Video Measurement of Jugular Venous Pressure for Congestive Heart Failure Management

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Executive Summary

Team Venous designed a camera-based system that enables heart failure patients to measure their jugular venous pressure (JVP) at home without the presence of a physician. 5.7 million people in the US suffer from congestive heart failure (CHF), resulting in over 1 million hospital visits annually. JVP correlates with excess fluid volume and yields prognostic information in CHF patients. Currently, JVP is measured during an in-person examination where the physician visually approximates the height of the JVP. While this method is accurate, it can be expensive and inconvenient for patients.

To address these problems, our system has the following requirements:

- Cost of less than $300
- Designed for people without medical training
- Minimally invasive
- Small form factor
- Provides useful clinical data to physician
- Processing time of less than 10 minutes

We determined that a computer vision approach using the Eulerian video magnification algorithm would best satisfy our requirements because of the low cost of a software approach, low number of hardware components necessary, and the proven accuracy of the algorithm in assessing the height of the JVP as concluded in the EuleriAn Video Magnification ApPLications In Heart Failure StudY (AMPLIFY).

Our solution consists of 2 main parts: an iOS mobile app and a Matlab desktop app. The iOS app allows the patient to record a 10 second video of his or her JVP and sends the video to the physician. The physician then processes the video using the Matlab desktop app, which amplifies the motion of the patient's JVP using the Eulerian algorithm and provides reference distances to help determine the JVP height.

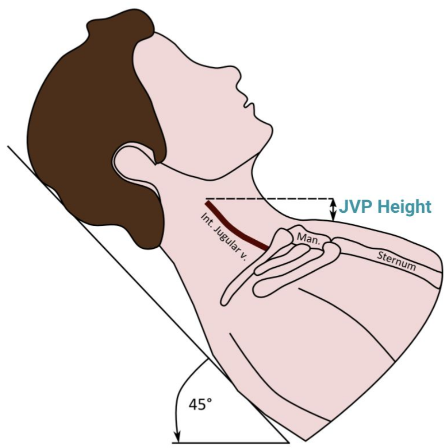
We conducted trials using three of our team members as test subjects. The JVP height is more visible from the amplified videos with reference distances compared to the raw videos, and the physician confirmed that he was able to determine the location of the JVP from the amplified videos. We asked 10 students at Rice to rate the ease of use of our mobile app, and received an average rating of more than 4 on a 5 point scale. Few hardware components are required and the processing time is 5-8 minutes. We successfully developed a system of simple and effective desktop and mobile apps that provides useful clinical data to the physician on assessing JVP.

Next steps would be to develop an algorithm to measure JVP height, further refine the desktop and mobile apps, create a tutorial feature in the mobile app, improve the speed of the algorithm so amplification can occur in the smartphone, create an Android version of the iOS mobile app, and obtain IRB approval and solicit patient feedback.

Introduction

Assessment of central venous pressure (CVP) is of utmost importance in the proper treatment of many of the most common reasons for hospitalization, including heart failure exacerbations. Assessment of the CVP is important because 5.7 million people in the US suffer from congestive heart failure (CHF), resulting in over 1 million hospital visits annually [1]. The gold standard for measurement of CVP is placement of a central venous catheter or right heart catheterization to directly measure right atrial pressure, or CVP. However, less invasive methods exist, and the most common and safe method to measure CVP is to assess the jugular venous pressure (JVP) on physical exam of the patient [2].

JVP is believed to be an accurate method to accurately assess CVP in most patients, and currently it can only be measured in the clinic or hospital setting with the presence of a physician or nurse. JVP measurement is performed by observing the fluctuations of the pulsations in the neck created by the jugular vein and assessing the vertical height, which we refer to as the JVP height, of the meniscus of the pressure. This height is the vertical distance between the angle of Louis and the highest point of the jugular vein pulsations as the patient lies reclined at a 30-45 degree angle [3].



While this method is non-invasive and fast, it requires regular visits to the hospital, which may be a financial and time burden for patients. Furthermore, since only physicians are trained to identify and measure JVP, patients are unable to assess their own JVP and may come to the hospital only once symptoms such as leg swelling have developed. At this point, the patient will most likely need to be hospitalized.

Ultrasound machines can be used to non-invasively measure the JVP. However, they are expensive and require visits to the hospital because only licensed professionals are able to perform the measurement [4].

Current methods for directly measuring CVP, including manometers, transducers, and ambulatory hemodynamic monitors, are costly and invasive. Manometers and transducers involve insertion of a catheter into the superior vena cava, the vein that returns deoxygenated blood to the right atrium of the heart [5]. Ambulatory hemodynamic monitors (ex/ CardioMEMS device) have shown promise in early detection of heart failure, but require implants and additional staff and resources are needed to manage them [2].

We studied some computational techniques and methods that could be used to measure JVP, including near-infrared spectroscopy and the Eulerian video magnification algorithm.

For the technique using near-infrared spectroscopy (NIRS), the CVP has been estimated using near-infrared sensitive cameras and skin-contact near-infrared spectroscopy devices. Generally, these devices work by projecting near-infrared light into the skin tissue to detect reflected light. Since haemoglobin mainly absorbs the near-infrared light, the amplitude changes in the reflected light can be mapped to the pulsations of the vein [6]. This technique has been used by a company named Mespere LifeSciences, in which it uses skin-contact near-infrared spectroscopy on the external jugular vein to estimate CVP, but it seems that this method has not been applied to the internal JVP [7]. However, these devices are expensive and are used to measure the external JVP, which is considered a poor estimator of the CVP.

Eulerian video magnification is an image processing algorithm that reveals subtle periodic motions in videos by amplifying them into larger, more discernible movements. The EuleriAn Video Magnification ApPLications In Heart Failure StudY (AMPLIFY) took recorded videos of at-risk patients' neck veins and used eulerian video magnification to amplify their JVP pulsations. Physicians evaluated the patients JVP using three methods: the traditional bedside examination, the unamplified and amplified videos, and the gold standard invasive method of right heart catheterization. Using the measurements from the catheterization method as the ground truth, the study concluded that eulerian motion magnification reduced the inaccuracy of physician assessment of the CVP compared to both the unamplified video and the bedside exam [2]. Since this method is successful in producing amplified recordings of the JVP pulsations, we decided to implement it in our design along with mobile and desktop apps that allow for remote JVP monitoring.

The main type of customers who will use our design are CHF patients and their physicians. Since we are designing a medical device, it will most likely be paid by insurance companies. The FDA, physicians, and insurance companies will authorize the use of our design.

Systems Engineering and Specifications

Introduction

The objective of this project is to develop a camera-based system that enables heart failure patients to measure their jugular venous pressure at home without the presence of a physician. Currently, JVP is measured during a bedside examination at a clinic or hospital where a physician visually approximates the height of the JVP. While this method is accurate, it requires regular visits to the hospital which can be a time and financial burden for patients. Thus, we are developing a low-cost system that patients can use to self-administer measurement of their JVP. Furthermore, because the system is meant for daily at-home monitoring of JVP, a reasonable processing time is ideal.

The following table lists the customer needs.

Ranking	**Customer Need**
1	Clinically useful information on JVP
2	Self-administered measurement of JVP
3	Reasonable processing time
4	Low cost

To meet these customer needs, we determined the following specifications for a low-cost, simple and effective at-home system to measure JVP.

Specification	**Target**
Cost	Less than $300
Desktop App Functions	Amplify and provide reference distances in videos
Clinical Utility of Amplified Video	Physician can determine location of JVP
Hardware Components for Physician	Less than 2
Hardware Components for Patient	Less than 5
Patient Ease of Use	User rating of 4 out of 5
Processing Time	Less than 10 minutes

A cost of less than $300 is ideal. Patients and insurance companies pay hundreds of thousands of dollars to stay in the hospital and monitor JVP. For patients without insurance, a $300 or less device is much more affordable than a visit to the hospital. Without insurance, the average cost to stay at a hospital for one day is about $4,000 [8]. Putting forward a low cost and effective device to assess JVP will allow physicians to reach more patients in a way that keeps patients out of the hospital and insurance companies satisfied.

We decided to pursue a computer vision approach using the Eulerian video magnification algorithm because of the proven accuracy of the algorithm in assessing the height of the JVP as concluded in the EuleriAn Video Magnification ApPLications In Heart Failure StudY (AMPLIFY). In addition, providing reference distances in the amplified videos would help the physician determine the JVP height.

Because the solution is self-administered and remote, it should be easy to use and require few hardware components. The patient should find the video recording process intuitive (user rating of 4 out of 5) and should ideally require less than 5 hardware components. The physician should ideally require only 1 hardware component, a computer, to process the videos.

Because our system is meant for daily at-home monitoring of JVP, a reasonable processing time of 10 minutes or less is ideal. The processing time does not need to be in real time. Our system does not administer treatment and is not used in high risk scenarios, so a short video processing time of 10 minutes or less is reasonable.

All specifications except for how we measured patient ease of use remained the same after the COVID shutdown. We initially planned on obtaining IRB approval and soliciting feedback from CHF patients at the Kelsey Seybold Clinic on the ease of use of our solution. Because of the COVID shutdown, we did not have enough time to meet with patients. Instead, we used ratings from 10 Rice students to meet the specification.

Major Concepts

We started off concept generation by developing the customer needs and target specifications. We then broke the problem up into different sub-problems based on those target specifications through problem decomposition. We decided to focus on gathering the input data and the data segmentation problem for this semester. We researched existing technology and methods that could be used to solve the sub-problem by utilizing expert consultation, patent search and literature search. We came together as a group to brainstorm ideas from the information we researched. Then we systematically examined the ideas we came up with to decide which ones were worth looking into. We then reflected on those ideas we came up with, making sure they were viable and would fit our customer needs, and asked for advice from our mentors.

In our concept selection process, we created a Pugh Matrix, as shown below, to evaluate and rank our different ideas from the concept generation process. We decided on the design criteria by looking at our customer needs. Then we rated the concepts according to the design criteria and totaled those ratings to produce a final ranking of the concepts. We selected the two highest ranking concepts, Lagrangian Magnification and Eulerian Magnification to work on. Then we reflected on our choices and discussed them. We were not happy with only choosing the software concepts, so we decided to combine parts of the not chosen hardware concepts, like Structured Light, to our chosen concepts.

Technology	Clinical Examination	Time of Flight	Structured Light	DLP	Stereoscopic Vision	Infrared Spectroscopy	Lagrangian Magnification	Eulerian Magnification
Low Customer Cost	0	1	-1	-1	1	1	1	1
Size	0	1	0	-1	1	0	1	1
Accuracy	0	-1	0	1	-1	-0.5	0.5	1
Low Development Time	0	1	-1	-1	1	0	0	0
Latency	0	1	0	0	0	1	0	0
Customer Ease of Use	0	-1	0	0	1	0	1	1
Total	0	2	-2	-2	3	1.5	3.5	4
Rank	6	4	7	7	3	5	2	1

This pugh matrix compares and ranks the 8 initial solutions we came up with to detect a patient's JVP. The scores were computed according to the 6 design criteria (low customer cost, size, accuracy, low development time, latency, and customer ease of use) listed in the leftmost column. We chose the clinical bedside examination as our reference solution because it is the current method used by physicians to estimate the height of a patient's JVP. We determined the rest of the potential solutions and computed their scores by brainstorming and researching various hardware (sensors) and software technology. Methods involving hardware include time of flight sensor, structured light, DLP, stereoscopic vision, and infrared spectroscopy. Software methods include Langrangian and Eulerian magnification.

These initial solutions belong to two categories: hardware and software/computer vision. All of the hardware methods except infrared spectroscopy serve the same purpose: measuring movement on a given surface or area. However, each of these hardware technologies accomplish this goal with different sensors and methods. We found these specific hardware options by searching for hardware that could measure movement on a small scale. Through extensive research, we found that there are 4 main standard hardware technologies commercially available to detect small movements of a 3D surface: Time of Flight, Structured Light, DLP, and Stereoscopic Vision. Notably, Structured Light and DLP project patterns onto surfaces and detect the motion change of those surfaces. However, whereas DLP uses varying pattern projections, Structured Light uses a single pattern. The fifth hardware option, Infrared Spectroscopy, detects changes in infrared light on a given surface and is the technology currently used in devices like the Apple Watch. We had it as an option because we considered using it to find the JVP based on changes of infrared light across the skin.

The 4 methods that measure movement do so in their own unique way. A Time of Flight camera sends out a laser or a modulated light source and records the time it takes for the laser to return. This is powerful because this would allow us to potentially just emit either a light or laser on the patient to detect movement. However, a main issue with this method is that it tends to perform poorly with small-scale movement, such as measuring JVP pulses. However, it did provide us with an option to detect movement in a non-intrusive way. This impacts the overall topic of the document by providing a way to measure the JVP data without video. Thus it potentially provides an additional way to measure the JVP pulse other than traditional video and therefore provide an additional source of data.

The Structured Light and DLP methods detect the movement on a 3D surface by measuring distoritions of visible or IR illumination. It is a rather straightforward method with industry-set standards and procedures. Because these methods provide even more precise detections in movement, we considered them as potential solutions. However, they were ranked poorly in our Pugh matrix because they require expensive equipment, there are less tools and options available, and they have a more involved process that would require an extensive amount of research to get working. Overall this affects the general topic of the document by providing an additional way to measure JVP that could potentially be paired with the video methods so that we can have additional and more thorough data.

Stereoscopic Vision requires using two cameras to mimic human eyes and therefore get a sense of depth in the videos. Stereoscopic Vision provides a more straightforward method that doesn’t require dedicated hardware and there are many techniques and resources online available on how to implement it. However, since the software solutions were just as effective and only required one camera to take the video, we decided not to use stereoscopic vision. The most significant part of the stereoscopic method was that it allowed us to understand all the possibilities when it came to recording and gathering data. Our research into the technology of stereoscopic vision allowed us to understand the use of multiple videos and the notion of depth when it came to gathering data on movement of the skin, increasing our available toolset. Thus, it allowed us to understand new methods of visually recording data as well as potentially adding new dimensions to our data or new features for us to work with through addition of depth to our video.

Finally, Infrared Spectroscopy measures the infrared levels beneath the skin. The significance of this technique is that it allows us to potentially measure the changes in JVP without using camera techniques and circumvent video processing. However, while this method would provide an entirely new method and feature to measure, it is impractical for a user to implement on his/her own neck. Therefore, we did not decide to proceed with this method.

The software solutions, Eulerian and Lagrangian magnification, are algorithms used to amplify motions in videos that are too small to perceive with the naked eye. Eulerian magnification applies spatial decomposition and temporal filtering to a normal video, resulting in a video that has certain parts amplified to reveal previously imperceptible information. In contrast, Langrangian magnification does not use temporal filtering and instead explicitly tracks motion by implementing motion compensation and magnification in one motion estimation step. Because they do not require any hardware components, they scored well on the low cost and size criteria. They also have high accuracy and it would be relatively easy for a patient to use these methods since they simply need to run the algorithms on a video taken of their neck while lying still. These reasons are why we ranked our software solutions as our best options.

Research shows that while the Lagrangian method works better for augmenting the motions of fine point features and allows for larger amplification, the Eulerian method works better for smoother features and small amplifications. The neck is a relatively smooth surface and a large magnification factor is not required to amplify the JVP pulse; in addition, the Eulerian approach also produces fewer artifacts than the Lagrangian approach. Therefore, we ranked Eulerian magnification as our best solution and Lagrangian magnification as our second best solution.

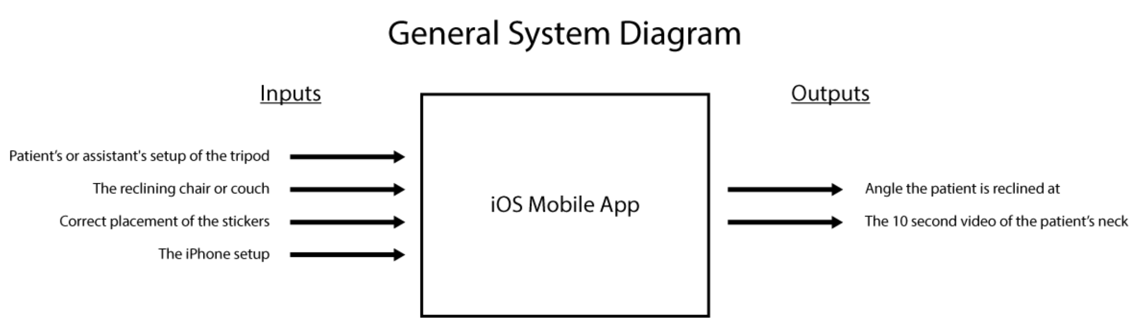
Design Implementation

The design consists of two parts: an iOS mobile app and a Matlab desktop app. The iOS mobile app is for the patient, with the aid of an assistant, to record a video of his or her JVP and send the video to the physician's computer for further analysis. The Matlab desktop app is for the physician to process the videos.

iOS mobile app

The input of the mobile app is the patient's or assistant's setup of the tripod, the reclining chair or couch, correct placement of the stickers, and the iPhone setup. The output is the angle the patient is reclined at and the 10 second video of the patient's neck, which are sent to the physician through email.

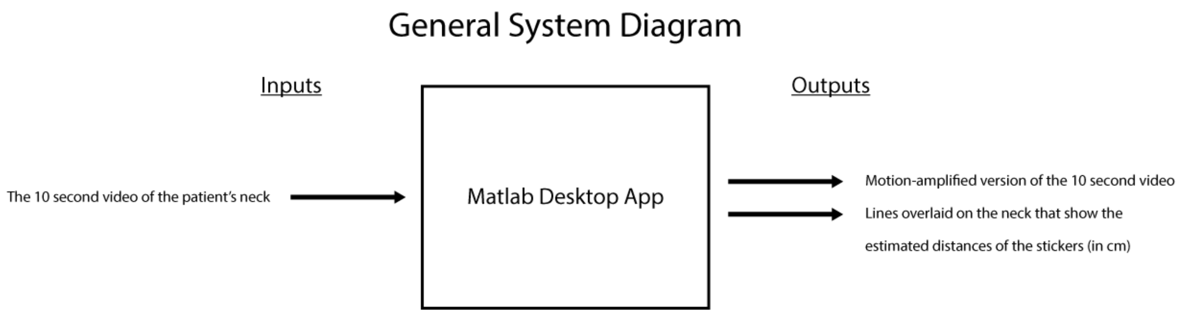
See Appendix A for the Github link and detailed instructions.



The patient or the assistant will be given an instruction document (Appendix A) for how to set up the tripod to ensure a stable video, and how the app interface works. The assistant might also undergo training to make the process more uniform. The patient will lie down on a reclined chair or couch, and the assistant will place the red circular stickers on the patient's neck at the specified locations. Next, the assistant will place the phone on the patient’s chest to measure the angle of recline, which will be recorded by the app. Then, the assistant will attach the phone to the tripod, making sure that the specific area of the neck and the stickers are in the camera frame and press record. The app will record for 10 seconds, then email the video to the physician to be processed by the Matlab desktop app.

Matlab desktop app

The input of the Matlab desktop app is the 10 second video the physician receives from the patient. The output is a motion-amplified version of the 10 second video with lines overlaid on the neck that show the estimated distances (in cm) of the stickers. See Appendix B for the Github link and detailed instructions.



The physician will download the 10 second video from the email sent by the patient. The physician will open the Matlab Desktop app and select the video to be processed. The app will call two different algorithms that process the video, producing an output video of the patient’s JVP that is motion amplified and tagged with the estimated distance.

Testing and Results

Criteria	Target	Product
Cost	Less than $300	$0
Desktop App Functions	Amplify and provide reference distances in videos	Achieved
Clinical Utility of Amplified Video	Physician can determine location of JVP	Achieved
Hardware Components for Physician	Less than 2	1
Hardware Components for Patient	Less than 5	3
Patient Ease of Use	User rating of 4 out of 5	Achieved
Processing Time	Less than 10 minutes	5-8 minutes

We successfully developed a camera-based system consisting of mobile and desktop apps that provides useful clinical data in assessing JVP. The cost is $0 for patients because the system will most likely be paid by insurance companies. We were able to amplify the JVP videos and provide reference distances to help determine the JVP height. The JVP height is more visible from the amplified videos with reference distances compared to the raw videos, and our client, a cardiologist at the Texas Medical Center, confirmed that he was able to determine the location of the JVP from the amplified videos.

The physician requires 1 hardware component (a computer) to run the Matlab desktop app and the patient requires 3 hardware components (iPhone, stickers, and tripod) to take a JVP video recording using the iPhone mobile app.

We asked 10 students at Rice to rate the ease of use of our mobile app, and received an average rating of more than 4 on a 5 point scale. The processing time of the system is 5-8 minutes.

Links to the original video side by side with the amplified videos with reference distances:
https://drive.google.com/file/d/12PmQmUBj-mznslN7EzEDwlblL5PhjFq_/view?usp=sharing
https://youtu.be/JUEhK6Lc_HY
Link to the demonstration of the mobile app and desktop app:
https://drive.google.com/open?id=1L6PDosL--ln6zHMsoXTOuhMMYp6w3Uz-
https://youtu.be/PIWZ2RrKJBg
* These files are also provided in our project Github repository (https://github.com/tammi-p/JVP) under the **Demo Videos** folder.
Please download them for a higher quality video.

Summary

Our system consists of an iOS mobile app for the patient, and a Matlab desktop app for the physician. The patient records a 10 second video using the iOS app. This video is emailed to the physician to be processed and amplified by the Matlab app. We utilized Eulerian Magnification to amplify the subtle movements in the internal jugular vein pulsations, and overlaid a reference height (distance between red stickers on the neck) for the physician to better estimate the JVP height.

Next steps would be to further refine the desktop and mobile apps, improve the speed of the algorithm, and obtain IRB approval and solicit patient feedback. We would like to add a tutorial feature to the iOS app that walks that patient through step by step how to properly set up the tripod and phone to ensure a good video recording. Ideally we would want to optimize the algorithm so that it can run on a smartphone. Currently our algorithm runs on a laptop which takes on average 5-8minutes depending on the processing power of the computer. In order for our system to be scalable for use on multiple patients across multiple clinics, having the ability for the algorithm to run directly on a smartphone would be ideal. Due to COVID-19, we were unable to obtain IRB approval. Moving forward, we would like to obtain IRB approval so that we can better tailor the parameters of our algorithm to real CHF patients, and get more feedback on how to improve the usability of our applications.

One lesson we learned along the way is to start the IRB process as soon as possible. At Rice, the IRB committee only meets once a month, so getting started with drafting and submitting an IRB is really important if you want to test the system on CHF patients. Another lesson learned is to be mindful of documenting everything. In our case with recording videos, it was important for us to keep track of the type of camera we were using, the settings used on the camera, and what lighting conditions we used in the setup.

References

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Appendix A - iOS Mobile App

Github: Files provided in **Mobile App** folder in https://github.com/tammi-p/JVP

Link to the instructions by itself:
https://docs.google.com/document/d/1IaSZSyR-wzz3cOvjBHWPVLPU4vBPkV20tVdJW3RANsU/edit?usp=sharing

Note: Our mobile app currently does not automatically scale for different iPhone screen sizes. User must manually select the device to run the app on in main.storyboard of the Xcode project to get a UI that fits the screen.

Note: Developer can change recipient email address in the Xcode project as needed.

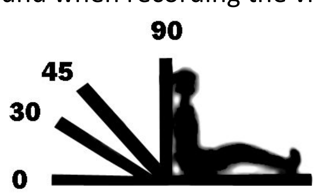
JVP iOS App Instructions

Requirements:

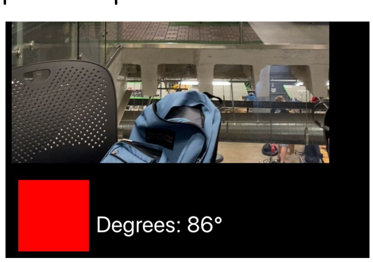
- Well-lit room (Lighting equipment if needed, such a lamp)
- Chair / sofa / pillows for patient to recline on
- Red sticker set provided by physician
- Tripod provided by physician
- No red objects in the background when taking the video recording
- **Patient must have an assistant to help with the setup and video recording**

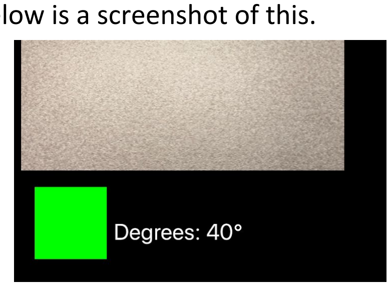
Instructions:

1. The patient must recline at a 30-45 degree angle, similar to the images shown below. Choose a place that is next to a wall with a solid color, such as a white wall, and make sure there are no objects that are red in the background when recording the video.



2. Next, open the app and place the phone flat on the chest with the screen facing up. If the patient is reclining at an appropriate angle for the measurement, the box at the lower left hand corner of the screen will be green. If the angle is incorrect, the box will be red. Adjust the patient's position until the box is green. Below is a screenshot of this.

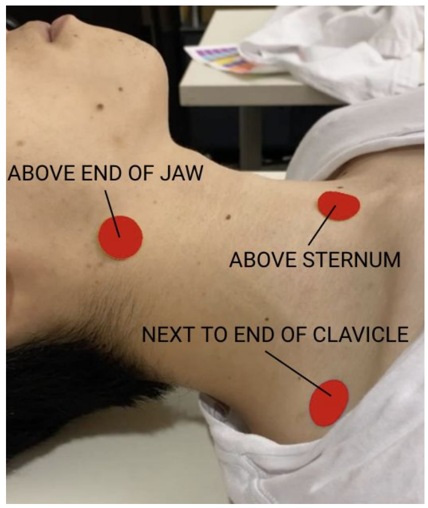




Red box: angle is not in correct range *Green box: angle is in the correct range*

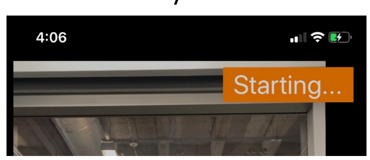
3. Put a tripod on the right side of the patient's chair so that the camera faces the right side of the patient's neck. The assistant must put the phone on the tripod and make sure that the right side of the patient's neck is clearly shown on the screen. To the left is a good reference for how the video should look after set up. Try to get the camera as close to the neck as possible so that the stickers are near the edges of the screen.

4. Next place stickers on the patient. There should be three stickers for the patient. One must be right below the end of the jaw. One must be next to the end of the clavicle. One must be right above the sternum. The same image has these instructions referenced.



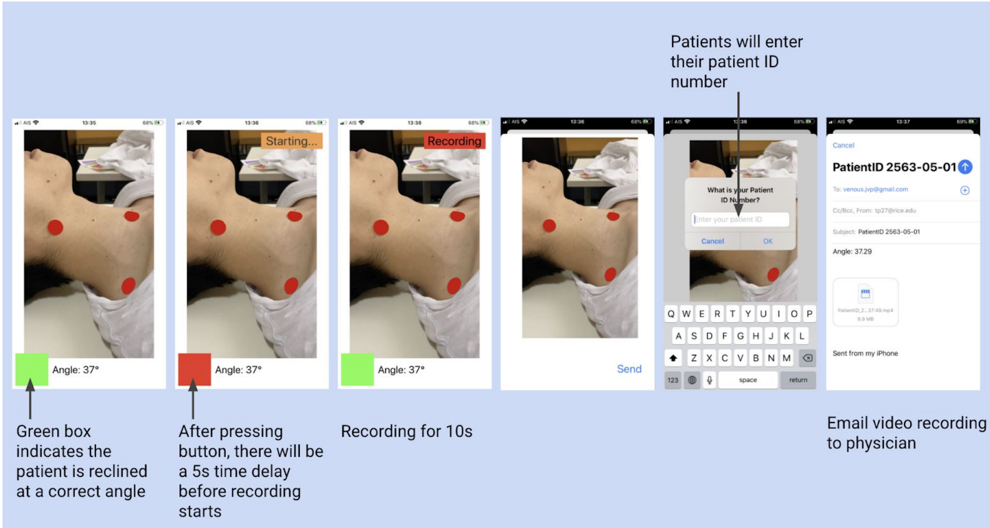
Placement of stickers

5. The assistant must press the box on the lower left hand corner to start recording. Once pressed, there will be a 5s time delay before recording starts. As shown below, there will be a message saying "Starting" displayed to indicate this delay.



Starting, displayed at the top, indicates that there is a delay before video starts recording

6. The app will automatically take a 10s video recording.
7. If you are satisfied with the recording, press the Send button.
8. An alert box will pop up to enter the patient's ID.
9. An email message with the recording as an attachment will be shown. Click the send symbol on the upper right hand corner of the page to send the recording to the physician.


Patients will enter their patient ID number
Starting...
Recording
Angle: 37°
Angle: 37°
Angle: 37°
Send
What is your Patient ID Number?
Cancel
OK
Cancel
PatientID 2563-05-01
Angle: 37.29
Sent from my iPhone
Green box indicates the patient is reclined at a correct angle
After pressing button, there will be a 5s time delay before recording starts
Recording for 10s
Email video recording to physician

Appendix B - Matlab Desktop App

Github: Files provided in **Desktop App** folder in https://github.com/tammi-p/JVP

Link to the instructions by itself:
https://docs.google.com/document/d/1DTHhpWU8IUbEi8Se2kBC04M-lsM98uKgraDp17wjRJ0/edit?usp=sharing

Instructions for the physician

Equipment to provide to patients:

The linked equipment below are just examples. They can be replaced with other brands
However, the Avery Print/Write Self-Adhesive Removable Labels, 0.75 Inch Diameter, Red is required and cannot be replaced unless the desktop algorithm is manually changed to detect a different color and size.

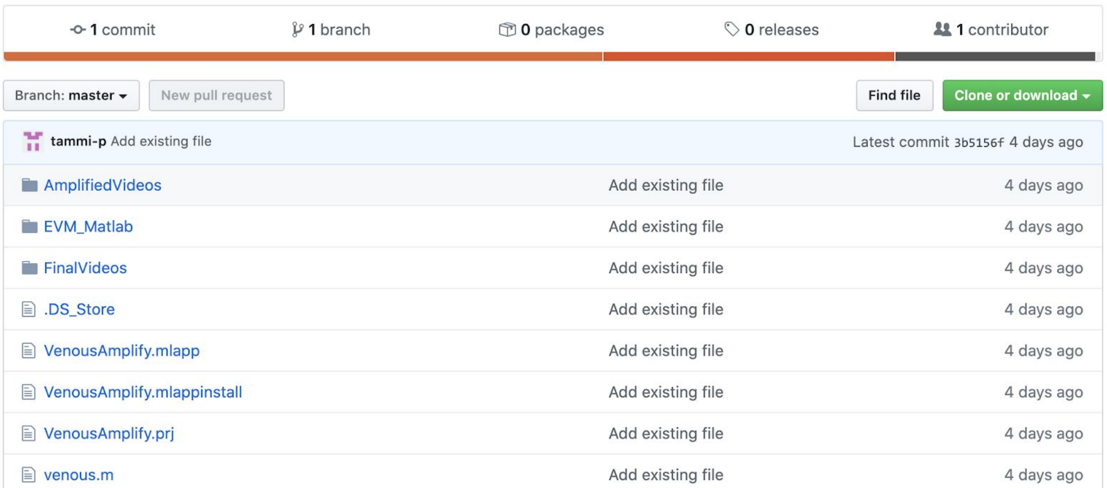
- Tripod
  https://www.amazon.com/AmazonBasics-60-Inch-Lightweight-Tripod-Bag/dp/B005KP473Q/ref=sr_1_3?dchild=1&keywords=tripod&qid=1588460003&sr=8-3
- Smartphone Tripod Adapter
  https://www.amazon.com/Vastar-Universal-Smartphone-Horizontal-Adjustable/dp/B01L3B5PBI/ref=sr_1_3?crid=328K86Z3ZNKLY&dchild=1&keywords=iphone+tripod+adapter&qid=1588460076&sprefix=iphone+tri%2Caps%2C191&sr=8-3
- Avery Print/Write Self-Adhesive Removable Labels, 0.75 Inch Diameter, Red

https://www.amazon.com/Avery-Self-Adhesive-Removable-Labels-Diameter/dp/B00007LPAG/ref=sr_1_5?dchild=1&keywords=avery+label+red&qid=1588460035&sr=8-5

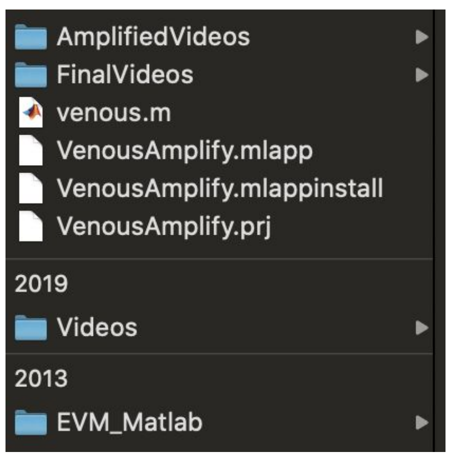
- (Optional, needed if the room is not well-lit) Lighting equipment
  https://www.amazon.com/TaoTronics-Portable-Desk-Lamp-Dimmable/dp/B07S1P3HZC/ref=sr_1_10?dchild=1&keywords=led+lamp&qid=1588460159&sr=8-10

Instructions:

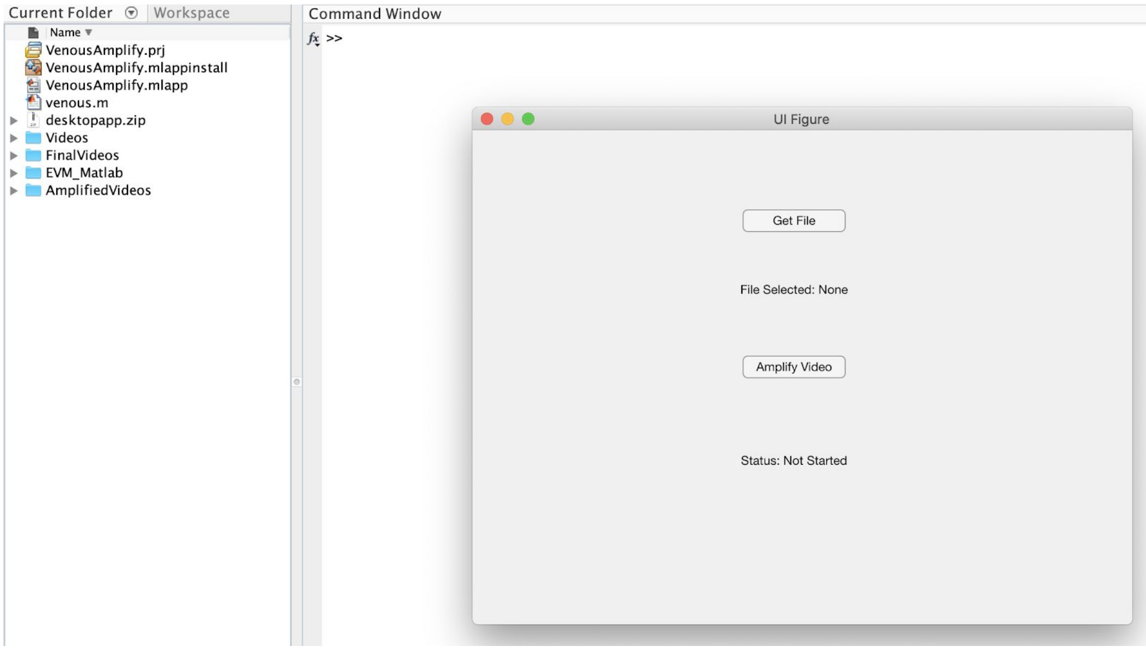
1. Download **all the files** for the desktop app in the **Desktop App** folder from https://github.com/tammi-p/JVP and put the files under a folder that will be specifically used for amplifying videos



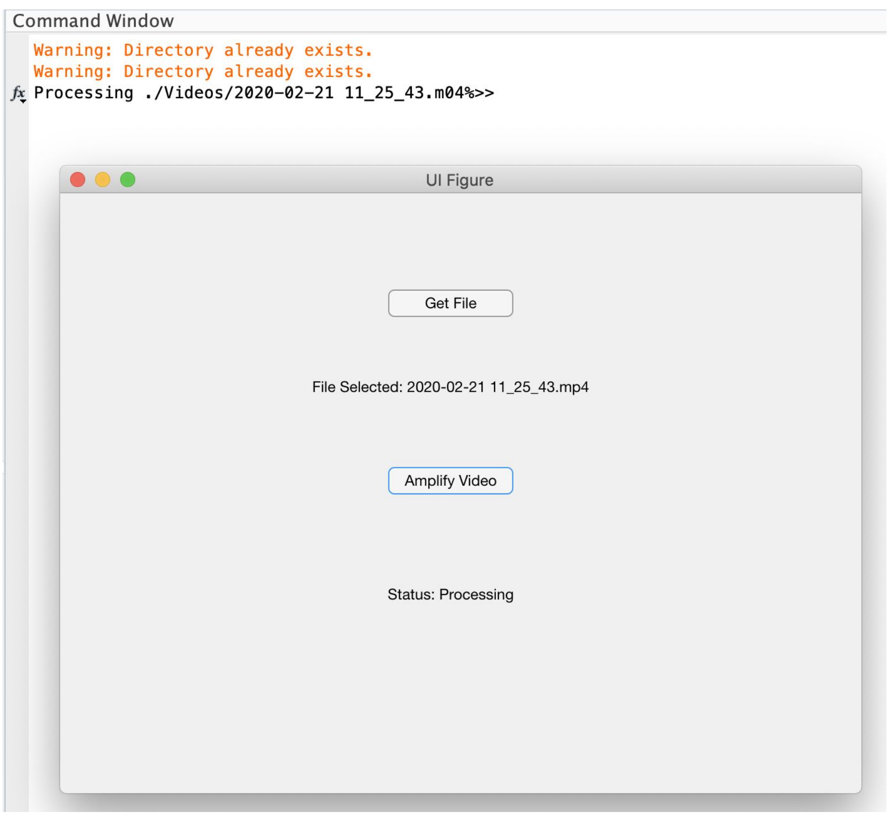
2. Click on **VenousAmplify.mlapp** to open the desktop app



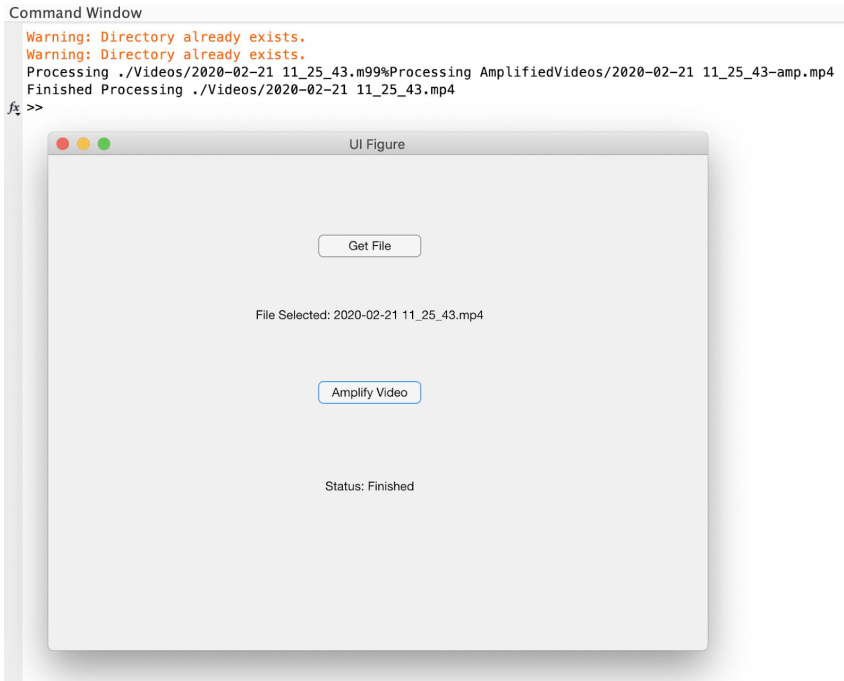
3. After a few seconds Matlab and UI Figure will pop up



4. Click on **Get File** in UI Figure and select the video you want to amplify
5. After selecting the video, click **Amplify Video**
6. The status will change to **Processing** (The Command Window will show the processing percentage)



7. Wait until the status changes to **Finished**



8. The amplified video with the reference distances will be outputted into the **FinalVideos** folder
9. In the **AmplifiedVideos** folder, there will be the same amplified video, but without the reference distances

Misc. Info:

- The iOS app does not need to be used if you want to record a video manually
- Recommended settings for recording manually
    - 1080p 30 fps Processing time for the desktop app will be around 8 min
    - 1080p 60 fps Processing time for the desktop app will be around 15 min
    - 720p 30 or 60 fps This will still work, but the quality will decrease compared to the above
    - Can record vertically or horizontally, but vertical is recommended