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Group planning report for iBSc/MEng Group Project

Heart Rate Variability (HRV) and its Applications

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Feedback box for project markers:

WHAT I liked about the report:
WHAT could/should be improved:

1. Introduction

From identifying effects of daily lifestyle choices to monitoring specific vitals facilitating the management of life-threatening conditions in an ICU, HRV is a relatively new method of determining wellbeing in a patient [1]. It makes an excellent application to improving general health, by tracking the state of important physiological systems and providing their quantitative indications. This project aims to investigate the importance of HRV and its applications, by researching:

1) Physiological systems, how these are measured in real-life cardiorespiratory monitoring and their relation to HRV
2) Importance, morphology and HRV implications in electrocardiogram (ECG) measurements
3) Signal processing and analysis of HRV samples, obtained by extracting ECG waveforms
4) Potential improvements to cardiorespiratory monitoring in the ICU today

All findings made throughout the project are being recorded on a wiki page (Figure 1).

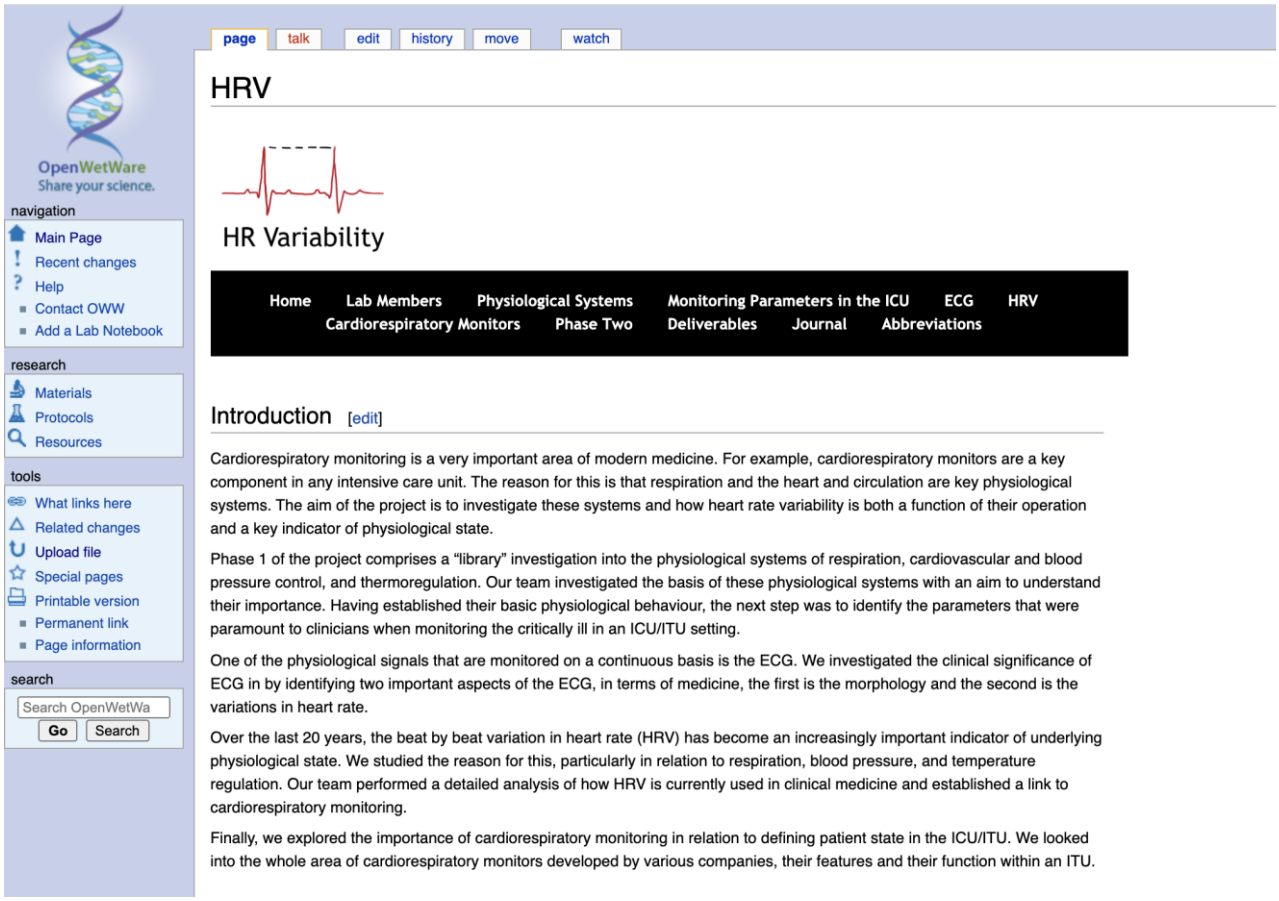


Figure 1: Landing page of the HRV wiki (https://openwetware.org/wiki/HRV).

2. Background

The ECG (Figure 2), a recording of the electrical activity in the heart [2], is used in the ICU to assess the patient's cardiovascular health [3]. Many cardiorespiratory monitors (Figure 3) can record ECGs, with 12 leads being the standard used in hospitals. Abnormalities in ECGs (Figure 4) are caused by various clinical conditions of the cardiorespiratory system. Appendix D explains more about different ECG morphologies and monitoring technologies.

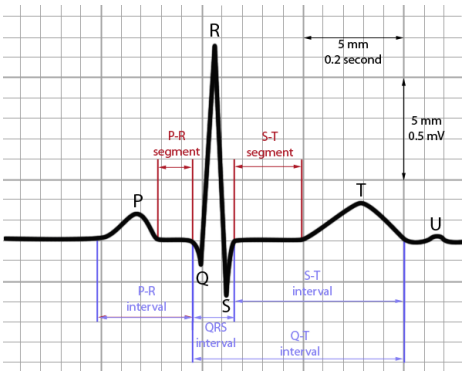
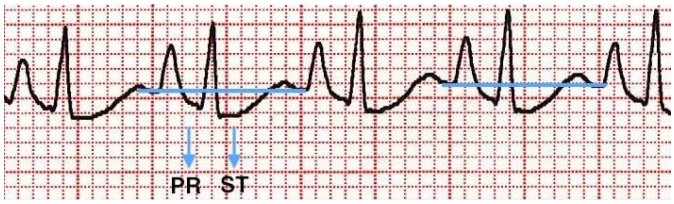


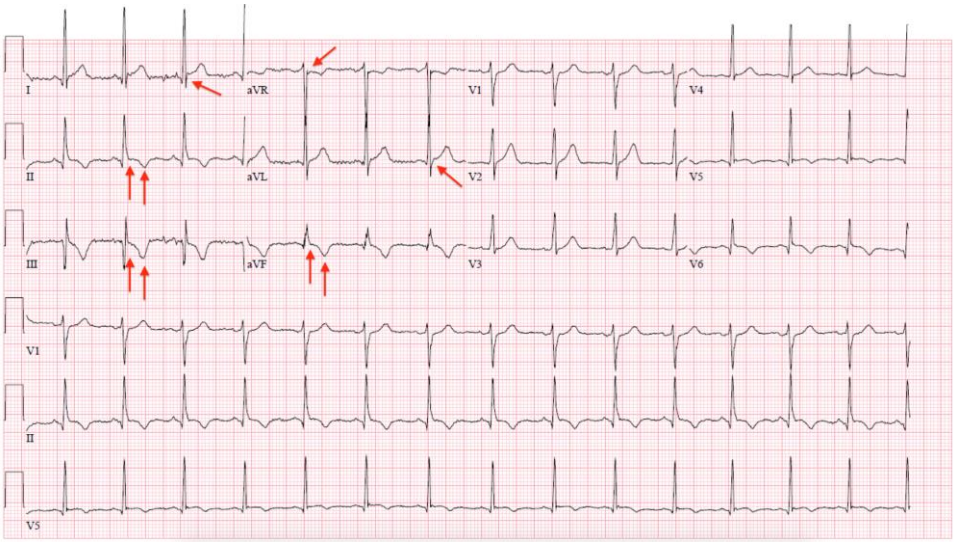
Figure 2: A typical ECG [4]

Figure 3: ECG device (Philips PageWriter TC70) [5]

(a) Multifocal Atrial Tachycardia can be identified with a fast HR and a minimum of 3 different P waveforms [6]



(b) ECG of an emphysema patient with sagging PR and ST intervals [7]



(c) ECG of a Covid-19 patient which shows ST elevation, ST depression, J-Point elevation and T-wave inversion [8]

Figure 4: Abnormalities in ECG recordings for cardiorespiratory conditions

HRV is the variation in time between consecutive R waves [9] and this variation is due to control of the heart by the autonomic nervous system (ANS) [10]. HRV is derived from the RR intervals of ECG signals [11], (Figure 5).

Figure 5: PQRST complexes from an ECG graph. The time between R waves varies from beat to beat, this variation is defined as HRV [12].

Understanding HRV is therefore helpful in comprehending imbalances within the ANS, as well as illnesses within the cardiorespiratory system, which often require admission to the ICU. The relationship between HRV and the ANS is illustrated in Figure 6. An in-depth analysis of HRV, how its measured and analysed, as well as its use to the clinician can be found in Appendix B.

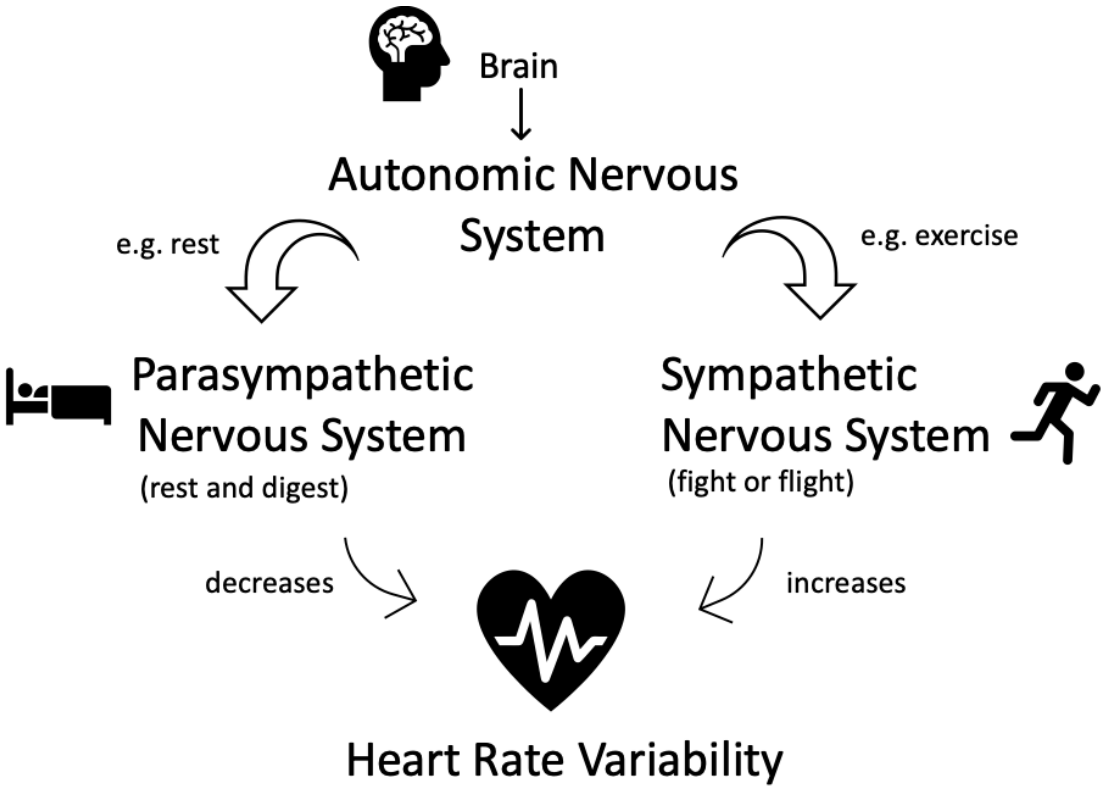


Figure 6: The relationship between HRV and the ANS

HRV can be used to track the progress of many illnesses that usually require treatment in the ICU, such as Acute Respiratory Distress Syndrome (ARDS) and sepsis [13]. HRV is an excellent application to predicting and managing such conditions that exhibit high morbidity and mortality rates [14], [15]. The overview of the disease, current modes of cardiorespiratory monitoring, key parameters tracked and the clinical significance of HRV in these contexts are further discussed in Appendices A and E respectively.

3. Preliminary findings

There are various methods for obtaining HRV from ECG data, these include analysis in time and frequency domains and also Poincare plots, however the time domain is most commonly used [12].

Applying signal processing techniques in the analysis of HRV is valuable, though not novel. Techniques such as autoregressive modelling and power spectral density date back to the 1980s [16] meaning there is a variety of well-established data available to build upon for this project. These are relevant as they make HRV analysis readily available and visualisable to the clinician, thus aiding decision making. A result from one of these techniques, a type of spectral analysis, is illustrated in figure 2 [17] which shows how this technique allows easy visualisation of changes in HRV by changing the amplitude and waves from an ECG to an instantaneous estimate of the time-varying energy.

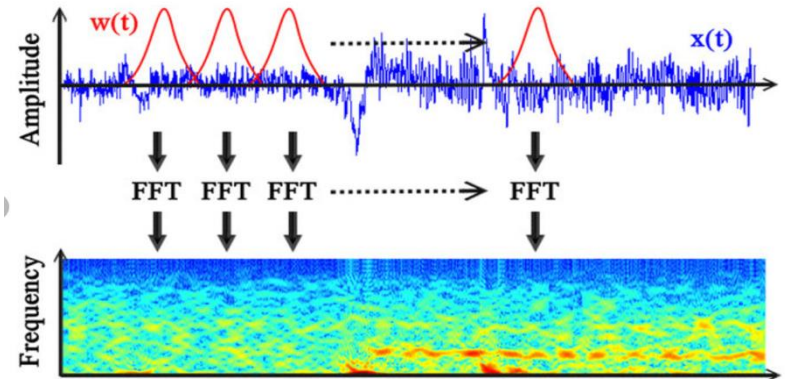


Figure 7: Example of a spectral analysis of HRV [17]

A study in Taiwan investigated how HRV can be used to predict septic shock in the hospital. It was found that specifically the root mean square successive difference measure of HRV was the best indicator to predict whether septic shock would occur [18]. When starting Phase 2, it is important to consider this method of HRV interpretation, but also to investigate whether other medical conditions may rely on different measures of HRV.

4. Task allocation

Name	Tasks Responsible For
Eva Tadros	Acting "team leader". Also responsible for aesthetics of presentations. Research into: • Heart Rate Variability – basics and physiology • Autonomic Nervous System • Medical devices by W.L.Gore and Lepu Medical Technology • Sepsis and its cardiorespiratory monitoring
Tarane Subramaniam	Taking minutes during team meetings with project supervisors. Research into: • Respiratory/Hemodynamic monitoring in the ICU • Specific clinical conditions: ARDS and COPD • Medical devices produced by Edwards Lifesciences and Terumo
Rebecca Vickery	Creating and monitoring the wiki. Research into: • ECG basics. • Medical devices by Getinge and Omron. • Target users of medical devices and interface. • Problems faced by healthcare providers in terms of cardiorespiratory monitors.
Calista Yapeter	Updating the wiki journal weekly. Research into: • Basics of cardiorespiratory monitoring • Medical devices by Abbott, GE Healthcare, Medtronic and Draeger • Remote monitors • Comparison between different types of monitors • Relationship of parameters with Covid-19 and COPD
Choi Wan Yip	Communications between the team and supervisors, outside of meetings. Research into: • Physiological systems • Medical devices by Hill-Rom and Philips Healthcare • Monitors from a clinician's and manufacturer's points of view • Cardiorespiratory monitoring in sepsis management

Table 1. Task allocation of each group member.

5. Implementation plan and Gantt chart:

Phase One

Understand how the physiological systems work, the relationship of ECG and HRV to cardiorespiratory conditions and monitoring techniques in the ICU by:

- Doing literature research
- Organising findings purposefully
- Summarising the key objectives of cardiorespiratory monitoring using ECGs and HRV
- Documentation through the Wiki Page and reports

Phase Two

Interpret ECG and HRV in clinically meaningful ways by:

- Collecting ECG waveforms
- Signal processing and analysis
- Software or app development

Figure 8 shows the tasks accomplished in Phase One and what is planned for Phase Two.

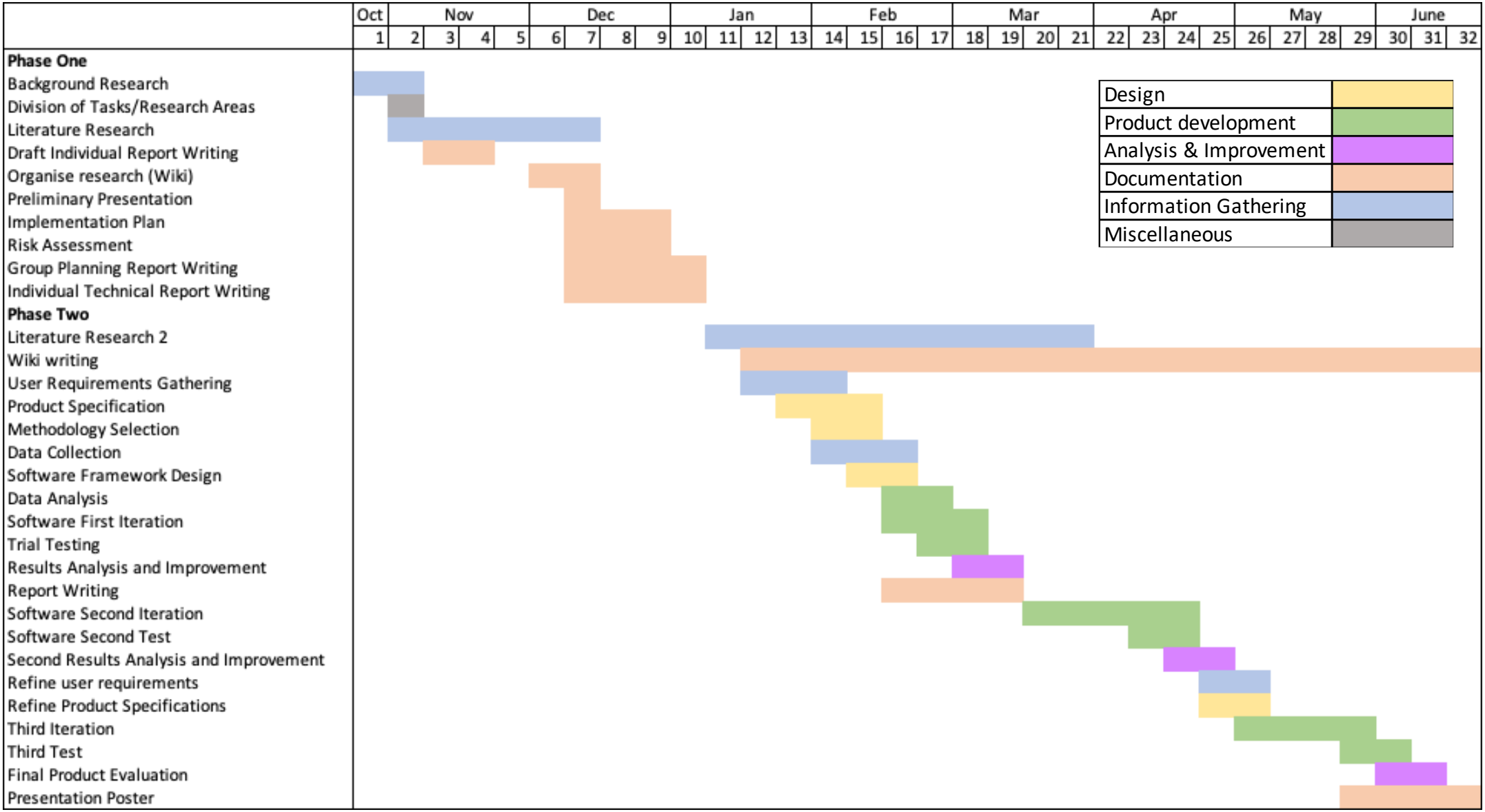


Figure 8: Gantt Chart of Project Timeline

6. Risk Assessment

No.	Potential Risks in Planning	Contingency Plan
1.	Losing important information/progress on deliverables due to computer malfunction	Save and backup files regularly in multiple locations
2.	Inability to meet members in person and use computer labs due to Tier 4 restrictions being extended	Work on remote desktop since project is software-based and schedule weekly Teams meetings
3.	Insufficient coding knowledge	Learn from online courses and divide workload based on ability/skills
4.	Implementation error in signal processing algorithm	Perform comprehensive research on signal processing methods before implementation
5.	Improper return codes from complex functions and logical errors on Python	Use online resources or Python help command to prevent coding mistakes
6.	Source files of ECG signals may be corrupt or undetectable by programming platform	Do a thorough search on the Internet and extract files from legitimate sources

Table 2. Risk Assessment

7. Conclusion

The team has conducted an in-depth investigation on the cardiorespiratory system, its associated clinical conditions and monitoring techniques in the ICU, with an emphasis on ECG monitoring. As such, problems in monitoring, such as the lack of continuity, have been identified. Applications of HRV focused particularly on common illnesses in the ICU with high morbidity and mortality rates such as sepsis and ARDS and briefly about COVID-19.

Various algorithms have been developed for ECG and HRV analysis. This will be consolidated with knowledge of coding and combined to produce a sophisticated signal processing method that will interpret ECGs and extract HRV in relation to the specific conditions mentioned, making it effective for clinician decision-making.

8. References (400 words)

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