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PREDICTORS OF PATIENT DETERIORATION OUTSIDE CRITICAL CARE UNITS AND OUTCOMES OF RAPID RESPONSE TEAM IMPLEMENTATION IN A TERTIARY CENTER IN A DEVELOPING THIRD WORLD COUNTRY

by
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AMERICAN UNIVERSITY OF BEIRUT

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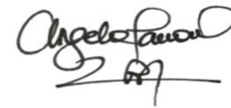

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ABSTRACT
OF THE PROJECT OF

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Title: Predictors of Patient Deterioration Outside Critical Care Units and Outcomes of Rapid Response Team Implementation in a Tertiary Center in a Developing Third World Country

Rapid Response Teams (RRTs) are in constant development and implemented across different hospitals with varying practices. RRTs have been implemented by many hospitals to provide urgent critical care expertise when activated. It is important to accurately identify patients with increased risk of mortality during their hospital stay, as this could lead to better prioritization for admission to critical care units and timely reexaminations of their care objectives. There is a gap in knowledge regarding the understanding of predictors that contribute to in-hospital mortality, cardiac arrests, and transfers to critical care units among patients who require rapid response team activations.

The primary aim of this quality improvement project is to identify standardized and well-defined predictors for patient deterioration (defined as a composite outcome of subsequent cardiac arrest, Intensive Care Unit [ICU] admission, or unexpected death within 24 hours of the activation of an RRT) as well as mortality before discharge in the index admission in adult Medical Surgical units. The secondary aim is to calculate quality indicators for RRT that will be used as a point reference for evaluating RRT efficiency at a tertiary medical center in Lebanon.

This quality improvement project was a retrospective chart review that included all RRT activations between January 2021 to June 2021. Cases were included if the patient was an adult (18 years and above) admitted to an inpatient Medical Surgical unit and an RRT activation was triggered. A list of possible predictors for deterioration in patients who had an RRT activation were collected and compared statistically with the patients' outcome after RRT activation, for the first aim. A list of literature generated quality indicators was used to report RRT quality indicators for the second aim. Using statistical tests, a bivariate analysis for subsequent cardiac arrest, ICU admission, or unexpected death were done using contingency tables, independent t test, or analysis of variance test, appropriately. Transfer to critical care and mortality before discharge, the primary outcomes, were used as the outcome variables to create two logistic regression models using significant variables from the bivariate analyses.

During January 2021 to June 2021, RRT was activated 204 times; 5 of these events were changed to code activation or cancelled RRT activations. A review of 199 cases revealed 56 (37.6%) patients were transferred to critical care units and 47 (31.5%) patients had mortality before discharge. Of the 199 activations, 3 (2%), patients had subsequent cardiac arrests and 2 (1.3%) patients had mortality within 24 hours of RRT activation.

After adjusting for covariates, as lactic acid increased the likelihood of critical care transfers increased (adjusted odds ratio 1.824; 95% confidence interval 1.195 – 2.786; p = .005), as Charlson comorbidity index increased the likelihood of mortality before discharge increased (adjusted interval odds ratio .838; 95% confidence interval .720 - .976; p = .023). The dummy variable cardiac in the reason for RRT activation was significant in comparison to sepsis (reference group) (adjusted odds ratio 3.443; 95% confidence interval 1.403 – 8.448; p = .007). Those with a cardiac reason for RRT activation were 3.443 times less likely to have mortality before discharge than those with a sepsis reason for RRT activation. In-hospital patients with RRT activations had readmissions at 30-days (44 [29.5%]), 60-days (29 [19.5%]), and 90-days (18 [12.1%]).

RRT activation among non-ICU patients identifies a population at high risk of transfers to critical care units and mortality at discharge. We identified several predictors for patient deterioration and outcomes of RRTs, which provide opportunities for future quality improvement and patient safety opportunities.

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ABBREVIATIONS

AUBMC – American University of Beirut Medical Center

CCI – Charlson Comorbidity Index

CCOT – Critical Care Outreach Team

CPR – Cardiopulmonary Resuscitation

DNR – Do Not Resuscitate

DNI – Do Not Intubate

EPIC – Health Information System

EWS – Early Warning Score

ICU – Intensive Care Unit

IRB – Institutional Review Board

LOS – Length of Stay

MAP – Mean Arterial Pressure

MENA – Middle East and North Africa

MEWS – Modified Early Warning Score

MEWS BPA – Modified Early Warning Score Best Practice Alert

NEWS – National Early Warning Score

RR – Respiratory Rate

RRS – Rapid Response System

RRT – Rapid Response Teams

SBP – Systolic Blood Pressure

CHAPTER I

INTRODUCTION

The concept of Rapid Response Teams (RRTs) was first introduced in the 1990's and its implementation has drastically expanded with almost universal adoption throughout the United States and other countries worldwide (Shappell et al., 2018). RRTs have been implemented by many hospitals to provide urgent critical care expertise when timely activated. These teams frequently include multidisciplinary experts such as critical care nurses, respiratory therapists, and critical care physicians. The goal for this team is to critically intervene when hospitalized patients exhibit abnormal vital signs and biochemical abnormalities in an effort to stop further deterioration. Hypotension, respiratory distress, arrhythmias, changing levels of consciousness, and clinical ward staff concerns about impending deterioration are common causes for RRT activations (Tran et al., 2020).

A. Background

More than 400,000 hospital avoidable deaths are thought to occur each year in the United States. Many take place on inpatient units and are preceded by obvious, notable vital sign abnormalities that may go unnoticed or unrecognized (Vandegrift et al., 2021). These high morbidity and mortality rates were linked to a delay between the deterioration of vital signs and early intervention provision. Rapid Response Systems (RRSs) have been proposed and are frequently used by hospitals in an attempt to improve such patient outcomes (Ko et al., 2020). They were created in response to findings that many deteriorating hospital patients suffered from "failure to rescue"

which further developed into major adverse events such as mortality, cardiac arrest, and spontaneous Intensive Care Unit (ICU) admissions (Al-Moteri et al., 2018; Bellomo, 2018).

RRSs are made up of RRTs which vary in composition but always includes a critical care registered nurse (Teuma Custo & Trapani, 2020). The team mobilizes around the hospital in response to high-risk patients outside of the ICUs. They use a combination of variables to predict the risk of patients deteriorating (Danesh et al., 2019). Therefore, RRSs, are a critical component of patient care in hospitals, have different approaches, and are continuously being developed (Vandegrift et al., 2021).

The RRS provides healthcare workers with essential data that could potentially affect patient care. RRT will be activated according to the Modified Early Warning Score (MEWS), regardless of patient diagnosis and comorbidities (Al-Omari et al., 2019). Though differences in methodological quality, staff composition, and operational protocols have previously made the effects of RRS debatable, significant evidence in recent years has emerged to support the need for an RRT system (Ko et al., 2022). The few studies that are available on the topic of RRS shed little light on the efficacy of quick response teams' system in tertiary hospitals of the region. This has led to even fewer studies that identify the particular elements that may reduce its effectiveness. Thus, more research over time is needed on the topic of RRS outcomes (Al-Omari et al., 2019). To note, the study by Al-Omari et al. (2019) reported decrease in both cardiac arrests and hospital mortality after introduction of RRS from 10.53 to 2.58 and 7.89 to 2.8 respectively per 1000 hospital admission on one hand, and a decrease in total ICU admissions on the other. Despite the scarceness of studies on this issue in the Middle East and North Africa (MENA) region, internationally that is not the case. Several

studies established positive patient outcomes like decreases in mortality and cardiac arrests rates after implementing RRT, one of which is that by Hall et al. (2020). In this study, he examined several patient outcomes namely overall hospital mortality, cardiac arrest rates, and ICU transfer rate, and it was found that though there was a decrease in cardiac arrest rates, the overall hospital mortality and ICU transfer rate outcomes were heterogeneous (Hall et al., 2020; Teuma Custo &Trapani, 2020). In addition, a study by Ko et al. (2022) reported that the overall cardiac arrests per 1000 admissions decreased by 34% after implementing an RRS. Further studies by Teuma Custo & Trapani (2020), reported significant findings to support implementation of an RRS due to its impact in decreasing cardiac arrests and eventually mortality, thus, the optimal composition of an RRT is not specific and could be decided according to preference, resources, and goals of an institution (Lee & Hong, 2019).

B. Significance and Aims

The RRS structure varies within institutions and may include an afferent arm, efferent arm, quality assurance, and administrative arms. The afferent arm recognizes individuals who are at risk for clinical deterioration and, if necessary, activates the efferent arm. A medical emergency team from the efferent arm examines the patients and participates in their care. The administrative arm makes sure that system policies and procedures are consistently updated while the quality assurance component examines program compliance and results (Vandegrift et al., 2021). To further explain the quality assurance limb, this role gathers and reports data to provide feedback to improve the system for future events (Lee & Hong, 2019; Olsen et al., 2019). The administrative limb is particularly essential in determining resource requirements and

outcomes, event rates, reason for each call, indicators like number of calls, unit where call was initiated, time of every call, number of calls altered to cardiopulmonary resuscitation (CPR), and number of transfers to ICU which aid in continuously improving the RRS (Lee & Hong, 2019). This is vital, as it is difficult to specify precisely the characteristics that improve the RRS since no two patients are the same, and diseases and treatments are continuously changing. Nonetheless, for most at-risk patients, hypoxia and/or hypoperfusion remain the primary pathophysiologic concern that requires immediate identification and correction to prevent deterioration (Vandegrift et al., 2021). Several studies have published positive results of RRSs however their quality and heterogeneity of effectiveness have been questioned because of improper afferent limb use and poorly understood escalation routes that may fail to identify deterioration or create unneeded burdens on the efferent limb (Teuma Custo, & Trapani, 2020). The success of the RRS depends on all the arms working effectively, however which processes or interventions within this structure, most significantly increase RRS effectiveness is still unknown (Ahn et al., 2020).

Therefore, the primary aim of this quality improvement project is to identify standardized and well-defined predictors for patient deterioration (defined as a composite outcome of subsequent cardiac arrest, ICU admission, or unexpected death within 24 hours of the activation of an RRT) as well as mortality before discharge in the index admission in adult Medical Surgical units. Patient death is considered unexpected unless it occurred after initiation of end-of-life care or a Do Not Resuscitate order. The secondary aim is to calculate quality indicators for RRT that will be used as a point reference for evaluating RRT efficiency at the American University of Beirut Medical Center (AUBMC).

CHAPTER II

REVIEW OF LITERATURE

Since their inception in the early 1990s, RRSs have and still are being developed to ensure better detection and prevention of sudden in-hospital cardiopulmonary arrests. To that end, this review will explore the literature regarding the triggers and risk factors of RRSs. Additionally, it aims to inspect the challenges facing RRSs in terms of their effective implementation and their risk stratification. Moreover, it will examine the efficacy and limitations of RRS in reducing ICU admissions, mortality, and cardiac arrests.

A. Triggers and Risk Factors for Rapid Response Systems in in-Hospital Patients

The distinctive characteristics of patients and the unpredictable nature of illnesses and treatments make it difficult to pinpoint the variables that affect complex adaptive systems like the RRS (Vandergrift et al., 2021). Nevertheless, observational studies have shown that initiation of RRSs can lead to positive outcomes, including lower hospital cardiac arrest and mortality rates (Okawa et al., 2021).

Observational studies have identified several risk factors that may trigger the activation of RRSs and the ensuing deployment of RRTs. One study reported hypoxia and/or hypoperfusion as the most common pathophysiological concerns which call for prompt action for the majority of high-risk patients (Vandergrift et al., 2021). Others reported tachypnea, decreased level of consciousness, and hypotension as the three most typical RRT triggers (Okawa et al., 2021) and arrhythmias, respiratory distress, and altered mental status in a third study (Tran et al., 2020). It is worth noting that not all triggers may be quickly noted and thus detected early. For instance, tachypnea; if not

very noticeable, is difficult to detect unless the respiratory rate (RR) is continuously being monitored in general wards (Okawa et al., 2021). Respiratory acidosis may cause death due to sudden changes associated with an increase in RR and minute ventilation, and it is often seen in congestive heart failure, sepsis, and pulmonary embolism (Okawa et al., 2021). Despite almost normal oxygen saturation levels which is due to compensatory changes brought upon by the increase in minute ventilation, the patient is effectively in a pseudo-stable condition and at risk for further acute deterioration. Thus, early recognition of these changes in RR is imperative for the prevention of deterioration. Studies have identified a RR greater than or equal to 25 to be more frequent in patients who passed away while being hospitalized, and that their RRT activation triggers were considerably different than those of patients who survived (Okawa et al., 2021; Shappell et al., 2018). According to Shappell et al. (2018), respiratory triggers, tachypnea (21%) or hypoxia (37%), were the most common reasons among patients who died in the index admission, while hypotension (24%) was the second most common predictor of mortality. According to other researchers, arrhythmia, heart failure, and myocardial infarctions were the most common causes of cardiac arrest, whereas those with respiratory conditions were the second most frequent causes. In addition, other risk factors that may trigger RRT activations in some patients include respiratory insufficiency, metabolic disturbances, and circulatory failure as a result of prior infections (Andersen et al., 2019).

Ward staff concerns due to one or multiple vital sign abnormalities are the most common reasons for RRS activations (Vandegrift et al., 2021). Also, those with multiple RRT triggers and vital sign abnormalities were at a higher risk of mortality than those with just one trigger (Shappell et al., 2018). Hence, this evinces that in-

hospital patients in different institutions who had numerous triggers are more likely to die within the index admission. While the reason for RRT activation remains primarily a respiratory or cardiovascular problem.

Poor outcomes following cardiac arrest are linked to a number of additional risk factors, including advanced age (older than 70 years) (Andersen et al., 2019). Additionally, mortality rates were greater in in-hospital male patients with pre-existing medical and surgical conditions, such as poor functional status, pneumonia, malignancy, sepsis, hypotension, renal dysfunction, and hepatic dysfunction (Shappell et al., 2018; Andersen et al., 2019). Therefore, age, gender, and pre-existing medical conditions remain unmodifiable risk factors that influence the clinical outcomes of in-hospital cardiac arrest (Andersen et al.,2019). However, what can be changed is the drug administration time and monitoring (Andersen et al., 2019) which are modifiable risk factors that can garner the attention of quality improvement efforts to help decrease ICU admissions, the risk of cardiac arrests and mortality.

B. Challenges and Strategies for Effective Implementation of Rapid Response Systems

The design of efficient acute care systems calls for early population identification by the afferent arm, which sets off prompt intervention delivery through the efferent arm. Based on system data regarding compliance and effectiveness, the administrative arm as well as the quality assurance arm must provide the required resources for these systems to operate effectively and continuously improve (Vandegrift et al., 2021). Studies have shown that even when the requirements for activation are met, noncompliance rates can exceed 75%, and the median wait time for activation can

be as long as 16 hours, when institutional protocols for activation are ineffective or not adopted with input from front-line employees (Tran et al., 2020). Although anybody can contact the RRT, nurses are more likely to do so because they are primarily responsible for identifying and interpreting physiological abnormalities. Nurses are in close touch with patients and are in-charge of making judgments on how frequently to assess patients' physiological conditions (Okawa et al, 2021).

Differences between medical and surgical patients in terms of cardiac arrests, ICU hospitalizations, and in-hospital mortality can be due to primary distinctions in illness pathophysiology, as well as attitude differences between nurses and doctors (Tran et al., 2020). For instance, some nurses despite being aware of the patients' poor condition believed that the clinical situation was under control in the medical/surgical setting and therefore delayed RRT activations. Additional elements of effective RRSs implementation included continual staff training to assure system compliance and performance audits to encourage continued improvement (Vandegrift et al., 2021). Moreover, fear of receiving hostile or negative response from coworkers for activating RRS has been identified as a challenge to the effective implementation of RRSs (Okawa et al, 2021). The failure to activate the RRS stems from the lack of clarity in justifying its activation. This ambiguity in the justification has been shown to be influenced by nurses' perceptions of the trigger criteria. When nurses perceive the patient condition or call criteria as either highly sensitive or not specific enough, it leads to the development of alarm fatigue. In other words, considering the patient condition and trigger criteria as excessively sensitive or vague contributes to the problem of alarm fatigue. Nonetheless, the ability to rapidly detect individuals at a high risk of cardiac arrest and to quickly

activate RRS without hesitation is crucial for the RRS to function effectively (Okawa et al, 2021).

Staff reluctance to submit an RRS request is a significant contributor to its delayed activation (Okawa et al., 2021). Therefore, for RRSs to work properly, it is vital to define the RRT call criteria using verified clinical symptoms. Interventions that are made specifically for each institution's needs have been demonstrated to be more successful at fostering a culture of safety and enhancing patient outcomes (Tran et al., 2020). The shared care pathway that was developed linked bedside assessment for early identification of at-risk patients, pathophysiologic classification of their decline, and protocolized interventions as crucial system components accountable for better patient outcomes (Vandegrift et al., 2021). In patients who need RRT intervention, prompt RRS activation is necessary (Okawa et al, 2021).

A large portion of RRT research has concentrated on the afferent function of RRTs, with many studies looking at clinical deterioration and predictors of cardiac arrest in patients on general wards as criteria for RRT activation. However, there is a lack of information to direct the efferent activities of RRTs, such as directing patients to ICUs or starting timely discussions about goals of care (Shappell et al., 2018). Qualitative data from Teuma Custo and Trapani (2020) suggest that the success of the RRS was hindered by inadequate structural factors such as heavy workload and attitudinal factors such as willingness to change practices. The evidence regarding the effectiveness of the RRS in reducing mortality and cardiac arrests may be considered weak. Most studies mentioned in Teuma Custo and Trapani's (2020) literature review were classified as Level 2 evidence, consisting of well-conducted case control or cohort studies with a low risk of confounding, bias, or chance, and a moderate likelihood of

causal relationship. Fewer studies were classified as 2-, case-control or cohort studies with a high risk of confounding bias or chance, and a significant risk of a non-causal relationship (Teuma Custo & Trapani, 2020). However, in the same paper authors also mentioned that as each year passes, increase in RRT activations was associated with a reduction in cardiac arrests. This supports the notion that improved recognition of deterioration, and response to deterioration, is desirable (Teuma Custo & Trapani, 2020). On the other hand, healthcare professionals may become less adept at managing deterioration as a result of transitioning the care of deteriorating patients to the efferent limb. Due to additional staff, equipment, education, and training needs RRSs also result in higher expenses. Consequently, it is doubtful whether RRSs will be widely used in all institutions (Teuma Custo & Trapani, 2020).

C. Challenges in Risk Stratification for Rapid Response Systems

Although any hospital staff can activate RRSs, nurses who represent the afferent arm are more likely to do so because they are primarily responsible for identifying and interpreting physiological abnormalities. Nurses are in direct contact with patients and are in charge of making judgments on how frequently to assess patients' physiological conditions (Okawa et al, 2021). Thus, the level of intervention, urgency of treatment, and distribution of medical resources can all be determined if an RRT activation can accurately stratify the severity or prognosis of the patient upon activation (Ahn et al., 2020). RRTs are activated differently in hospitals, where the majority of research revealed various institutional processes for triggering RRTs. RRT triggers are relied on Early Warning Scores (EWS), National Early Warning Scores (NEWS), or Modified

Early Warning Signs (MEWS) to find patients at risk of clinical deterioration (Shappell et al., 2018; Ahn et al., 2020).

EWS, which might raise concern and indicate the need for additional patient evaluation or intervention, are one method for improving the early diagnosis and treatment of deteriorating patients (Okawa et al, 2021; Vandegrift et al., 2021). However, according to Ahn et al., 2020, overt clinical deterioration frequently occurs several hours before aberrant changes in physiologic measures, such as vital signs or mental status. Therefore, the problem with using EWS is that it does not offer quick answers as to what might be wrong with the patient or how to fix it. The patient must be reexamined in order to determine the pathophysiology in charge of its activation before therapies may start (Vandegrift et al., 2021). Although some studies have produced conflicting findings, several have proven great effectiveness in reducing failure to rescue (Vandegrift et al., 2021). Some problems that have been encountered with triggering the RRS is that in clinical practice, not all patients identified as high-risk by EWS receive higher levels of intervention by RRTs. This can occur due to limitations in the discriminatory power of EWS, resulting in low-risk patients being falsely classified as high-risk or high-risk patients not receiving adequate intervention due to resource constraints (Ahn et al., 2020).

As for NEWS, it may not be able to distinguish enough between high-risk RRT patients and low-risk RRT patients due to the likelihood that the degree of sickness will vary greatly across all floor patients and those requiring RRT (Shappell et al., 2018). Therefore, the performance of the NEWS in forecasting in-hospital mortality among patients who receive RRT calls has significant implications, as the results indicate that NEWS performs poorly in such cases. The reason for this may be that patients who

receive RRT calls have already experienced clinical deterioration, necessitating the development of new techniques for reliable outcome forecasting (Shappell et al., 2018). Additionally, as mentioned by Ahn et al. (2020) both the MEWS and NEWS have demonstrated insufficient predictive abilities for 28-day mortality in patients who activate the RRS, suggesting that they may not be suitable for categorizing the severity and prognosis of general ward patients who activate RRT. These findings justify the need for a new and effective scoring system that the RRS can use to determine optimal patient care and resource allocation. Implementing risk stratification at the time of the RRT call could increase the efficiency of RRS, improve resource allocation, facilitate discussions about care objectives, and enable prompt transfer to a higher level of care for patients at high risk. As a result, RRS may become more successful all around (Shappell et al., 2018). However, due to disparities in system design and the variability of illness severity among hospitalized patients, comparing RRT performance across institutions can be challenging (Shappell et al., 2018).

D. Examining the Efficacy and Limitations of Rapid Response Systems in Reducing ICU Admissions, Mortality and Cardiac Arrests

In numerous studies, the use of RRSs have been used to reduce ICU admission, cardiac arrests, and mortality (Ahn et al., 2020; Okawa et al., 2021). Initial support for the use of RRSs came from several randomized control trials which showed significant reductions in mortality and/or cardiac arrests (Teuma Custo & Trapani, 2020). However, those that used randomization control trials of RRS implementation did not specify how the randomization process was generated casting doubts on the effectiveness and fidelity of the randomization process (Teuma Custo & Trapani, 2020).

Additionally, Andersen et al. (2019) reported that there are few rigorous RCTs due to the disparities between hospital systems even though RRSs are usually reinforced by literature. These reported findings give conflicting evidence regarding the efficiency of RRSs, indicating a need for further research.

RRSs may cause unexpected effects such as improper use of the afferent limb as well as poorly understood escalation pathways. These effects could lead to a failure to recognize deterioration or an increase in unnecessary workload (Teuma Custo & Trapani, 2020). However, recent studies revealed findings that benefit RRSs by reducing failure to rescue incidents, but they were constrained by the poor quality of the study's design and its inconsistencies in results (Vandergrift et al., 2021). It was also mentioned by Teuma Custo & Trapani (2020) that some RCTs did not show a significant reduction in outcomes such as unexpected deaths, non-ICU cardiac arrests, and unplanned ICU admissions. Further risk of outcome reporting bias exists, as the researchers claimed significant results without reporting actual p-values. However, findings from all studies should be interpreted with caution, as it is possible that hospitals already had an efficient system to recognize and respond to deterioration (Teuma Custo & Trapani, 2020). Studies that were historically controlled increase bias as findings may reflect overall improvements of unit-based care independent of RRS implementation (Teuma Custo & Trapani, 2020).

In conclusion, the wide use of RRSs make it difficult to assess their effectiveness. Investigating the conditions under which an intervention might be effective rather than focusing on whether it is always effective may be more suitable. If the actual process cannot be generalized and is not deemed successful, outcomes may

not be conclusively examined when evaluating the effectiveness of complex system interventions like RRSs.

CHAPTER III

METHODS

A. Settings

This quality improvement project took place at the American University of Beirut Medical Center (AUBMC) in Beirut, Lebanon. AUBMC is a private, non-profit, academic institution that has been gradually growing since 1902. It is the largest hospital in Lebanon, also referred to as a tertiary medical center due to its acceptance of all patient populations and its five specialized centers of excellence: including Abu-Haidar Neuroscience Institute; the Children's Cancer Center (pediatric), Naef K. Basile Cancer Institute (adults), Multiple Sclerosis Center, and Mufid Farra Heart and Vascular Institute. AUBMC delivers healthcare to those in Lebanon and those in the MENA region and has a capacity of more than 400 inpatient beds with over 360,000 patient visits annually.

AUBMC has an active RRT system in place across the hospital for inpatients, outpatients, and pediatric populations dating back to 2013. For the purpose of this quality improvement project, we included patients admitted to the inpatient setting, medical/surgical units. There are 11 inpatient units, which are: Medical Units (Psychiatry Inpatient Unit, COVID Inpatient Unit, 5-South, 9-South, and 9-North), Surgical Units (Delivery Suite, 10 North, and 10 South), Mixed Medical Surgical (Neurology Medical/Surgical), and Oncology Units (8-North Basile Inpatient, and Bone Marrow Transplant [BMT] unit).

B. Sample

Patients included in this quality improvement project were adults (18 years or older) admitted to inpatient medical surgical units, a code status of Full Code, and having had an RRT activation in the index admission.

There was a total of 502 RRT activations from January to December 2021. For the purpose of this quality improvement project a subset of these activations was audited from the beginning of January till the end of June, resulting in 204 RRT audited activations. Since this is a quality improvement project the approval of Institutional Review Board (IRB) was not needed. The data was gathered from reports generated by the hospital's health information system (EPIC).

C. Measurement

The Hospital's Health Information System (EPIC) was used to retrieve individual patient data. Data were organized in an excel spreadsheet. For the first aim, a list of possible predictors for deterioration in patients who had an RRT activation was collected. These predictors, retrieved from the literature when applicable and from clinical judgment otherwise, were used and compared statistically with the patients' outcome after RRT activation.

For the second aim, we referred to a list of literature generated quality indicators that was used to report RRT quality indicators in AUBMC between January 2021 and December 2021. Data for quality indicators was derived from the literature and included: rate of RRT activations per 1000 discharges, promptness of RRT reporting to bedside, transfers to ICU post RRT activation, survival to discharge post RRT activation and rate of cardiac arrest outside the ICU per 1000 discharges.

The data for predictors and outcomes was generated by EPIC. Data was system generated and validated by the study Co-PI; a second validation was done by the Cardiology Clinical Nurse Specialist.

1. *Description of Predictors and Outcomes*

Predictors of patient deterioration that were included in this data analysis were: Age, Gender, Admitting Diagnosis, Admitting Unit, Weighted Charlson Comorbidity Index, Length of Hospital Stay Prior to RRT Activation, Length of Stay in the Index Admission, Prior ICU Stay in the Index Admission, MEWS Score for RRT activation, Triggers for RRT Activation (High Mews, Asterix, or Subjective concern), Reason for RRT Activation (cardiac, respiratory, neuro, sepsis, or other), the Type of RRT (Medical/Surgical), Lactic Acid Level, Number of RRT Activations During the Same Admission, the Time RRT Started, the Time RRT Arrived, Activation to Arrival Time, RRT Duration in Minutes, if there was a delay in response of RRT (agreed upon arrival time is 5 minutes), Code Status Immediately After RRT, Code Status Before Discharge, and Expected or Unexpected Death.

Outcomes after RRT activation included: Immediate Outcome (Cardiac Arrest), Death Within 24 Hours of the Event, Mortality Before Discharge, and Transfer to Critical Care Units (within 24 hours). Secondary outcomes were also retrieved and included: 30-day readmission, 60-day readmission, and 90-day readmission.

a. Admission Diagnosis

Reasons for admission were grouped together based on pathophysiology as such: Septic Shock, Oncologic/Hematologic, Orthopedic, Respiratory Disorders, Nephrological Disorders, Gastric Disorders, Cardiac Disorders, Infectious, and Others.

b. Admitting Unit and Specialty of Unit

Patients admitted to the medical surgical units are either triaged through the emergency department or are direct admissions and are assigned to a unit by case managers. For the purpose of this analysis, we divided the units as such: Medical Units, Surgical Units, Mixed Medical Surgical, and Oncology Units

c. RRT Activation Triggers

The activation of RRT is triggered by three reasons, either a high MEWS score, an Asterix, or a subjective concern. A high MEWS is a MEWS score of 6 or more, Asterix are the marked vital signs parameters that score a 3, and subjective concern is a concern that the family or healthcare providers has regarding the patient, these can activate RRT (refer to figure 1). In addition to subjective concern activations, the decision to consider an "RRT activation trigger" as a subjective concern is conjoined with taking into consideration that the RRT activation did not appear on the MEWS Best Practice Alert [BPA]. The MEWS BPA is an EPIC generated report that includes concerning vital signs that has been inputted into the EPIC system. If the vital signs revealed a triggering value at the time of RRT activation then this would be shown on the MEWS BPA.

Parameters	0	1	2	3
Respiratory Rate [breaths/minute]	9 to 20	--	8 or below; 21 to 29	30 or above
SpO2 [%]	93 or above	90 to 92	85 to 89	**84 or below***
Temperature [Celsius]	36.1 to 38	35.5 to 36; 38.1 to 38.5	35.1 to 35.4; 38.6 to 39	35 or below; 39 or above
Heart Rate [beats/minute]	60 to 90	50 to 59; 91 to 100	40 to 49; 101 to 139	**140 or above*; 40 or below***
Systolic Blood Pressure [mmHg]	100 to 150	81 to 99; 151 to 170	71 to 80; 171 to 200	**70 or below*; 200 or above***
Level of Consciousness	Alert	Confusion; Obtunded [responds to verbal commands]	New onset of Agitation; Stupor [responds to painful stimuli]	**Unresponsive Seizure**
*** Parameters with an Asterix** immediately activate the **Rapid Response Team**				
Seizure: **Condition 1**: New onset, first time seizure activity **Condition 2:** Tonic – Clonic Seizure, lasting more than 5 minutes following 1st dose of Benzodiazepine, for patients known to have seizure activities				

Figure 1. MEWS Parameters

d. RRT Type

RRT activations are split into medical or surgical RRT. Once medical RRT is activated this notifies the medical physician on-call to be involved in the RRT. When the surgical RRT is activated, the notification goes to the surgical physician on-call to be involved in the RRT.

e. Reason for RRT Activation

The reason for RRT activation was divided into 5 groups, including: Cardiac, Respiratory, Neurologic, Sepsis, and others. Patients with cardiac issues included tachycardia, bradycardia, syncope, arrhythmias, hypertension, among others. Those with respiratory concerns included desaturation, tachypnea, and other respiratory

illnesses. Neuro concerns included seizures, decrease level of consciousness among others. Sepsis mainly included hypotension and fever. Others included, continuously febrile oncology patients with no other concerns, suicide attempt, panic attack, and bleeding.

D. Data Analysis Plan

Data analysis for the primary aim was performed using the Statistical Package for the Social Sciences version 25. The level of significance for statistical tests was set at a p-value < 0.05. Predictors and outcomes were summarized as means or percentages whenever applicable. Bivariate analyses for subsequent cardiac arrest, ICU admission, unexpected death or mortality before discharge were done using contingency tables, independent t-test, or analysis of variance tests as appropriate. ICU admission, and mortality before discharge, the primary outcomes, were used as the outcome variables to create the best logistic regression model using significant variables from the bivariate analyses.

For the secondary aim of quality indicators, the below was how these were calculated:

1. ***Rate of RRT activations per 1000 discharges = [Number of RRT activations] / [Total number of discharges] x 1000***
    - This indictor measures the prevalence of RRT activations in relation to the total number of patient discharges.

2. ***Promptness of RRT reporting to bedside = Mean time of RRT reporting to bedside = [Time of RRT arrival to bedside - Time when RRT was activated] in minutes***

- This indicator focuses on the timeliness of the RRT's response from the moment the team is activated until they arrive at the patient's bedside.
- RRT teams are required to arrive to the scene of activation within 5 minutes or it is considered that there is a delay in RRT response.

3. ***Transfers to ICU post RRT activation = [Number of patients transferred to ICU post RRT] / [Number of RRT activations] x 100***

- This indicator assesses the proportion of patients who were transferred to the ICU following an RRT activation. This helps evaluate the effectiveness of the RRT in identifying and managing patients whose conditions require higher levels of care in the ICU.
- This indicator helps provide an estimate of the severity of the patient condition.

4. ***Survival to discharge post RRT activation = [Number of patients survived to discharge after RRT] / [Number of RRT activations] x 100***

- This indicator examines the percentage of patients who survived and were discharged from the hospital after an RRT activation.
- This provides insight into the overall effectiveness of the RRT in improving patient outcomes and reducing mortality rates.

5. ***Rate of cardiac arrests outside the ICU per 1000 discharges = [Number of coded patients in a non-ICU area] / [Number of discharges] x 1000***

- This indicator measures the frequency of cardiac arrest events occurring in non-ICU areas in relation to the total number of patient discharges.
- This indicator contributes to the efficacy of RRTs aimed to improve patient safety and outcomes in non-ICU settings. Lower rates of cardiac arrests outside critical

care units suggest better patient monitoring and timely interventions, that contribute to better-quality patient care and safety in the hospital setting.

CHAPTER IV

RESULTS

A. Sample Characteristics

The total number of RRT activations was 204; five of these cases were either cancelled activations or switched to code and as such these patients were not included in this analysis. Thus, at total of 199 RRT activations were included in this analysis. There were 39 [19.6%] patients who had more than one RRT activation in the index admission ranging from 2 to 6 reactivations. Thus, the total number of RRT activations would be 199 for the sample size of 149 patients.

In this sample, the mean age of patients was 58.45 ± 21.36 years with the majority being males 122 (61.3%) mainly admitted to oncology units (48.2%) followed by 40.2% admitted to medical units, 9% to surgical units, and 2.5% to mixed medical surgical units (refer to Table 1 for Patient Sociodemographic Characteristics). The admission diagnosis varied among 29.1% Oncologic/Hematologic, 27.6% Septic Shock, 16.6% Respiratory Illness, 7% Infectious, 5% Gastric Conditions, 4% Nephrological Disorders, 4% Orthopedic, 3.5% Cardiac Illnesses, and 3% other diagnoses. The mean weighted Charlson Comorbidity Index was 4.93 ± 3.02 points and around 11.1% of the patients had a prior ICU stay. The mean length of hospital stay for the sample was 30.42 ± 52.0 days in the index admission and 9.17 ± 9.44 days prior to RRT.

Table 1. Patient Sociodemographic Characteristics

Patient Characteristics	Mean ± SD or n [%]
Age	58.45 ± 21.36 years
Gender [**Male**]	122 [61.3%]
Admission Diagnosis	
Oncology	58 [29.1%]
Septic Shock	55 [27.6%]
Respiratory Disease	33 [16.6%]
Infectious	14 [7%]
Gastric Conditions	10 [5%]
Nephrological Disease	8 [4%]
Orthopedic	8 [4%]
Cardiac Disease	7 [3.5%]
Other (Overdose/Suicide, Vaginal Laceration, Pain, Hydrocephalus, Hyperglycemia, Ulcer)	6 [3%]
Admitting Unit	
Medical Units	80 [40.2%]
Surgical Units	18 [9%]
Mixed Medical Surgical Units	5 [2.5%]
Oncology Units	96 [48.2%]
Weighted **Charlson Comorbidity** Index	4.93 ± 3.02 points
Length of hospital **stay prior to RRT**	9.17 ± 9.44 days
Length of hospital **stay in the index admission**	30.42 ± 52.0 days
Prior ICU stay in the index admission [Yes]	22 [11.1 %]

B. RRT Event Characteristics

RRT activations were primarily medical in 88.9% of the cases while 11.1% were surgical. The mean MEWS score was 4.33 ± 2.16 and more than half of the activated RRT were triggered by an Asterix (55.8%) followed by subjective concern (28.1%) and high MEWS (16.1%). RRT activation was mainly due to sepsis (37.2%) and the mean lactic acid level for activated RRTs was 2.79 ± 2.21. Additional reasons for RRT activation were cardiac (31.7%), respiratory (21.1%), and neurologic (3.5%) in nature among others (6.5%). Once activated, the mean arrival time of the RRT was 2.76 ± 3.33 minutes lasting around 21.97 ± 54.68 minutes with an 12.6% delay in response (please refer to table 2).

Table 2. RRT Event Characteristics

RRT Characteristics	Mean ± SD or n [%]
MEWS score	4.33 ± 2.16
RRT Activation Triggers	
High MEWS	32 [16.1 %]
Asterix	111 [55.8 %]
Subjective Concern	56 [28.1 %]
Reason for RRT Activation	
Sepsis	74 [37.2%]
Cardiac	63 [31.7%]
Respiratory	42 [21.1%]
Neuro	7 [3.5%]
Others	13 [6.5%]
RRT Type	
Medical	177 [88.9%]
Surgical	22 [11.1%]
RRT Logistics	
RRT Activation to Arrival Time in minutes	2.76 ± 3.33
Delay in Response of RRT team [Yes]	22 [12.6%]
RRT Duration in Minutes	21.97 ± 54.68
Lactic Acid Level	1.79± 2.21

C. Outcomes Post RRT

In this sample, the outcomes of the activated RRTs were either transfer to Critical Care Units (37.7%), mortality before discharge (32.45%), cardiac arrest (2%), or death within 24 hours of the event (1%). Additionally, 45.45% were readmitted within 30 days, 32% within 60 days, and 19.67% within 90 days (please refer to table 3).

Table 3. Outcomes of RRT

Outcomes of RRT	Mean ± SD or n [%]
Cardiac Arrest	3 [2]
Death within 24 hours of the event	2 [1.3]
Transfer to Critical Care Units	56 [37.6]
Mortality Before Discharge	47 [31.5]
30 days readmission	44 [29.5]
60 days readmission	29 [19.5]
90 days readmission	18 [12.1]

1. ***Subsequent Cardiac Arrest***

Only 3 out of the total sample of 149 patients experienced a subsequent cardiac arrest directly after RRT activation. All three patients were females; two of these patients, ages 62 and 80 years old had a medical history of cancer and a CCI score of 8 or greater. The third patient was a 47-year-old with a CCI score of 1 and was admitted with sepsis post a recent knee replacement surgery complicated by necrotizing fasciitis and infectious organisms such as pseudomonas aeruginosa, klebsiella pneumonia, carbapenem resistant enterococcus, Acinetobacter baumannii, providencia stuartii and underwent several debridements during her stay.

2. ***Transfer to a Critical Care Unit***

Independent sample t-tests were done between possible predictors and transfer to ICU post RRT. There was no significant relationship between age, level of comorbidity as measured by the weighted CCI, and length of stay and transfer to critical care. Lactic Acid levels were significantly higher in patients who were transferred to the critical care units compared to those who remained in medical surgical (3.59 ± 2.84 versus 2.10 ± 1.11; $p = 0.003$) (please refer to table 4).

Table 4. Bivariate Analysis of Transfer to Critical Care A

Predictor	Transferred	Remained	p-value
Age	61.99 ± 18.62	56.57 ± 22.52	.089
CCI	4.72 ± 2.38	5.04 ± 3.32	.487
LOS in Index Admission	34.29 ± 38.16	28.37 ± 58.06	.446
MEWS Score	4.49 ± 2.39	4.24 ± 2.03	.431
Lactic Acid Level	3.59 ± 2.84	2.1 ± 1.11	.003
Activation to Arrival Time in minutes	2.78 ± 3.54	2.75 ± 3.23	.965
RRT Duration in Minutes	21.40 ± 15.12	22.28 ± 66.68	.915
RRT Activations in Index Admission	1.66 ± 0.89	1.83 ± 1.34	.355

Additionally, a chi-square test was done among categorical predictors (Reason for RRT Activation; Admission Diagnosis; Admitting Unit; Prior ICU stay; RRT Activation Triggers; Specialty of Unit; RRT Type; and Delay in response of RRT team) and transfer to critical care. There was no significant association between gender, Prior ICU Stay in the Index Admission, RRT Activation Trigger, RRT Type, and Delay in response of RRT team and transfer to a critical care unit (please refer to table 5). More males (68.1%) were transferred to a critical care unit than females (31.9%) but this was not statistically significant. Among those patients who were transferred to a critical care unit, the majority (88.4%) had no prior ICU stay in the index admission. Asterix was the most prevalent RRT Activation Trigger, followed by subjective concerns, and then high MEWS score. More medical RRTs (89.9%) were transferred to a critical care unit than surgical (10.1%) but this was not statistically significant.

There was a significant association between the reason for RRT activation and transfer to critical care [X2 (4, N = 199) = 23.4, p < 0.001], Admission Diagnosis [X2 (8, N = 199) = 51.39, p < 0.001], and Specialty of Unit [X2 (3, N = 199) = 10.93, p = 0.012] and transfer to critical care. Sepsis was the main reason for transfer to critical

care units (42%), followed by respiratory conditions (36.2%). Likewise, a significant association between admitting diagnosis and transfer to critical care [$X2$ (48, N = 199) = 51.39, $p < 0.001$] existed. Septic Shock was the most common admitting diagnosis that required transfer to critical care, followed by Respiratory Disease (please refer to table 5).

Table 5. Bivariate Analysis of Transfer to Critical Care B

Predictor	Transferred n[%]	Remained n[%]
Gender X2 (1, N = 199) = 2.07, p = 0.151		
Male	47 [68.1]	75 [57.7]
Female	22 [31.9]	55 [42.3]
Prior ICU Stay in the Index Admission X2 (1, N = 199) = 0.03, p = 0.86		
No Prior ICU Stay	61 [88.4]	116 [89.2]
Previous Stay	8 [11.6]	14 [10.8]
RRT Activation Trigger X2 (2, N = 199) = 4.78, p = 0.092		
High MEWS	10 [14.5]	22 [16.9]
Asterix	33 [47.8]	78 [60.0]
Subjective Concern	26 [37.7]	30 [23.1]
RRT Type X2 (1, N = 199) = 0.09, p = 0.765		
Medical	62 [89.9]	115 [88.5]
Surgical	7 [10.1]	15 [11.5]
Delay in response of RRT team X2 (1, N = 174) = 0.21, p = 0.647		
Delay		
No Delay		
Reason for RRT Activation X2 (4, N = 199) = 23.4, p < 0.001		
Cardiac	12 [17.4]	51 [39.2]
Respiratory	25 [36.2]	17 [13.1]
Neuro	0 [0]	7 [5.4]
Sepsis	29 [42.0]	45 [34.6]
Others	3 [4.3]	10 [7.7]
Admission Diagnosis X2 (8, N = 199) = 51.39, p < 0.001		
Septic Shock	38 [55.1]	17 [13.1]
Oncology	8 [11.6]	50 [38.5]
Orthopedic	1 [1.4]	7 [5.4]
Respiratory Disease	10 [14.5]	23 [17.7]
Nephrological Disease	4 [5.8]	4 [3.08]
Gastric Disease	4 [5.8]	6 [4.6]
Cardiac Diseases	3 [4.3]	4 [3.1]
Infectious	0 [0]	14 [10.8]
Other	1 [1.4]	5 [3.8]
Specialty of Unit X2 (3, N = 199) = 10.93, p = 0.012		
Medical	29 [42]	51 [39.2]
Surgical	7 [10.1]	11 [8.5]
Neurology	5 [7.2]	0 [0]
Oncology	28 [40.6]	68 [52.3]

3. Unexpected Death within 24 hours

Patient death was considered unexpected unless it occurred after the initiation of end-of-life care or a do not resuscitate order. Only 2 patients out of this sample died within 24 hours of RRT activation. Both patients were females, who were admitted with septic shock. The first, was a 47-year-old with a CCI score of 2, a recent cancer diagnoses and a recent splenectomy surgical procedure. Her stay was rapidly complicated by blood transfusion reactions, leading to respiratory failure and the need for dual pressors within one day of her admission. The second was a 93-year-old with a CCI score of 6, admitted for septic shock.

4. Mortality Before Discharge

Independent sample t-tests were done between possible predictors and mortality before discharge in RRT patients. Age was statistically significant ($p < 0.001$) where the mean age of patients who died was 65.99 ± 21.41 years and those who lived was 54.62 ± 20.37 years. Likely patients who passed away before discharge had a higher comorbidity score 5.9 ± 2.97 versus 4.44 ± 2.95 ($p < 0.001$).

There was a statistically significant difference in the length of stay during the initial admission between patients who were alive at discharge and those who died (24.81 ± 28.13 days versus 41.48 ± 79.73 days respectively; $p = 0.032$) (please refer to table 6).

Table 6. Bivariate Analysis of Mortality Before Discharge A

Predictor	Alive	Dead	p-value
Age	54.62 ± 20.37	65.99 ± 21.41	< 0.001
Charlson Comorbidity Index [CCI]	4.44 ± 2.95	5.9 ± 2.97	<0.001
Length of Stay in Index Admission	24.81 ± 28.13	41.48 ± 79.73	0.032
MEWS Score	4.36 ± 2.23	4.27 ± 2.03	0.788
Lactic Acid Level	2.43 ± 1.32	3.27 ± 2.99	0.110
Time of Start of RRT – Time of RRT Arrival	2.62 ± 2.69	3.03 ± 4.33	0.444

Additionally, a chi-square test was done among categorical predictors (Reason for RRT Activation; Admission Diagnosis; Admitting Unit; Prior ICU stay; RRT Activation Triggers; Specialty of Unit; RRT Type; and Delay in response of RRT team) and mortality before discharge. There was no significant association between gender, Prior ICU Stay in the Index Admission, RRT Activation Trigger, and Delay in response of RRT team and mortality before discharge (please refer to table 7). More males (58.2%) had mortality before discharge than females (37.1%) but this was not statistically significant. Among those patients who had mortality before discharge, a few patients (13.4%) had a prior ICU stay in the index admission. Asterix was the most prevalent RRT Activation Trigger, followed by subjective concerns, and then high MEWS score, with no significance.

More medical RRTs (97%) had mortality before discharge than surgical (3%) and this was statistically significant [X2 (3, N = 199) = 6.69, p = .01]. There was a significant association between the reason for RRT activation and mortality before discharge [X2 (4, N = 199) = 27.42, p <.001], Admission Diagnosis [X2 (8, N = 199) = 60.1, p <.001], and Specialty of Unit [X2 (3, N = 199) = 8.12, p = .044] and mortality before discharge. Sepsis was the main reason for mortality before discharge (40.3%), followed by respiratory conditions (37.3%). Likewise, a significant association between

admitting diagnosis and mortality before discharge [X2 (8, N = 199) = 60.1, p <.001] existed. Septic Shock (58.2%) was the most common admitting diagnosis with mortality before discharge, followed by Respiratory Disease (19.4%) (please refer to table 7).

Table 7. Bivariate Analysis of Mortality Before Discharge B

Predictor	Alive n [%]	Dead n [%]
Gender X2 (1, N = 199) = 0.41, p = 0.52		
Male	83 [62.9]	39 [58.2]
Female	49 [37.1]	28 [41.8]
Prior ICU Stay X2 (1, N = 199) = 0.58, p = .446		
Yes	13 [9.8]	9 [13.4]
No	119 [90.2]	58 [86.6]
RRT Activation Trigger X2 (2, N = 199) = 3.02, p = .221		
High MEWS	23 [17.4%]	9 [13.4%]
Asterix	77 [58.3%]	34 [50.7%]
Subjective Concern	32 [24.2%]	24 [35.8%]
Delay in Response of RRT Team X2 (1, N = 174) = 0.07, p = .795		
Yes	14 [12.2%]	8 [13.6%]
No	101 [87.8]	51 [86.4]
RRT Type X2 (3, N = 199) = 6.69, p = .01		
Medical	112 [84.8%]	65 [97%]
Surgical	20 [15.2%]	2 [3%]
Reason for RRT Activation X2 (4, N = 199) = 27.42, p <.001		
Cardiac	53 [40.2]	10 [14.9]
Respiratory	17 [12.9]	25 [37.3]
Neuro	3 [2.3]	4 [6]
Sepsis	47 [35.6]	27 [40.3]
Others	12 [9.1]	1 [1.5]
Admission Diagnosis X2 (8, N = 199) = 60.1, p <.001		
Septic Shock	16 [12.1]	39 [58.2]
Oncology	52 [39.4]	6 [9]
Orthopedic	8 [6.1]	0 [0]
Respiratory Disease	20 [15.2]	13 [19.4]
Nephrological Disease	7 [5.3]	1 [1.5]
Gastric Disease	9 [6.8]	1 [1.5]
Cardiac Diseases	5 [3.8]	2 [3]
Infectious	9 [6.8]	5 [7.5]
Other	6 [4.5]	0 [0]
Admitting Unit X2 (10, N = 199) = 25.48, p = .005		
Psychiatry	1 [0.8]	0 [0]
5S	9 [6.8]	6 [9]
8N	54 [40.9]	28 [41.8]

BMT	14 [10.6]	0 [0]
9S	12 [9.1]	14 [20.9]
9N	22 [16.7]	15 [22.4]
10S	9 [6.8]	0 [0]
10N	2 [1.5]	4 [6]
CV	1 [0.8]	0 [0]
4N (NMS)	5 [3.8]	0 [0]
7N	3 [2.3]	0 [0]
Specialty of Unit X2 (3, N = 199) = 8.12, p = .044		
Medical	45 [34.1%]	35 [52.2%]
Surgical	14 [10.6%]	4 [6%]
Neurology	5 [3.8%]	0 [0%]
Oncology	68 [51.5%]	28 41.8%]

D. Predictors of ICU Admissions after RRT

A binomial logistic regression was performed to ascertain the effects of RRT activation reason (cardiac, respiratory, oncology, and others), specialty unit (medical surgical versus oncology), and lactic acid levels on the likelihood that participants will be transferred to critical care units. The logistic regression model was statistically significant [$X^2(5) = 28.084$, $p < 0.001$]. The model explained 31.9% (Cox & Snell R square) and 42.6% (Nagelkerke R square) of the variance in transfers to critical care. The model also classified 75.3% of the cases correctly. The Hosmer-Lemeshow test showed that the overall model is nonsignificant (p = .062) and indicates that the data fit the model well.

The classification table predicted a sensitivity of 70.6% for those who were transferred to critical care units were supposed to be transferred to critical care units. As well as a specificity of 79.5% of patients who were not transferred to critical care units were correctly predicted by the model not to be transferred to critical care units.

The odds ratio of Lactic Acid was 1.824 meaning that a one unit increase in Lactic Acid leads to a 1.824-fold increase in the odds of transfer to a critical care area. Given that reason for RRT activation and specialty unit are considered.

A statistical significance was seen for specialty unit (p = .008). The odds ratio of Medical Surgical specialty units were 5.511 times more likely to be transferred to critical care units than Oncology units. No statistical significance was seen for the reason of RRT activation using sepsis as the reference category.

Table 8. Predictors of ICU Admission after RRT

Predictor	B	Wald	Sig	Exp (B)
Constant	-2.194	8.685	.003	.111
Medical Surgical	1.707	7.127	.008	5.511
Lactic Acid	0.601	7.743	.005	1.824
RRT Activation Reason		7.708	.052	
Cardiac	-1.083	2.384	.123	.339
Respiratory	.885	.854	.355	2.424
Other	-2.951	3.760	.052	.052

E. Predictors of Mortality Before Discharge

A binomial logistic regression was performed to ascertain the effects of RRT activation reason (cardiac, respiratory, oncology, and others), specialty unit (medical surgical versus oncology), age, CCI and length of stay in the index admission on the likelihood that participants will have mortality before discharge. A logistic regression was performed to ascertain the effects of reason for RRT activation, specialty unit, LOS in the Index admission, CCI, and age on the likelihood that participants will have mortality before discharge. The logistic regression model was statistically significant, X2(7) = 43.921, p < .001. The model explained 19.8% (Cox & Snell R square), 27.5%

(Nagelkerke R2) of the variance of mortality before discharge and correctly classified 74.4% of cases.

The Hosmer-Lemeshow test showed that the overall model is nonsignificant (p = .096) and indicates that the data fit the model well.

The classification table predicted a sensitivity of 50.7% for those who died before discharge were supposed to have morality before discharge. As well as a specificity of 86.4% of patients who were alive at discharge were correctly predicted by the model not to have mortality at discharge.

The odds ratio of CCI was .838 meaning that a one unit increase in CCI leads to a .838-fold increase in the odds of mortality before discharge. The other two predictors, age and LOS in the index admission are not significant.

The reason for RRT activation is represented by 3 dummy variables in comparison to sepsis (reference group). The dummy variable cardiac in the reason for RRT activation was significant (p = .007) in comparison to sepsis, meaning those with a cardiac reason for RRT activation were 3.443 times less likely to have mortality before discharge than those with a sepsis reason for RRT activation. Both respiratory and others in the reason for RRT activation were not significant in comparison to sepsis.

Table 9. Predictors of Mortality Before Discharge

Predictor	B	Wald	Sig	Exp (B)
Constant	2.647	15.471	<.001	14.110
Medical Surgical	-.178	.215	.643	.837
CCI	-.176	5.188	.023	.838
Age	-.014	1.423	.233	.986
LOS in the Index Admission	-.012	3.005	.083	.989
RRT Activation Reason		16.320	.001	
Cardiac	1.236	7.288	.007	3.443
Respiratory	-.774	3.234	.072	.461
Other	.657	.648	.311	1.930

F. RRT Quality Indicators

1. Rate of RRT Activations per 1000 discharges

This was calculated as such: Rate of RRT activations per 1000 discharges = [Number of RRT activations] / [Total number of discharges] x 1000.

Equation 1

$$\frac{199}{7213} \times 1000 = 27.59 \text{ RRT activations per 1000 discharges}$$

2. Promptness of RRT Reporting To Bedside

This was calculated as the mean of the difference between RRT reporting to bedside and RRT activation. Mean time of RRT reporting to bedside was 2.76 ± 3.33 minutes.

3. Transfers to ICU Post RRT Activation

This was calculated as the [Number of patients transferred to ICU post RRT] / [Number of RRT activations] x 100.

Equation 2

$$\frac{56}{199} \times 100 = 28.1\% \text{ of patients were transferred to the ICU post RT activation}$$

4. Survival to Discharge Post RRT Activation

This was calculated as the number of patients who survived to discharge after RRT divided by the Number of RRT activations multiplied by 100.

Equation 3

$$\frac{102}{199} \times 100 = 51.3\% \text{ of patients survived to discharge post RRT activation}$$

5. Rate of Cardiac Arrest Outside ICU

This was calculated as the number of coded patients in non-ICU areas divided by the number of discharges multiplied by a 1000.

Equation 4

$$\frac{27}{7213} \times 1000 = 3.74 \text{ cardiac arrests occur outside the ICU per 1000 discharges}$$

CHAPTER V

DISCUSSION

A. Sample Characteristics

AUBMC caters to a diverse regional patient cohort in terms of age, gender, socioeconomic level, etc. For this quality improvement project, the mean patient age was 58 ± 21 years whereas similar studies reported mean ages of 63 years, 70 years, and 78 years (Hyun et al., 2022; Okawa et al., 2021; Tran et al., 2020). This age difference may be linked to scarcity of available hospice care in Lebanon, prompting patients to seek medical attention at more advanced stages of their illnesses. Additionally, the patient spectrum in our cohort encompasses mild to end-of-life cases. This may be explained by the fact that data collection occurred during the COVID-19 pandemic, a period marked by heightened health concerns and reluctance to visit healthcare facilities due to the risk of infection. Consequently, patients may have delayed seeking medical attention until their conditions reached a critical stage, potentially impacting the frequency and timing of RRT activations. Furthermore, findings showed that the majority of RRT activations were for male patients (61.3%) (Ahn et al., 2020; Hyun et al., 2022; Shappell et al., 2018; Tran et al., 2020; Okawa et al., 2021). In conjunction with Hyun et al. (2022), the CCI in their study reported a mean of 5.4, and aligns closely to the findings in our study, 4.93 ± 3.02. In addition, those with an oncology related admitting diagnosis and subsequently admitted to an oncology unit (8N and BMT) were predominant in comparison to the other groups, similar to Hyun et al.'s study (2022). Moreover, the second most activations occurred in patients admitted to medical surgical units, and despite the admitting diagnoses not being oncologic in

nature the majority of which had a history of an oncologic disease. However, the majority of other studied did not mention oncology and excluded COVID-19 patients.

A peculiar observation that stood out in our study was the anticipation of a predominant prevalence of respiratory diseases attributed to COVID-19; however, this category constituted only 16.6% of the total sample and was insignificant in data analyses. Moreover, while as we mentioned previously in the literature review, the most common reasons for RRT were respiratory symptoms such as hypoxia, tachypnea, and respiratory distress (Okawa et al., 2021; Tran et al., 2020, and Vandegrift et al., 2021), in our study the most common were sepsis (hypotension and fever) followed by cardiac concerns (arrhythmias). Similarly, in occurrence with our study's findings, patients with longer length of stay were observed to be more susceptible to RRT activations (Ahn et al., 2020; Shappell et al., 2018). Our study revealed a median LOS of 18 days in the index admission whereas other studies had a median LOS of 22.5 days and 27 days, and had higher risks for mortality (Ahn et al., 2020; Tran et al., 2020).

B. Gathering Data and Interpretation

Our meticulous data collection efforts encompassed the entirety of RRT activations and their corresponding patient cases from January 2021 to June 2021. To note, individual patients who had multiple activations were identified to ensure a comprehensive analysis. This approach, while offering a holistic view, introduced the challenge of potential repetition of demographic data. Notably, for the purpose of this study, patients who were discharged and then readmitted at a later date with a different admitting diagnosis and had a RRT activation were counted as two separate patients though they had the same case number. Excel and SPSS were used for data analysis

with each RRT activation being documented under a unique study code. Multiple activations were retained for analysis rather than consolidated into a single patient record. To mitigate such intricacies, manual validation and documentation were conducted, encompassing critical parameters such as sample size, ICU transfers, mortality rates, survival to discharge, and readmissions over various intervals. This thorough process aimed to ensure the accuracy and consistency of our analysis, as similar studies have underscored the need for standardized practices to enhance data integrity (Tan et al., 2021).

C. RRT Event Characteristics

At AUBMC, both the reason for RRT activation and the RRT activation trigger are not automatically documented or mandated in the EPIC system documentation. In our study the MEWS was manually calculated case-by-case based on vital signs at the time of RRT activation for two of the three triggers, and cross-referenced with MEWS BPA to ascertain for subjective concerns. Consequently, considering inclusion of RRT activation trigger data in RRT documentation is warranted. Although this characteristic lacked significance in SPSS analyses, our investigation highlights the complexities associated with RRT activation triggers and their predictive value. It emphasizes the need to consider a holistic approach to patient assessment and care, recognizing the limitations of relying solely on specific scoring systems like MEWS and NEWS (Ahn et al., 2020). To note, all instances of high MEWS value with an Asterix were classified as Asterix RRT activation triggers.

In related studies, some employed EWS as a scoring system for RRT activation (Okawa et al., 2021). However, relying solely on EWS might fall short in addressing

underlying issues or suitable interventions (Vandegrift et al., 2021). Apart from EWS, RRSs use mnemonic tools, or a 10-signs of vitality (10-SOV) in addition to the EWS to prioritize treatments in critical scenarios (Vandegrift et al., 2021). An effective healthcare system doesn't rely solely on one element; to distinguish high-risk from low-risk RRT patients. Interestingly, EWS and other forms such as NEWS and MEWS have proven inadequate in predicting in-hospital mortality among patients receiving RRT calls (Shappell et al., 2018; Vandegrift et al., 2021).

In our analyses the majority of patients (88.9%) had a medical RRT activation, however we did not include RRT type as medical vs. surgical as most studies do (Teuma Custo & Trapani, 2020; Shappell et al., 2018). This is to account for the oncology population. If we had focused solely on medical vs surgical, the oncology population would have been grouped with the medical category (as it is in the hospital). However, our approach was driven by the need to ensure adequate representation of the oncology patients, given their substantial presence in our study sample. Due to similarities between RRT type, admission diagnosis and specialty of unit we chose specialty of unit to avoid collinearities. Therefore, for our logistic regression model, RRT type and admitting diagnosis were not included in the data analyses, but specialty unit (admitting unit) was. The specialty of units for the purpose of this study were grouped into two categories (medical, surgical, and neurology [mixed medical and surgical] vs. oncology). This adjustment was made to ensure a balanced comparison across units. Surgical units had 18 patients, mixed medical surgical units had 5 patients, added to medical units, leaving us with a total of 103 patients in one group labeled Medical Surgical, compared to 98 oncology patients. By excluding oncology, we would have undermined the significance and importance of their contribution.

As we delve further into optimizing RRT processes, there’s a clear need for comprehensive strategies that encompass various tools and approaches to ensure effective patient outcomes.

D. Outcomes of RRT

As the discussion unfolds, it's important to address the issue of patient readmissions. Our research findings bring to light a noteworthy trend in which a considerable percentage of patients experience readmissions within specific time frames. We found that approximately 30% of patients were readmitted within 30 days, roughly 20% within 60 days, and about 12% within 90 days. It's intriguing to note that the existing body of literature regarding patient readmissions is relatively sparse, highlighting a gap in our comprehension of this significant aspect. The observed 30% readmission rate is indeed considerable, warranting careful consideration due to its potential impact on patient outcomes and the allocation of healthcare resources.

In the analysis of our outcomes, we included the predictors lactic acid for transfer to ICU, CCI, age and length of stay for mortality before discharge, as our continuous variables because these were statistically significant. The reason for RRT activation (cardiac, respiratory, sepsis, and others) and specialty unit (medical, surgical, neurology, and oncology) were the categorical predictors included in our study. In addition, concerning the immediate outcomes (cardiac arrest and death within 24 hours), the sample size was insufficient and lacked sufficient statistical power to conduct a meaningful analysis.

E. Predictors of ICU Admissions after RRT

An association between elevated lactic acid levels and a heightened likelihood of requiring ICU admission has been discovered through our analysis. Consequently, lactic acid is not taken on all patients, they were taken on those who were suspected to be septic or to rule out sepsis. Lactic acid monitoring among patients following RRT activation may be crucial in identifying those that should be transferred to critical care units and preventing further activations, particularly for those displaying hyperthermia (>38 C) or hypothermia (<36 C), hypotension relative to their baseline (SBP ≤ 90 mmHg or MAP ≤ 65 mmHg), tachypnea (> 20 breaths per minute), and tachycardia (heart rate more than 90 beats per minute) (Wayne et al., 2021; Zhu et al., 2023). Moreover, patients with elevated lactic acid levels may not be suitable candidates for ongoing care within regular units as these patients are considered sicker. Rather, their condition might necessitate a transfer to a more suitable environment where more intensive monitoring and specialized care can be provided. Additionally, our study has revealed a distinct subset of patients who triggered RRT activations post-ICU transfer, constituting 12.8% of the cases, similar to that of a study done by Shappell et al., (2018) who reported, those who survived to discharge, 12% required RRT activations after ICU transfer, and 16% of those who required RRT activation after ICU transfer died. This intriguing finding highlights the need for a nuanced approach in patient care post-ICU transfer. It suggests that a thorough evaluation of the appropriateness of the ICU transfer or the consideration of a dedicated step-down unit at our institution could potentially be beneficial. Such a unit would ensure ongoing vigilant monitoring until these patients attain stabilization, prior to transitioning them to a general ward.

F. Predictors of Mortality Before Discharge

Though studies have emphasized that patients with respiratory problems such as hypoxia and tachypnea were the leading causes of mortality in inpatients, this was not the case in our study (Shappell et al., 2018; Tran et al., 2020; Vandegrift et al., 2021). Similar to Hyun et al. (2022) and Okawa et al. (2021), the majority of the patients who were likely to have mortality before discharge were patients with sepsis. Moreover, during the course of this study, several observations were made. This included instances where patients warranted RRT activation, yet experienced delays due to the absence of a specific reason for activation, despite their critical (or very sick) condition. This delay may be attributed to potential increases in nurses' workload that is associated with RRT activations. However, sometimes RRT activations are non-emergencies such as continuously febrile patients or increasing the rate of a continuous vasopressor infusion in the absence of available ICU beds. However, the reasons for activation yet lacked documented evidence. Remarkably, due to the recent integration of the CCOT (critical care outreach team) in 2023 at AUBMC, there are less frequent RRT activations. This change has proven beneficial for patients situated on regular floors, in need for continuous monitoring where a critical care nurse would sit at the bedside of an inpatient in the absence of available ICU beds.

In the context of this project, it's important to consider the optimal timing for discussion of end-of-life care and/or code status following RRT activations. Having a timely discussion has been proposed as a potential measure to prevent cardiac arrests (Shappell et al., 2018). In our study, few critical patients with an expected death, those placed on DNR/DNI code status consisted of only 8 patients directly after RRT activation, yet full management was done. The majority of critical patients transferred

to critical care units with a poor prognosis had delayed code discussions, in which 34 patients were placed on DNR/DNI code status after all interventions were implemented prior to their death. Therefore, the ability to consider expected and unexpected deaths in relation to code status was difficult and unsuitable. This consideration becomes even more significant given the influence of cultural norms on the nature and frequency of preventable cardiac arrests, particularly within the context of Lebanon. RRT activations aligned with a patient's existing health conditions should serve as the trigger for personalized discussions surrounding goals of care and the potential utilization of palliative services, as and when appropriate (Shappell et al., 2018). This strategy has the potential to not only optimize the use of limited healthcare resources but also to empower RRTs to actively partake in conversations centered around the care goals of individual patients. A central aspect involves recognizing the factors contributing to mortality within this specific patient population (Shappell et al., 2018). This recognition can serve as a catalyst, prompting primary medical teams to address patient comfort proactively and engage in transparent discussions regarding prognosis and the limitations of treatment options with both patients and their families. Ultimately, these considerations can lead to enhanced patient comfort, optimized resource utilization, and more meaningful discussions about patients' care objectives. A key point to note is that some patients may not be placed on do not resuscitate/do not intubate (DNR/DNI) orders but still face an anticipated end-of-life scenario.

G. RRT Quality Indicators

Quality indicator data was taken from AUBMC’s EPIC system and used as a benchmark to compare the quality indicators calculated in this project. The EPIC

generated data was taken from two quarters in 2021 (from January 1 to June 30), and to note, did not include COVID-19 patients.

When comparing the rates extracted from AUBMC's EPIC system, their prevalence of RRT activations stood at 28.8 per 1000 discharges, indicating a variation of 1.21 activations per 1000 discharges in comparison to our study. As for the promptness of RRT reporting to bedside based on AUBMC's records, the average time recorded was 2.6 minutes. In contrast, our study yielded a calculated average of 2.76 minutes for RRT reporting to bedside, with a standard deviation of 3.33 minutes and a median of 2 minutes. Notably, it's worth mentioning that the standard deviation incorporates outliers identified in our study, thereby causing some deviation in the outcome.

The proportion of transfers to the ICU after RRT activation at AUBMC was 17.7%, whereas our study yielded a calculated percentage of 28.1%, indicating a discrepancy of 10.4%.

The survival rate to discharge at AUBMC, excluding COVID cases as well as DNR/DNI cases, was 75%. In this project, 77.4% of patients survived to discharge. It's crucial to highlight that this calculation excluded patients with a DNR/DNI code status, as these patients were deducted from the overall count of RRT activations. Whereas, if DNR/DNI code statuses were not removed from the equation, survival to discharge post RRT activation was 51.3%.

The frequency of cardiac arrests in non-ICU settings was recorded as 2.06 when COVID-19 patients were excluded from the equation and 3.76 when COVID-19 patients were included in the EPIC-generated data at AUBMC. This specific indicator was not manually computed within our study due to the focus solely on RRT activations and not code activations. Nevertheless, this indicator holds significant importance for

observation. The reason being that instances were found where RRT activations were transitioned to code situations, implying the presence of cases with code activations occurring without preceding RRT activations.

H. Recommendations for Future Quality Improvement Projects

Based on the identified issues and opportunities for improvement in the study, the following recommendations are proposed:

1. ***Enhance RRT Documentation Quality:***
   - Establish standardized documentation procedures for vital sign documentation, RRT triggers, and reasons for RRT activations.
   - Regularly audit RRT documentation to verify accuracy, correct timings, staff arrival, and comprehensiveness.
   - Consider integrating adjustments within the EPIC system to facilitate more efficient and accurate documentation:
     - Once RRT is activated an automated start of RRT event should be recorded on the EPIC system. If changed by the efferent arm it should show that it was adjusted.
     - For the afferent arm activating RRT, integrate an RRT activation trigger [High MEWS, Asterix, Subjective Concern].

- For the efferent arm responding to the RRT activation, integrate reason of RRT activation [Cardiac, Respiratory, Sepsis, Neuro, other] and specification of the concern.

2. ***Nursing Education on RRT Activation:***
   - Provide comprehensive training to both afferent and efferent registered nurses on clear and concise documentation for RRT activation procedures
   - Ensure that any transition from RRT activation to a code situation is clearly documented therefore facilitating identified areas for improvement.

3. ***Modification of Activation Predictors:***
   - Consider customizing an institutional-based protocol in addition to the MEWS to activate RRT.
   - Encourage implementing a lactic acid testing protocol associated with reason of RRT activation (sepsis) in patients who exhibit symptoms like fever and hypotension.

4. ***Continuous Monitoring:***
   - Assess the feasibility of providing acute monitoring directly after RRT activation, especially for patients unable to be transferred to ICU settings. In contrast, offering meticulous observation for patients transferred out of a critical care unit.
     - In alignment to the CCOT, consider a step-down unit at our institution with continuous monitoring until stabilized, thereby facilitating a seamless transition to a regular unit or conversely to a critical care unit.

5. ***Enhance RRT outcomes:***

- With the aid of the palliative care team, consider discussion of goals of care, code status and/or end-of-life care after RRT activations that align with patient's existing health conditions.

I. Conclusion

In conclusion, this quality improvement project investigated predictors of patient deterioration outside critical care units in relation to patient outcomes after RRT activation, such as subsequent cardiac arrest, ICU admissions, unexpected death within 24 hours and mortality before discharge. In addition, the study was also used to report quality indicators at AUBMC using EPIC generated data as a benchmark to compare quality indicators in this study. The findings demonstrated evident predictors for patient deterioration associated with ICU transfers and mortality before discharge. However, the study highlights existing gaps in standardizing institutional based protocols for RRT documentation and implementation. Moreover, further investigations are needed to evaluate the outcomes that can be improved leading to better patient care and optimized healthcare responses to deteriorating patients outside ICU units in developing third world countries.

APPENDIX

DATA COLLECTION SHEET

A. Demographics and Clinical Information

Study Code		Medical Record Number		Age in years/year born	
Gender		Admitting Diagnosis		Admitting Unit	
Charlson Index Explained					

B. Events Prior to RRT

LOS prior to RRT		LOS in Index Admission		Prior ICU Stay	
MEWS Score		RRT Activation Trigger		Reason for RRT Activation	
Lactic Acid Level		RRT Type [Medical or Surgical]		RRT Activations During the Same Admission	
Code Status Before Discharge					

C. RRT Logistics

RRT Start Time		RRT Arrival Time		Activation to Arrival Time	
Delay in Response to RRT		RRT Duration in Minutes			

D. Disposition

Immediate Outcome		Death Within 24 hours		Mortality before Discharge	
Transfer to Critical Care		Expected versus Unexpected Death			
30 Days Readmission		60 Days Readmission		90 Days Readmission	

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