for the tests we can lower the amount of blood transfusions these children will need to undertake and lower the chances of infection from external sources

The Python script was able to make conclusions on large sets of Excel data. A single hand calculation on three smart sets to meet the same standards could take 45 minutes to an hour and the current structure of the code can handle up to four in an instant. The function takes a large mental load off physicians as the code will automatically check if the patient is able to have all the tests requested. The expert system was also able to save analytical volume and reduce waste by packing in as many tests as possible per tube based on the lab criteria. This test was conducted strictly on Endocrinology Smart Sets, but as new Excel databases are created for Hematology and Gastroenterology the same function can be used.

Final Charts

Patient	Set 1	Set 2	Set 3	Weight in lb	Hematocrit	Age	Code OutPut	Maximum Blood draw in mL	Can the draw be conducted?
1	N - ENDO AMB BONE LABS [210197202] Released	A - ENDO AMB HCG PROTOCOL (EXTERNAL) [210557] Released	C - ENDO AMB ORAL GLUCOSE TOLERANCE/ ACTH STIM TEST (EXTERNAL) [210566]	70	0.5	10	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Luteinizing hormone', 'Follicle stimulating hormone', 'Testosterone, Total', 'Dihydrotestosterone', '17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'GGT', 'Alkaline phosphatase, isoenzymes', 'Phosphorus', 'Parathyroid Hormone', 'Vitamin D 25 hydroxy', 'Vitamin D 1,25 dihydroxy'], 'VolumeForTubeInML': 12.9336, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Calcium'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'Red', 'Time': 30.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin'], 'VolumeForTubeInML': 12.526079999999999, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Karyotype, blood', 'Calcium, ionized WB'], 'VolumeForTubeInMl': 4.703, 'Version': 'Version 1'}]	63.43	Yes
2	D - ENDO AMB CLONIDINE/A RGININE STIM TEST (EXTERNAL) [210624] Released	B - ENDO AMB ORAL GLUCOSE TOLERANCE TEST (EXTERNAL) [210559] Released	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	60	0.7	10	[{'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Glucose', 'Insulin', 'Cortisol, plasma', 'Growth hormone', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol'], 'VolumeForTubeInML': 14.433200000000001, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2.132, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2.0228, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Glucose', 'Insulin', 'Growth hormone', 'Cortisol'], 'VolumeForTubeInML': 2.1428, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Glucose', 'Insulin', 'Growth hormone', 'Cortisol'], 'VolumeForTubeInML': 2.1428, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2.1079999999999997, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Glucose', 'Insulin', 'Growth hormone', 'Cortisol'], 'VolumeForTubeInML': 2.1428, 'Version': 'Version 1'}]	54.4	Yes
3	I - ENDO AMB GLUCAGON/ ARGININE STIM TEST (EXTERNAL) [210649] Released	C - ENDO AMB ORAL GLUCOSE TOLERANCE/ ACTH STIM TEST (EXTERNAL) [210566]	D - ENDO AMB CLONIDINE/A RGININE STIM TEST (EXTERNAL) [210624] Released	90	0.9	10	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 13.132800000000003, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma'], 'VolumeForTubeInML': 18.636000000000003, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'Red', 'Time': 30.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 43.0464, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 150.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 180.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}]	81.5	No
4	L - ENDO AMB ANNUAL TURNER SYNDROME STUDIES [210012015] Released	P - ENDO AMB ANNUAL DIABETES LABS [210789456] Released	C - ENDO AMB ORAL GLUCOSE TOLERANCE/ ACTH STIM TEST (EXTERNAL) [210566]	50	0.3	8	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Immunoglobulin A', 'Estrone', 'TSH', 'T4, free', 'IGF 1', 'Transglutaminase IgA', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cholesterol', 'Triglycerides', 'HDL', 'LDL', 'Vitamin D 25 hydroxy', 'Follicle stimulating hormone', 'Luteinizing hormone', 'Vitamin D 25 hydroxy'], 'VolumeForTubeInML': 7.895485714285712, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': 0.0, 'Test List': ['Estradiol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'Red', 'Time': 30.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin'], 'VolumeForTubeInML': 8.947199999999999, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Red', 'Time': 0.0, 'Test List': ['Anti-Thyroidperoxidase'], 'VolumeForTubeInMl': 3.503, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Lavender', 'Time': 0.0, 'Test List': ['Hemoglobin A1c'], 'VolumeForTubeInMl': 2.903, 'Version': 'Version 1'}]	45.4	Yes

5	J - ENDO AMB IGF-1 GENERATION TEST (EXTERNAL) [210667] Released	F - ENDO AMB LEUPROLIDE STIM TEST (EXTERNAL) [210638] Released	D - ENDO AMB CLONIDINE/ARGININE STIM TEST (EXTERNAL) [210624] Released	70	0.2	8	[{'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma', 'Growth hormone', 'Follicle stimulating hormone', 'Luteinizing hormone', 'Testosterone, Total', 'IGF 1'], 'VolumeForTubeInML': 5.3715, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': 0.0, 'Test List': ['Estradiol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Growth hormone', 'Follicle stimulating hormone', 'Luteinizing hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Growth hormone', 'Follicle stimulating hormone', 'Luteinizing hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': '24Hour', 'Test List': ['Follicle stimulating hormone', 'Luteinizing hormone', 'Testosterone, Total', 'IGF 1'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': '24Hour', 'Test List': ['Estradiol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}]	63.4	Yes
6	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	K - ENDO AMB HYPOGLYCEMIA [2101972] Released	C - ENDO AMB ORAL GLUCOSE TOLERANCE/ACTH STIM TEST (EXTERNAL) [210566]	60	0.5	8	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Growth hormone', 'C Peptide', 'Free Fatty Acids, Total Serum'], 'VolumeForTubeInML': 9.163680000000001, 'Version': 'Version 1'}, {'Tube': 'Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma', 'Amino Acids QN, plasma', 'Acylcarnitines, plasma, quantitative'], 'VolumeForTubeInML': 9.847199999999999, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': 0.0, 'Test List': ['Acetone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'Red', 'Time': 30.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Cortisol'], 'VolumeForTubeInML': 12.54048, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Insulin', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Insulin', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}]	54.4	Yes
7	B - ENDO AMB ORAL GLUCOSE TOLERANCE TEST (EXTERNAL) [210559] Released	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	K - ENDO AMB HYPOGLYCEMIA [2101972] Released	40	0.4	6	[{'Tube': 'Green', 'Time': 0.0, 'Test List': ['Glucose', 'Insulin', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol', 'Growth hormone', 'C Peptide', 'Cortisol, plasma', 'Amino Acids QN, plasma', 'Acylcarnitines, plasma, quantitative'], 'VolumeForTubeInML': 8.419, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': 0.0, 'Test List': ['Acetone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'Red', 'Time': 0.0, 'Test List': ['Free Fatty Acids, Total Serum'], 'VolumeForTubeInML': 3.0060000000000002, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Glucose', 'Insulin', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Glucose', 'Insulin', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Glucose', 'Insulin', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}]	36.35	Yes
8	M - ENDO AMB ANNUAL GROWTH HORMONE LABS [210123159] Released	N - ENDO AMB BONE LABS [210197202] Released	A - ENDO AMB HCG PROTOCOL (EXTERNAL) [210557] Released	60	0.7	6	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Luteinizing hormone', 'Follicle stimulating hormone', 'Testosterone, Total', 'Dihydrotestosterone', 'TSH', 'T4, free', 'IGF 1', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'GGT', 'Alkaline phosphatase, isoenzymes', 'Phosphorus', 'Parathyroid Hormone', 'Vitamin D 25 hydroxy', 'Vitamin D 1,25 dihydroxy'], 'VolumeForTubeInML': 12.866399999999997, 'Version': 'Version 1'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Calcium'], 'VolumeForTubeInML': 2.0211999999999994, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Karyotype, blood', 'Calcium, ionized WB'], 'VolumeForTubeInMl': 4.703, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Lavender', 'Time': 0.0, 'Test List': ['Hemoglobin A1c'], 'VolumeForTubeInMl': 2.903, 'Version': 'Version 1'}]	54.4	Yes

9	M - ENDO AMB ANNUAL GROWTH HORMONE LABS [210123159] Released	O - ENDO AMB GROWTH EVALUATION [210789123] Released	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	50	0.6	6	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol', 'TSH', 'T4, free', 'IGF 1', 'IGF Binding Protein 3', 'Transglutaminase IgA', 'Immunoglobulin A'], 'VolumeForTubeInML': 3.4074000000000004, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Lavender', 'Time': 0.0, 'Test List': ['Hemoglobin A1c', 'Hemogram', 'ESR'], 'VolumeForTubeInMl': 7.103, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Karyotype, blood'], 'VolumeForTubeInMl': 4.103, 'Version': 'Version 1'}]	45.4	Yes
10	O - ENDO AMB GROWTH EVALUATION [210789123] Released	None	I - ENDO AMB GLUCAGON/ ARGININE STIM TEST (EXTERNAL) [210649] Released	30	0.3	4	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Growth hormone', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'TSH', 'T4, free', 'IGF 1', 'IGF Binding Protein 3', 'Transglutaminase IgA', 'Immunoglobulin A'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma'], 'VolumeForTubeInML': 6.005142857142857, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 150.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 180.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Lavender', 'Time': 0.0, 'Test List': ['Hemogram', 'ESR'], 'VolumeForTubeInMl': 4.703, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Karyotype, blood'], 'VolumeForTubeInMl': 4.103, 'Version': 'Version 1'}]	27.32	Yes

11	None	H - ENDO AMB GH SUPPRESSION TEST (EXTERNAL) [210647] Released	E - ENDO AMB ACTH STIM TEST (EXTERNAL) [210630] Released	40	0.4	4	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol', 'Glucose', 'IGF 1', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Cortisol', 'Glucose', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Cortisol', 'Glucose', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Glucose', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Glucose', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}]	36.35	Yes
12	A - ENDO AMB HCG PROTOCOL (EXTERNAL) [210557] Released	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	D - ENDO AMB CLONIDINE/ARGININE STIM TEST (EXTERNAL) [210624] Released	30	0.5	4	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Luteinizing hormone', 'Follicle stimulating hormone', 'Testosterone, Total', 'Dihydrotestosterone', 'Growth hormone', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol'], 'VolumeForTubeInMl': 3.00864, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma'], 'VolumeForTubeInMl': 4.8072, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Growth hormone', 'Cortisol'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Growth hormone', 'Cortisol'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Growth hormone', 'Cortisol'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Karyotype, blood'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}]	27.32	Yes

13	I - ENDO AMB GLUCAGON/ ARGININE STIM TEST (EXTERNAL) [210649] Released	C - ENDO AMB ORAL GLUCOSE TOLERANCE/ ACTH STIM TEST (EXTERNAL) [210566]	A - ENDO AMB HCG PROTOCOL (EXTERNAL) [210557] Released	35	0.2	3	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Luteinizing hormone', 'Follicle stimulating hormone', 'Testosterone, Total', 'Dihydrotestosterone', '17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Growth hormone'], 'VolumeForTubeInMl': 3.2885999999999997, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma'], 'VolumeForTubeInMl': 3.0045, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Insulin'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'Red', 'Time': 30.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Growth hormone'], 'VolumeForTubeInMl': 6.0557999999999999, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Insulin', 'Growth hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Insulin', 'Growth hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 150.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Tube': 'White', 'Time': 180.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Karyotype, blood'], 'VolumeForTubeInMl': 2, 'Version': 'Version 3'}]	31.84	Yes
14	None	N - ENDO AMB BONE LABS [210197202] Released	None	30	0.8	3	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'GGT', 'Alkaline phosphatase, isoenzymes', 'Phosphorus', 'Parathyroid Hormone', 'Vitamin D 25 hydroxy', 'Vitamin D 1,25 dihydroxy'], 'VolumeForTubeInML': 12.741600000000002, 'Version': 'Version 1'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Calcium'], 'VolumeForTubeInML': 3.0318, 'Version': 'Version 1'}, {'Whole Blood Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Calcium, ionized WB'], 'VolumeForTubeInMl': 2, 'Version': 'Version 1'}]	27.32	Yes
15	None	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	D - ENDO AMB CLONIDINE/A RGININE STIM TEST (EXTERNAL) [210624] Released	27	0.4	3	[{'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma', 'Growth hormone', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol'], 'VolumeForTubeInML': 7.211200000000002, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Growth hormone', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Growth hormone', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Growth hormone', 'Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}]	24.6	Yes
16	G - ENDO AMB LOW/HIGH DOSE ACTH STIM TEST (EXTERNAL) [210645] Released	None	None	25	0.7	2	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol'], 'VolumeForTubeInML': 2.3263999999999996, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2.132, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2.036, 'Version': 'Version 1'}]	22.8	Yes

17	J - ENDO AMB IGF-1 GENERATIO N TEST (EXTERNAL) [210667] Released	E - ENDO AMB ACTH STIM TEST (EXTERNAL) [210630] Released	F	30	0.6	2	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cortisol', 'Follicle stimulating hormone', 'Luteinizing hormone', 'Testosterone, Total', 'IGF 1'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': 0.0, 'Test List': ['Estradiol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 20.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 40.0, 'Test List': ['Cortisol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Cortisol', 'Follicle stimulating hormone', 'Luteinizing hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Follicle stimulating hormone', 'Luteinizing hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'White', 'Time': '24Hour', 'Test List': ['Follicle stimulating hormone', 'Luteinizing hormone', 'Testosterone, Total', 'IGF 1'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}, {'Tube': 'none', 'Time': '24Hour', 'Test List': ['Estradiol'], 'VolumeForTubeInML': 2, 'Version': 'Version 1'}]	27.32	Yes
18	I - ENDO AMB GLUCAGON/ ARGININE STIM TEST (EXTERNAL) [210649] Released	None	C - ENDO AMB ORAL GLUCOSE TOLERANCE/ ACTH STIM TEST (EXTERNAL) [210566]	20	0.5	1	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2.62656, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 0.0, 'Test List': ['Adrenocorticotropic Hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Cortisol, plasma'], 'VolumeForTubeInML': 3.7272, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'Red', 'Time': 30.0, 'Test List': ['17 Alpha Hydroxyprogesterone', '17-Hydroxypregnenolone', 'DHEA', 'Androstenedione', 'Progesterone', 'Cortisol', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 8.609279999999998, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 150.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 180.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}]	18.3	No
19	B - ENDO AMB ORAL GLUCOSE TOLERANCE TEST (EXTERNAL) [210559] Released	None	I	17	0.9	1	[{'Tube': 'Light Green', 'Time': 0.0, 'Test List': ['Glucose', 'Insulin', 'Cortisol, plasma', 'Growth hormone'], 'VolumeForTubeInML': 18.956400000000002, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Glucose', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Glucose', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 90.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Glucose', 'Insulin', 'Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 150.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 180.0, 'Test List': ['Growth hormone'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}]	15.58	No
20	None	L - ENDO AMB ANNUAL TURNER SYNDROME STUDIES [210012015] Released	B - ENDO AMB ORAL GLUCOSE TOLERANCE TEST (EXTERNAL) [210559] Released	15	0.3	1	[{'Tube': 'Red', 'Time': 0.0, 'Test List': ['Glucose', 'Insulin', 'Immunoglobulin A', 'Estrone', 'TSH', 'T4, free', 'IGF 1', 'Transglutaminase IgA', 'Sodium', 'Potassium', 'Chloride', 'Carbon Dioxide', 'Urea Nitrogen', 'Glucose', 'Creatinine', 'Calcium', 'Total Protein', 'AST (Aspartate Aminotransferase, Roche should have it)', 'ALT (Alanine Aminotransferase, Roche should have it)', 'Alkaline Phosphate', 'Albumin', 'Total Bilirubin', 'Cholesterol', 'Triglycerides', 'HDL', 'LDL', 'Vitamin D 25 hydroxy', 'Follicle stimulating hormone', 'Luteinizing hormone'], 'VolumeForTubeInML': 2.4497142857142857, 'Version': 'Version 4'}, {'Tube': 'none', 'Time': 0.0, 'Test List': ['Estradiol'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 15.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 30.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 60.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Tube': 'White', 'Time': 120.0, 'Test List': ['Glucose', 'Insulin'], 'VolumeForTubeInML': 2, 'Version': 'Version 4'}, {'Whole Blood Tube': 'Lavender', 'Time': 0.0, 'Test List': ['Hemoglobin A1c'], 'VolumeForTubeInMl': 2, 'Version': 'Version 4'}]	13.78	No

Conclusion

The pediatric blood calculator is designed to optimize blood use by minimizing sampling needed to conduct blood tests. This system was broken down into three separate parts, the hardware used by the physician, the user interface created in Tkinter, and the expert system that generates the optimized blood volume. The hardware of the project was a Raspberry Pi touch screen with an external casing. This portion of the project worked as intended with a user having access to a small portable device with the imbedded application easily accessible. For future improvements on this piece I would recommend switching from a 120V plug in to a 9V or 12V battery supply. I would also recommend going from a seven-inch touch screen to a 10-inch touch screen as applications became harder to build as space began to run low.

The Tkinter interface allowed medical professionals to choose their specialty, add patient information, select smart sets, and finalize orders. The interface was uploaded to the physical system and worked on the touch screen. This portion of the project could be improved by having a section in the software that enables medical staff to input new tests and easily update the database of existing smart sets. The system is designed so that it is easy to add new Excel databases but difficult to modify existing ones in the system. Another improvement would be using a different on-screen touch keyboard. The one installed for this project worked but was not user friendly.

The brain of the project, the expert system, was able to correctly determine the maximum amount of blood that can be taken from a patient in the Blood-V function. The code was also successful at minimizing the amount of blood required for standard tests by combining tubes and lowering blood volumes when needed based on patient data. Compared to the hand calculations the biggest flaw in the expert system was the ability to handle whole blood tests. The system was able to separate whole blood tests from standard tests but would occasionally mix the two when determining final tubes. Whole blood tests are a special edge case, but future versions of the code must be able to handle this separation to be used in hospitals. Main improvements to the expert system include handling whole blood tests and removing tube types when anti-coagulant in the blood stream. These edge cases fall out of the scope of this project but will be handled in newer iterations.

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References (20-25 references)

1. Bain, A., & Blackburn, S. (2004). Issues in transfusing preterm infants in the NICU. *Journal of Perinatal & Neonatal Nursing, 18*(2), 170–184. https://doi-org.ezproxy.uakron.edu:2443/10.1097/00005237-200404000-00011
2. Curley, A., Stanworth, S. J., Willoughby, K., et al. (2019). Randomized Trial of Platelet-Transfusion Thresholds in Neonates. N Engl J Med, 380(3), 242-251. doi:10.1056/NEJMoa1807320
3. Haenlein, M., & Kaplan, A. (2019). A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence. California Management Review, 61(4), 5–14. https://doi-org.ezproxy.uakron.edu:2443/10.1177/0008125619864925
4. Haocheng T. (2017). A Brief History And Technical Review Of The Expert System Research. *IOP Conference Series: Materials Science & Engineering, 242*(1), 1.
5. Holland, J., Peralta, R. M., Moss, R. L., Feane, K., & Uprichard, J. (n.d.). A single-centre review of iatrogenic anaemia in adult intensive care. TRANSFUSION MEDICINE, 30(3), 196–200. https://doi-org.ezproxy.uakron.edu:2443/10.1111/tme.12674
6. Jackson, P. (1998). Introduction to Expert Systems. Addison-Wesley Longman Publishing Co., Inc. https://dl.acm.org/doi/book/10.5555/521024
7. Jakacka, N., Snarski, E., Mekuria, S. (2016). Prevention of Iatrogenic Anemia in Critical and Neonatal Care. Adv Clin Exp Med, 25(1), 191-197. doi:10.17219/acem/32065
8. Lopriore, E. (2019). Updates in Red Blood Cell and Platelet Transfusions in Preterm Neonates. Am J Perinatol, 36(S 02):S37-S40. doi:10.1055/s-0039-1691775

9. McCall, R. E., & Tankersley, C. M. (2008). Phlebotomy essentials (5th ed.). Philadelphia: Wolters Kluwer Health.

10. Mutawa, A. M., & Alzuwawi, M. A. (2019). Multilayered Rule-Based Expert System For Diagnosing Uveitis. *Artificial Intelligence In Medicine, 99*. https://doi-org.ezproxy.uakron.edu:2443/10.1016/j.artmed.2019.06.007

11. Novak, R. (2009). Maximum Allowable Draw Volume Guidelines for Pediatric Patients (<14 years of age). Akron Children's Hospital.

12. Raspberry Pi Foundation. *Raspberry Pi Touch Display.* https://www.raspberrypi.org/documentation/hardware/display/

13. Raspberry Pi Foundation. *Raspberry Pi 3 Model B+*. https://static.raspberrypi.org/files/product-briefs/200206+Raspberry+Pi+3+Model+B+plus+Product+Brief+PRINT&DIGITAL.pdf

14. Sasikumar, M., Ramani, S., Raman, S. M., Anjaneyulu K. S. R., & Chandrasekar, R. (2007). *A Practical Introduction to Rule Based Expert Systems*. Narosa Publishers. https://www.researchgate.net/profile/Srinivasan_Ramani/publication/265038834_A_Practical_Introduction_to_Rule_Based_Expert_Systems/links/551faa1d0cf2a2d9e1407dce.pdf

15. Shaheamlung, G., Kaur, H., & Singla, J. (2019). A Comprehensive Review of Medical Expert Systems for Diagnosis of Chronic Liver Diseases. *2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE), Computational Intelligence and Knowledge Economy (ICCIKE), 2019 International*

Conference On, 731–735. https://doi-org.ezproxy.uakron.edu:2443/10.1109/ICCIKE47802.2019.9004438

16. Wang, Y. C., Chan. O. W., Chiang, M. C., et al. (2017). Red Blood Cell Transfusion and Clinical Outcomes in Extremely Low Birth Weight Preterm Infants. Pediatr Neonatol, 58(3), 216-222. doi:10.1016/j.pedneo.2016.03.009
17. Whitehead, N. S., Williams L. O., Meleth S., et al. (2019). Interventions To Prevent Iatrogenic Anemia: A Laboratory Medicine Best Practices Systematic Review. *Crit Care, 23*(1), 278. doi:10.1186/s13054-019-2511-9
18. Cincinnati Children's. (2019, April). Normal Growth. https://www.cincinnatichildrens.org/health/g/normal-growth
19. Arsene, O., Dumitrache, I., & Mihu, I. (2011). Medicine expert system dynamic Bayesian Network and ontology based. Expert Systems With Applications, 38(12), 15253–15261. https://doi-org.ezproxy.uakron.edu:2443/10.1016/j.eswa.2011.05.074
20. Liebowitz, J. (1997). The Handbook of Applied Expert Systems (1st ed.). CRC Press.