Heart Failure in the Emergency Department:

treatment impact and short term outcomes

A MAJOR QUALIFYING PROJECT

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ABSTRACT

Heart failure (HF) is now considered an emerging epidemic of the 21st century, affecting 5.7 million Americans and causing a \$32.7 million strain on the healthcare system. Most admitted HF patients enter the hospital through the ED; however, there are not comprehensive established guidelines and treatment goals for ED physicians. This retrospective chart abstraction study investigates the impact of ED treatment on HF patient outcomes to determine which treatment courses are most effective and efficient.

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WHAT IS HEART FAILURE?

Heart failure (HF) is the inability of the heart to pump enough blood to meet the demands of the body. This can manifest itself acutely or chronically, though most cases are chronic. If the heart can no longer pump enough blood to the body, the body responds in an attempt to compensate. This compensation starts with the sympathoadrenal system, which (when stimulated) increases cardiac rate, contractility of the ventricles, and constriction of the arterioles. This system also uses hormones and nerve signals to increase blood volume by increasing water reabsorption in the kidneys. It accomplishes this by increasing renin secretion which activates the renin-angiotensin-aldosterone system. Activation of this system, in turn, leads to increased salt in water retained by the kidneys. The increased volume gets backed up behind the heart, since its pumping function is impaired.

Pumping inadequacy in the left ventricle leads to an increase in pressure in the left atrium. This pressure backs up and causes the fluid to enter and congest the lungs (congestive heart failure, CHF). If the pumping inadequacy is in the right ventricle, pressure builds in the right atrium and backs up into the rest of the body. This causes edema in systemic circulation: swelling in the legs, ankles, and abdomen. The increased blood volume also places additional stress on the heart through work overload. The ventricles enlarge to compensate for the increased blood volume and have a higher metabolic demand for oxygen. All of this leads to a cycle in which the heart's inadequate pumping causes symptoms and systemic compensation which further aggravates the heart. The heart's inadequate pumping also leads to a reduced blood flow to the body. This hypoperfusion can have effects (especially during physical activity), such as difficulty breathing, fatigue and dizziness.

There are several different mechanisms of heart failure: systolic heart failure, diastolic heart failure, left heart failure, and right heart failure (Table 1). These mechanisms are not mutually exclusive; patients may suffer from one or more of these types of heart failure.

Table 1: Heart Failure Mechanisms.

Heart Failure Type	Mechanism	Symptoms	Causes
Left Heart Failure	left side, specifically the left ventricle has impaired function	pulmonary edema, dyspnea, cough with pink-frothy mucus, decreased urine output, fatigue, weakness, weight gain	MI, HTN, too much alcohol consumption, leaky heart valves, heart muscle infections
Right Heart Failure	right side, specifically the right ventricle, has impaired function	edema and engorged veins in the lower extremities/hands, palpitations, weakness, fatigue, shortness of breath	left ventricular failure, COPD, right ventricle infarction, pulmonary embolism
Systolic Heart Failure	one/both of the ventricles have impaired ejection upon contraction	symptoms reflect those of left heart failure, right heart failure, or both	causes reflect those of left heart failure, right heart failure, or both
Diastolic Heart Failure	refilling abnormality in one/both ventricles caused by ventricular stiffening	symptoms reflect those of left heart failure, right heart failure, or both	causes reflect those of left heart failure, right heart failure, or both

Heart failure patients that enter the emergency department (ED) are generally complaining of angina, edema, or dyspnea (Peacock and Emerman 2004; Bundkirchen and Schwinger 2004). They may also complain of persistent coughing and wheezing from the fluid buildup in the lungs. The decreased blood flow can cause fatigue and lack of appetite/nausea as the body diverts towards more vital organs such as the brain and heart. As the body compensates for this decreased blood blow, heart rate will increase and patients may complain of palpitations or a racing/throbbing heart. Confusion or other altered mental status is also common, resulting from the ion and fluid imbalance.

CHARACTERISTICS OF THE HF POPULATION

Several studies have found a set of characteristics that typify the heart failure population. In 2005, the ADHERE database was created to define the characteristics and outcomes of admitted patients with a heart failure diagnosis (Adams et al. 2005). This database was a multi-center project that enrolled 107,362 subjects. The study recorded past medical history, treatment, diagnostic test results, vital signs, length of stay, and other outcomes to better characterize the heart failure population. The findings are not a 100% accurate representation of the general population but do serve as a valid database to make some generalizations about the heart failure population as a whole. This database found a mean ejection fraction (EF) of 34.4%, a median length of stay (LOS) of 4.3 days, required mechanical ventilation in 23% of patients, and an in hospital mortality rate of 4%. This mortality rate increased to 10.6% for patients who required care in the intensive care unit (ICU).

Other studies have found that heart failure patients commonly have a significant past medical history, including: hypertension (HTN), coronary artery disease (CAD), diabetes mellitus (DM), atrial fibrillation (A Fib), chronic obstructive pulmonary disease (COPD), and asthma (Adams 2005; Gheorghiade et al. 2005). A study in Worcester, MA in 2005 looked at mortality rates and factors affecting fatality risk in heart failure patients. This study found an increased risk of fatality for older patients, patients with impaired renal function, patients arriving to the hospital with low blood pressure, patients with a history of anemia or stroke, and patients of normal/non-obese weight (Goldberg). Patients with high BUN, serum creatinine, and heart rate upon admission also had higher mortality rates (Goldberg 2005).

STAGES OF HEART FAILURE (AHA)

The American Heart Association (AHA) has published that there are four stages of heart failure. In the first stage (Stage A), patients show no symptoms or actual heart damage but are at high risk for developing heart failure. This risk is based on a history of hypertension, diabetes, coronary artery disease, or family history of heart failure. During this stage, preventative measures should be considered such as treatment for related diseases (HTN, DM, CAD), increased exercise, no smoking, and possible pharmacological interventions (ACE inhibitors, or

β blockers). In Stage B, patients remain asymptomatic but now exhibit some heart dysfunction and should be managed pharmacologically. In Stage C, symptoms arise, including: shortness of breath (SOB), fatigue, edema, reduced exercise tolerance. Treatment for this stage includes ACE inhibitors, β blockers, diuretics, dietary management and other preventative strategies mentioned earlier. In this stage, the therapies are successful in diminishing symptoms and treating heart failure. The last stage (Stage D) is called refractory heart failure and is when, even with maximal therapy, patients experience worsening symptoms and poor quality of life with recurrent hospitalizations. The therapy for this stage often includes palliative care or high tech procedures (i.e. transplants).

PREVALENCE OF HEART FAILURE IN THE U.S.

Heart failure is an emerging epidemic of the 21st century in the United States (Massie 1997; Goldberg 2005). Recent studies estimate that 5.7 million Americans currently suffer from this disease, with an added 500,000 diagnosed every year (AHA 2009; Fonarow 2004). The number of hospital discharges related to heart failure has been steadily increasing. In 1979, 377,000 of the nation's discharges were attributed to heart failure. This number increased to 978,000 in 1998 and 1,106,000 in 2006 (AHA 2009; AHA 2005; USDHHS 2004). Over the decade of 1985-1995, the number of hospitalizations with a heart failure diagnosis skyrocketed from 1.7 to 2.6 million (AHA 2005; USDHHS 2004). It has already become the leading cause of hospitalization for persons over the age of 65 and hospitalization numbers are expected to increase over the next two decades (Adams et al. 2005; Kannel 1994; Anonymous 1994).

This drastic increase in prevalence of heart failure is partially a result of the aging baby boomer population (Massie 1997; Bundkirchen and Schwinger 2004; Goldberg 2005; Bonneux et al. 1994). In 2006 the 65 and older age group accounted for 12.1% of the population (Census Bureau 2006). Current estimates predict that by 2020, that percentage will rise to 16.5% and by 2050 it will rise to 20% (Census Bureau 2000). Because heart failure is most prevalent in this elderly population, the aging baby boomers will cause a dramatic increase in the prevalence of heart failure. Increases in heart failure diagnoses and incidences are also partially due to increased heart disease survival rates (Goldberg 2005). Improved management and increased public awareness of myocardial infarction, diabetes, and hypertension have decreased early mortality rates from such diseases (O'Connell 2000). With higher survival rates for these cardiac-related illnesses, the number of heart disease sufferers increases. With more heart disease sufferers (a common cause of heart failure), there are more individuals with weakened hearts that contribute to the increased prevalence of heart failure.

FINANCIAL BURDEN OF HEART FAILURE TREATMENT

The treatment of this large, sick population is causing heart failure to become an increasing burden on the health care system, not only clinically, but also economically (Goldberg et al.

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2005). Although calculating the exact cost of heart failure management is difficult, some studies have ventured estimations. O'Connell (2000) estimates that hospital charges average approximately $10,000 per heart failure visit. The national expenditure for heart failure management is estimated to reach $32.7 billion annually (AHA 2009). Approximately 50% of these expenses are accounted for by hospital stays (AHA 2004). In recent years, Medicare has released statements that rank heart failure expenses as surpassing those of cancer (O'Connell & Bristow 1994; O'Connell 2000).

MANAGEMENT OF HEART FAILURE IN THE EMERGENCY DEPARTMENT

Approximately 75% of heart failure admissions enter the hospital through the emergency department (ED) (Silvers 2007). Of all these HF admissions, 80% are diagnosed as such in the ED (Peakcock and Emerman 2004). These statistics highlight the importance of the emergency department in the diagnosis and treatment of heart failure patients.

DIAGNOSIS

Diagnosis of heart failure is based on the signs and symptoms discussed earlier and clinical findings. Clinical tests performed to diagnose heart failure include: B-type natriuretic peptide test, electrocardiogram, chest x-ray, and echocardiography (Hobbs 2004).

The B-type natriuretic peptide (BNP) test is gaining popularity because it is a rapid, reliable biomarker that can be tested for from a patient's blood (Peacock and Emerman 2004; Hobbs 2004). BNP is a neurohormone secreted by the ventricles when they are stretched (Morrian et al. 2002). Stretching is common in heart failure due to the increased blood volume and subsequent pressure overload. When stretching occurs, BNP is secreted into the bloodstream, in a concentration dependent manner. The peptide levels correlate to the severity of the heart failure incident and the patient's prognosis (Morrian et al. 2002). For ED heart failure diagnoses, the BNP test accurately detects heart failure about 83% of the time and reduces diagnosis uncertainty from 43% to 11% (Morrian et al. 2002). The test requires a small amount of the patient's blood to be

Table 2: BNP as a HF diagnostic tool.

Blood BNP Concentration	Heart Failure Severity Indication
below 100 pg/mL	no heart failure
100-300 pg/mL	heart failure is present
300-600 pg/mL	mild heart failure
600-900 pg/mL	moderate heart failure.
above 900 pg/mL	severe heart failure.

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analyzed in a machine that determines the BNP concentration in the blood in pg/mL. Normal BNP concentration is less than or equal to 100pg/mL; values above this indicate various levels of heart failure (Table 2). Patients with severe decompensated heart failure can have blood BNP concentrations of up to 5000pg/mL.

All patients suspected of having heart failure undergo at least one ECG while in the ED. This is a non-invasive method of detecting the heart's electrical activity. It is useful for determining the presence of arrhythmias, which are often present in heart failure patients, although no specific abnormal ECG feature indicates heart failure. Heart failure patients also suffering from atrial fibrillation, atrial tachycardia, or ventricular tachycardia have a poorer prognosis than those not, so this information is an important part of ED diagnosis and care. (Shamsham and Mitchell)

Chest radiography (chest x-ray) is a tool that aids in the diagnosis of many conditions affecting the contents of the chest. It allows for the assessment of pulmonary congestion and for the differential diagnosis between heart failure and lung infection (such as pneumonia) (Nieminen 2005). Chest x-rays can help diagnose systolic vs. diastolic heart failure as well. Hearts in systolic failure appear enlarged and have a larger cardiothoracic ratio. Hearts in diastolic dysfunction do not show enlargement. Chest x-rays of heart failure patients also show Kerley lines, lines that appear on the x-ray due to the fluid build-up associated with pulmonary edema (Figure 1 and Figure 2). Haziness in the x-ray or pleural effusion are commonly associated with heart failure as well. (Shamsham and Mitchell)

Figure 1: **Chest X-ray in Normal Patient**. Picture copied from: http://www.med.yale.edu /intmed/cardio/imaging/findings/kerleylines/index.html

Figure 1: Chest X-ray in Heart Failure Patient. Arrows indicate Kerley lines. Picture copied from: http://www.thics.com/cxrapps.jpg

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Echocardiography is used to monitor ventricular function, valvular structure/function, pericardial pathology, and mechanical complications of a myocardial infarction (Nieminen 2005). It is a sonogram (or ultrasound) of the heart that yields two-dimensional slice images of the heart. Using Doppler echocardiography, physicians can determine the flow rate of blood at any given point in the image. This allows for the calculation of cardiac output and ejection fraction (EF). Ejection fraction is the percentage of blood that exits a ventricle during a single heart beat. In a normal patient the ejection fraction is 50%, meaning that during contraction, 50% of the ventricle's blood is pushed out (through the aorta or pulmonary arteries) and 50% remains as residual volume. In heart failure patients, the EF is generally decreased since the heart cannot pump out as much volume. However, heart failure patients may also have increased EFs caused by stiffening of the ventricle walls.

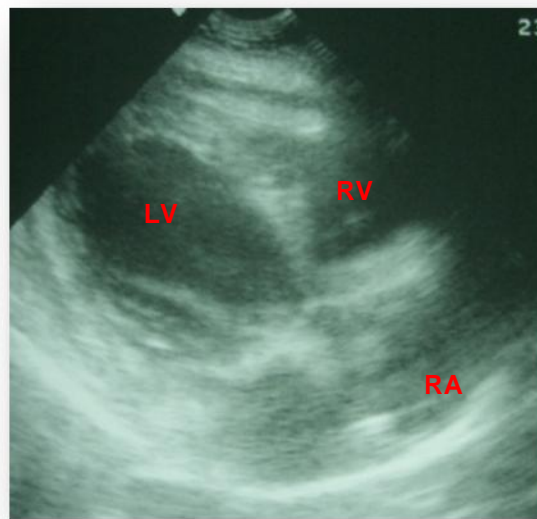**Figure 3: Echocardiogram for Normal Patient. (LV = Left Ventricle, RV = Right Ventricle, RA= Right Atrium)**
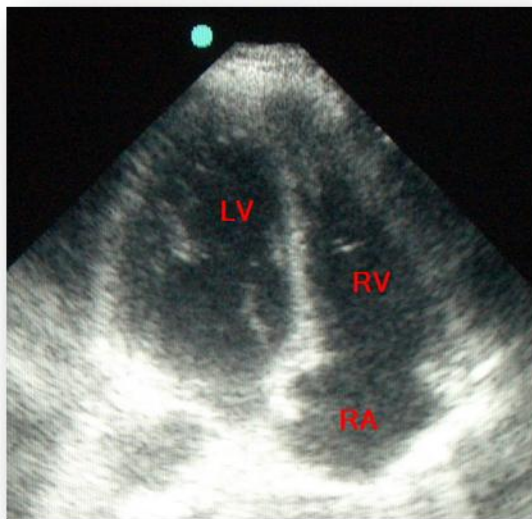
Figure 2: Echocardiogram in Heart Failure Patient Showing Enlarged Left Ventricle. (LV= Left Ventricle, RV= Right Ventricle, RA= Right Atrium)

During their stay in the ED, patients are monitored through other lab tests as a part of the diagnosis: partial pressure of O_2 (pO_2) for assessment of oxygenation, partial pressure of CO_2 for assessment of respiratory adequacy, pH for assessment of acid/base balance. Their vital signs and oxygen saturation (SpO_2) are also monitored as a part of the diagnostic and treatment process.

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TREATMENT

There are a range of treatments for heart failure, each addressing different facets of the disease. Treatments include pharmacological interventions (such as morphine, vasodilators, ACE inhibitors, diuretics, β blockers, inotropes) and non-pharmacological interventions (such as oxygenation, mechanical ventilation). In the ED, treatment generally aims to stabilize patients quickly through early administration of vasoactive medications and/or adequate ventilation/oxygen (Gheorghiade et al. 2005).

The reduced blood flow of heart failure requires that patients be kept on supplemental oxygen to increase perfusion. Patients that are breathing on their own and don't require ventilation, may require oxygen supplied by a nasal cannula or non-rebreather mask at various oxygen flow rates. For these patients, low flow rates (2-6L/min) are generally sufficient for good oxygen saturation. Many patients, with more severe heart failure will require ventilation in the ED (or prior, during pre-hospital care). Ventilation can be achieved through non-invasive (NIV) methods such as CPAP (continuous positive airway pressure) or BiPAP (bi-level positive airway pressure) which blow air at prescribed pressures into the patient's airway to aid in respiration. Invasive methods, such as endotracheal intubation, are used for more serious cases. Patients who are in severe respiratory distress or who are not breathing at all will be intubated and ventilated mechanically. Non-invasive methods are generally the preferred method of ventilation, if adequate, because they reduce the need for intubation and mechanical ventilation (which are expensive and more harmful to the patient) (Nieminen 2005).

Morphine has been used to treat heart failure in its early stages. It induces venodilation, mild arterial dilation and reduces heart rate. Because of these effects, it is used especially for restless, dyspneic patients (Nieminen et al. 2005).

Diuretics help relieve the fluid congestion in heart failure patients through increasing urine output. They induce excretion of water, Na^+, Cl^-, and other ions which has a number of effects on the body. It decreases plasma volume, extracellular fluid volume, blood pressure and in turn, peripheral and pulmonary edema. Diuretics have been the classic ED heart failure treatment since they can relieve one of the most pressing symptoms. Most patients receive intravenous diuretic in the ED and as many as 3% receive it en route to the hospital (Peacock and Emerman 2004). However, some studies have linked diuretics with a decline in kidney function and worse overall outcomes (Gheorghiade 2005, Peacock and Emerman 2004). Common diuretics are: furosemide (Lasix), bumetanide, and acetazolamide.

About 30% of heart failure patients receive vasoactive therapy during their hospital stay (Peacock and Emerman 2004). These types of therapy include inotropes and vasodilators and are usually given to patients with EFs less than 40, chronic renal insufficiency, and pulmonary edema. Some research has found that these drugs can lead to side effects such as hypertension and increased mortality, without enough benefit to justify widespread use (Peacock and

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Emerman 2004). Because of this, their use is decreasing. Vasoactive medications can be broken down into inotropes and vasodilators. Vasodilators are the first line therapy for many heart failure patients as long as they have stable blood pressure and show signs of congestion and low dieresis. Vasodilators increase the circumference of blood vessels (mostly veins, but arteries as well at higher dosages). The common vasodilators are nitroglycerin, nitroprusside, isosorbide dinitrate and glyceryl trinitrate 5-mononitrate. Natriuretics are the newest type of vasodilator. One of these medications, nesiritide, is a vasodilator that acts similarly to endogenous natriuretics. It can cause vasodilation of veins, arteries, and coronary vessels which reduces stress on the heart and increases cardiac output without causing an increased oxygen demand by the heart muscle (as some medications do). Vasodilators are only recommended for those with stable blood pressure because they greatly decrease blood pressure. They can lead to severe drops in blood pressure which may exacerbate heart damage and renal hypoperfusion (Gheorghiade et al. 2005). Inotropes are medications that affect muscle contraction strength. With heart failure, they are used to increase the heart's pumping strength. Although this has its benefits, it can increase the heart's oxygen demand and cause heart damage and possibly increased mortality (Gheorghiade et al. 2005). Common inotropes are: dopamine, dobutamine, and milrinone.

Angiotensin converting enzyme (ACE)-inhibitors are used to treat heart failure as well, though there is much debate over which patients should receive and at what time during their hospital stay. ACE inhibitors act on the vascular system by decreasing angiotensin II (AII) and aldosterone and increasing angiotensin I and plasma renin activity (Nieminen et al. 2005). Angiotensin II normally causes vasoconstriction, release of aldosterone, and release of vasopressin. All of these events lead to an increase in blood pressure. ACE inhibitors slow the activity of ACE, decreasing these processes and leading to a decrease in blood pressure. With lower blood pressure, there is less stress on the heart and heart function can improve. Some common ACE inhibitors are: enalapril (also known as vasotec/renitec) and lisinopril (also known as lisodur/lopril/novatec/prinivil/zestril.).

 β-blockers are another class of therapy for heart failure patients. Although heart failure had traditionally been a contraindication for β-blockers, studies in the 1990s found they can reduce risk of mortality and hospitalization in heart failure patients treated with normal heart failure medications. It has recently become standard care for many heart failure patients (Chavey 2000). β blockers act by inhibiting the stimulation of β receptors. This leads to a reduction in the effect of exertion on the heart, reduction in heart oxygen demand, decrease in heart rate, dilation of blood vessels, and increase in ejection fraction. The most common β blockers are: metoprolol, bisoprolol, and carvedilol.

PROBLEMS ASSOCIATED WITH ED TREATMENT OF HEART FAILURE: THE ROLE OF THIS STUDY

Despite its labeling as the new epidemic of the 21st century, heart failure remains understudied in comparison with other cardiac diseases, such as acute coronary syndrome. Gheorghiade et al. wrote in 2005: "there is no consensus on its definition, epidemiology, pathophysiology, appropriate therapeutic options, and directions for future research."

There has been controversy over what methods are most effective for treatment of heart failure. Debate over the effectiveness and safety of certain drugs has led to differences in treatment preferences among physicians. While some guidelines advocate for early and aggressive diuretic use, other studies have found that higher/more frequent doses of diuretics can increase mortality rates or cause renal damage (Butler et al. 2004; Philbin, Cotto, and Rocco 1997; Gheorghiade, 2005). Similar controversies exist with administration and dosage guidelines for vasodilators. Studies continue to examine nitroglycerine, even after decades of use, to determine the most effective dosage. Nesiritide, a newer vasodilator, has been supported in some studies for its symptom reduction and opposed in others for its cost and risk (Sackner-Bernstein et al. 2007; Peacock et al. 2006). There are also no therapeutic goals for ED physicians to base their care on. With no goals in terms of vital signs or urine output, indecision about drug dosages and usage continues (Darling, personal communication). To add to the indecision, 20% of heart failure patients are mis-diagnosed in the ER (Peacock and Emerman 2004).

Because of this type of confusion and uncertainty, it has been recommended that more studies be completed to develop more effective care strategies (O'Connell 2000). Prior to 2007, the only existing guidelines for heart failure treatment addressed general treatment and were not specific to care in the ED (Nieminen 2005; Hobbs 2004). A set of guidelines for ED management of heart failure was released in 2007 by the American College of Emergency Physicians. These guidelines filled a void by providing a standard of care for emergency physicians treating heart failure. However, the guidelines were limited and addressed only four main issues: diagnosis with BNP, use of NIV, role of vasodilators, and the role of diuretics. Even these four topics were labeled only as Level B (moderate clinical certainty) or Level C (limited supporting data) recommendations.

Even with guidelines, there is little data about how actual ED management compares to the written standards. In some cases, a treatment gap between what is recommended in guidelines and what ED physicians put into practice clinically has been discovered (Fonarow 2004). For example, numerous studies have shown the benefit of ACE inhibitors and beta blockers (Hjalmarson, A. et al. 2000; CONSENSUS 1987; SOLVD 1991). In these studies, both drug classes decreased mortality risk or re-hospitalization risk or both: ACE inhibitors reduced the all-cause mortality rate by 20-25%, beta blockers reduced the mortality rate by 34-35% (Fonarow 2004). Since these studies were published, these drugs have been guidelines for all stabilized

patients with left ventricle systolic dysfunction (and no contraindications) (Fonarow 2004). Despite this, ACE inhibitors and beta blockers are underused in heart failure patients.

In addition, little effort has been put into studying the effect of ED management of heart failure on patient outcomes. Studies have shown that early re-admission for heart failure and mortality within 30 days of discharge are both independently associated with the care that patient received in the hospital (Fonarow 2004). However, it is unknown whether ED care *specifically* effects patient outcomes or simply treats symptoms. ED care in other diseases has been known to have significant impacts on patient outcomes. Nguyen et al. (2000) observed the care of critically ill patients that entered the ED and later transferred to the ICU. The results showed that ED care of critically ill patients greatly impacted the progression of organ failure and mortality *and* that predictable outcomes may be established prior to ICU admission (Nguyen 2000). Another study in sepsis patients found similar results. This study focused on Early Goal-Directed Therapy (EGDT) and its ability to improve survival in early care septic patients in the ED and ICU (Rivers et al. 2001). This study enrolled some patients in EGDT (a method that changes the WAY traditional therapies are administered, not the type of therapy) and some in normal care and compared the outcomes. They found that EGDT created patients with higher central venous oxygen saturation, lower lactate concentration, and higher blood pH than patients treated with traditional, long standing therapies (Rivers et al. 2001). Patients treated with EGDT had higher survival rates as well. Another study, from 1992 observed patient outcomes (mortality and hospital LOS) in patients that received pre-hospital medications heart failure medications vs. those who received no pre-hospital medications (Wuerz and Meador 1992). The results showed that those treated pharmacologically in the pre-hospital setting received medications approximately 36 minutes earlier and had decreased mortality rates and hospital LOSs (Wuerz and Meador 1992). These studies all support the idea that ED treatment timeliness and manner can have significant effects on patient outcomes.

If ED care does affect outcomes in the case of heart failure, the HOW or WHAT remains unknown. Beyond a lack of knowledge about how ED care affects short term patient outcomes in heart failure, there is also uncertainty about which measures are most important. If ED heart failure management can in fact affect patient outcome, than should it focus on cardiopulmonary indices, symptom relief, hospital LOS, mortality, or some other outcome goal?

Timing of diagnostic tests and treatment is another important part of emergency care. A national study in 2007 (Diercks et al.) found that the longer patients spent in the ED, the further their care strayed from published guidelines. Patients who spent 8 hours or more in the ED received inferior care and were less likely to meet treatment goals than patients who went 4 hours or less in the ED (Diercks et al. 2007). Although the study didn't address the reasons for the longer ED stays and their corresponding poor treatment, ED crowding is a likely suspect. Crowding not only leads to longer ED stays but also overburdened EDs with higher patient to nurse ratios (2:1 in the ICU, 10:1 in the ED) (Hollander and Pines 2007). The ED is not set up for continuing care and reassessment; it is designed for stabilization, initial intervention, and discharge to allow for

prioritizing the next patient (Hollander and Pines 2007). In addition to total time spent in the ED, for ST-segment elevation myocardial infarction (STEMI) and non-ST-segment elevated myocardial infarction (NSTEMI), several studies have found significant differences in outcomes based on timing of certain tests and therapies (Hollander and Pines 2007). From these studies, early ECG administration, fibronolytic therapy, and balloon inflation for STEMI/catherization for NSTEMI have become well-known, accepted goals for patients with acute coronary syndrome (Braunwald et al. 2002; Hollander and Pines 2007). It is not unreasonable to hypothesize that early care in heart failure might have similar effects. Even in the case of STEMI/NSTEMI where it is accepted that early care is important, there are no guidelines with specific time periods for early treatment and reassessment (Hollander and Pines 2007). Which time points are important for improved outcomes are also unknown: early diagnosis, early care, early reassessment, or early transfer to hospital floor. For the above reasons, this study will also look at ED lengths of stay and the timing of medical care and whether this has effects on patients' outcomes.

Another issue is the heterogeneity of the heart failure population. While most heart failure patients present to the ED with similar symptoms, the mechanisms (systolic vs. diastolic dysfunction) underlying their disease can vary greatly. Recent studies have found that because of this, it is important to separate patients with systolic and diastolic dysfunction and treat them accordingly (Chavey 2000). Because this information is recent, the idea of taking these underlying mechanisms into account in emergency care has not yet taken hold. Women with heart failure tend to be older and have stiffened hearts with diastolic dysfunction. They generally have normal to high EFs and have a history of hypertension and diabetes (Philbin et al 2000). Men with heart failure, on the other hand, tend to be younger and suffer from systolic dysfunction. They generally have very low EFs and a poor prognosis. The differences in the mechanism and prognosis of systolic and diastolic dysfunction, as well as the differences in heart failure between men and women are usually not addressed in ED care. Outcomes may improve if these factors were taken into account in treatment during early care in the ED.

In 2004, O'Connell wrote: "resources and personnel are limited, efforts must be made to develop novel strategies to reduce the burgeoning cost of care of these [heart failure] patients without compromising effectiveness of that care." More and more critically ill patients are being admitted to the ED as their first point of care due to increased patient volume, limited ICU space, and increased utilization of the ED as a source of primary care (Nguyen 2000). In addition, nearly 75% of the hospital costs in a heart failure hospital admission are accumulated during the first 48 hours, which are directly affected by ED care (O'Connell 2000). Because most hospitals lose money on heart failure admissions, strategies to decrease costs are valuable information (Peacock and Emerman 2004). Thus, heart failure treatment presents a large economic and resource burden that requires new solutions. The emergency department is a promising location for such new solutions since 80% of heart failure patients are admitted through the ED (Silvers 2007). Possible methods of decreasing costs include reducing hospital admissions from the ED,

decreasing hospital LOS, increasing use of the observation or clinical decision unit, reducing re-admissions, and reducing the use of expensive, high-resource areas such as the ICU (Peacock and Emerman 2004). All this must be done without affecting patient care. Simply discharging patients earlier to decrease LOS can be detrimental to the patient and can be more costly if it leads to increased readmissions (O'Connell 2000). O'Connell (2000) suggests that the focus should be on medical-based targets rather than economic-based targets such as stabilizing patients and improvement of primary, secondary, and tertiary care strategies (which will lead to decreased hospital admissions and decreased costs). These medical-based targets may be a possibility in ED care to help decrease hospital costs.

In addition to the obvious economic concerns, the high and increasing incidence of heart failure combined with its poor prognosis have caused it to reach epidemic status. The risk of heart failure development in men and women over the age of 40 is approximately 1 in 5 (AHA 2009). For those diagnosed with heart failure, their 6 year mortality rate is between 77 and 84% (O'Connell 2000). It may be possible that ED care has the potential to be more effective and efficient at treating heart failure patients. This study will look at this possibility in the hopes of finding solutions that can lead to decreased mortality risk, shorter hospital stays, and less crowded EDs.

DATA COLLECTION

Patients for this study were enrolled retrospectively from an existing ED heart failure database. Patients in this database were all discharged from UMass Memorial Medical Center between May and November of 2008 with a primary diagnosis of heart failure. 85 patients from this database were enrolled into this study. These patients' charts were pulled from medical records and information about their demographics and hospital stay were recorded on a data collection sheet (Figure 6). This was an IRB approved study that did not require consent due to its non-invasive, retrospective nature. The following Accounting of Research Disclosures sheet (Figure 5) was filed into each patient's chart to indicate that their information was used in the study:

Figure 4: Accounting of Disclosures form added to the back of each chart

The following is the data collection sheet that was used, it indicates all information retrieved from each chart:

Figure 5: Data Collection Sheet used for the study.

The demographics data were obtained from the chart and MEDITECH (an electronic database of UMass patient information). This information includes: Name, MRN (Medical Record Number), Age, Gender. Time and date of ED arrival/admission, admission location, and LOS were recorded as stated in MEDITECH Abstract, with LOS in whole days. The tables of Pre-Hospital Medication, Vital Signs, Medication, Airway Management, Urine Output, and ER chart diagnosis were recorded from the physician and nurse ED records. Home medications were recorded from the Medication Reconciliation Form. Medical history was compiled from a combination of forms including the nurse records, physician records, discharge summary, and interdisciplinary care form. Laboratory values (Na, Cl, K, HCO_3, BUN, Cr, glucose, BNP) and EF were recorded from the Laboratory data section of MEDITECH.

After all required data were collected, each data collection sheet was entered into an Excel database as seen in Figure 7. A key for this database can be found in Table 3, which explains the definition of each column header.

Figure 6: Example Portion of Excel Database. Names and Medical Record Numbers are blurred for patient privacy

Table 3: Information Entered into Excel Database (with definitions)

Column Title	Definition
DOS	Date of Stay (Admission Date)
(Name)	Patient Name (Last, First initial)
Age	Age (years)
Gender	Male or Female, where Male = 1, Female= 0
n	Patients number in the study
MRN	Medical Record Number
LOS	Length of Stay in whole days
Floor	Patient admission to a floor, where yes = 1, no = 0
ICU	Patient admission to the ICU, where yes = 1, no = 0
Death	Patient mortality/survival, where mortality = 1, survival = 0
NIV	Non-Invasive Ventilation (CPAP/BiPAP) during ED stay, where yes = 1, no = 0
Vent/ETI	Ventilation through Endotracheal Intubation, where yes = 1, no = 0
Vaso?	Administration of vasodilator during ED stay, where yes = 1, no = 0
Min 1st vasodil	Minutes from ED arrival to administration of the first dose of vasodilator
BP goal?	Did the patient's BP reach ≤ 140 systolic during the ED stay
Min BP ≤ 140	Minutes from ED arrival to achievement of BP goal (≤ 140 systolic)
Initial ED SBP ≤ 140	BP at goal (≤ 140 systolic) upon arrival to ED
Diuretic	Administration of diuretic during ED stay, where yes = 1, no = 0
Min 1st lasix	Minutes from ED arrival to administration of the first dose of diuretic
ACEI	Administration of ACE-inhibitor during ED stay, where yes = 1, no = 0
Min 1st ACEI	Minutes from ED arrival to administration of the first dose of ACE-inhibitor
Total UO	Total urine output during ED stay (in ml)
BNP	B-type natriuretic peptide value for any time during this hospital stay
Creat	Creatinine level for first set of labs
ED arrival	Time of ED arrival (in military time)
To Floor	Time of floor/ICU admission (in military time)
Time to Admit	Minutes between "ED arrival" and "To floor," equal to total minutes in the ED
3 week return?	Patient return to ED for HF exacerbation in the next 21 days, where yes = 1, no = 0
Blank (for other notes)	Other notes such as: death during later admission, return outside the 21 day limit, admissions during the 21 day limit for other diagnoses, other important diagnoses during hospital stay

The data from the database was analyzed using the program GraphPad which contains statistics, curve fitting, scientific graphing abilities.

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CHARACTERISTICS OF STUDY POPULATION

This study enrolled 85 patients, 50 males and 35 females. The range of patient ages was 41-95 years, with a mean age of 75.02 and standard deviation of ± 13.97. The average age for the female patients was 80 years and the average age for male patients was 69 years. ED lengths of stay averaged at 587 minutes, or 9.78 hours, with a range of 40 to 1600 minutes. Hospital lengths of stay ranged from 1 day to 22 days, with a mean of 5.23 days and a standard deviation of ± 4.3. 65 of the 85 patients were admitted only to a hospital floor after leaving the ED. The average EF was 42%, the average BNP was 1468pg/mL, and the average urine output (UO) during ED stay was 1078mL. A summary of this information can be found in Table 4. Five patients were admitted only to the ICU after leaving the ED. 15 patients were admitted to both the ICU and a floor during their hospital stay. Only three of the patients died during the studied admission. 44 patients arrived to the ED with systolic blood pressures at the goal ($\leq$ 140mmHg), another 28 reached the blood pressure goal during their ED stay. 18 patients required non-invasive ventilation, while three patients required intubation and invasive mechanical ventilation. Patient information regarding pharmacologic treatment can be found in Table 5.

Table 4: Characteristics of Study Population during ED Stay

Characteristic	Minimum	Maximum	Average
Age (years)	41	95	75.02
ED LOS (minutes)	40	1600	587
Hospital LOS (days)	1	22	5.23
EF (% volume)	10	75	42
BNP (pg/mL)	110	6125	1468
UO (mL)	0	3055	1078

Table 5: Drug Administration during ED Stay

Treatment received	Number of Patients	Average time to Treatment (min)
Vasodilator	34	40
Diuretic	63	181
ACE Inhibitor	3	389

POPULATION VALIDATION

There is a significant difference between EFs in men and women (p= 0.0292) and between EFs in young patients (<65 years) and old patients (>65 years) (p=0.0199). These results (Figure 8 and Figure 9) are consistent with existing data showing that the average EF for a female in the studied population was around 48% while the average EF for a male in the studied population was around 38% (Philbin et al 2000; Senni et al. 1998). In addition, those above the age of 65

had an average EF of 45% while those under the age of 65 had an average EF of 33% (Philbin et al. 2000; Wong, Fukuyama, and Blanchette 1989). As stated earlier, it is now believed that heart failure in men and women comes from distinct mechanisms. In women, heart failure tends to occur later in life. This is also consistent with our study population, in which the average female age was 80 years while the average male age was 69 years. It usually manifests itself as diastolic dysfunction with a stiffened heart and normal to high EFs (Philbin et al 2000). In men, heart failure tends to occur earlier in life, as a result of systolic dysfunction (Philbin et al. 2000). Men generally have very low EFs and a poor prognosis.   This is thought to be due to gender-specific differences in myocardial adaptation to pressure overload. A study of men and women with isolated systolic hypertension found differences in their echocardiographs (Krumholz, Larson, and Levy 1993). Women tended to have concentric left ventricular hypertrophy with no changes in the inner ventricle size. Men had eccentric hypertrophy with left ventricle chamber enlargement. The fact that the data of this study is congruent with previously published data (Krumholz, Larson, and Levy 1993; Philbin and DiSalvo 1998; Philbin et al 2000) indicates that this study has targeted the correct population (heart failure patients).

Figure 7: Average Ejection Fraction in Males and Females. There was a statistically significant difference between these two populations, p=0.0292, run as a two-tailed Student's T test.
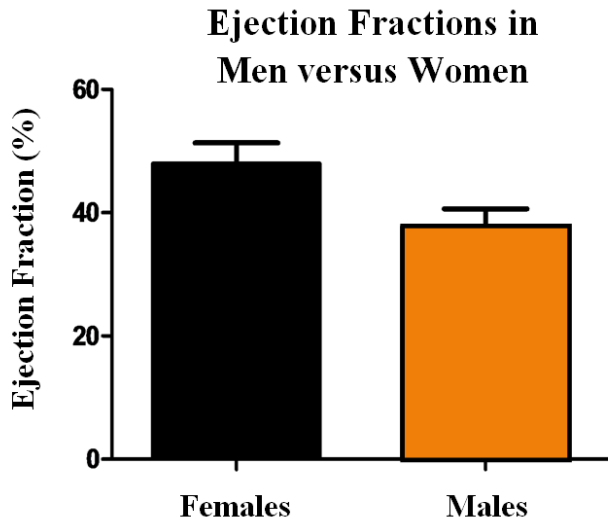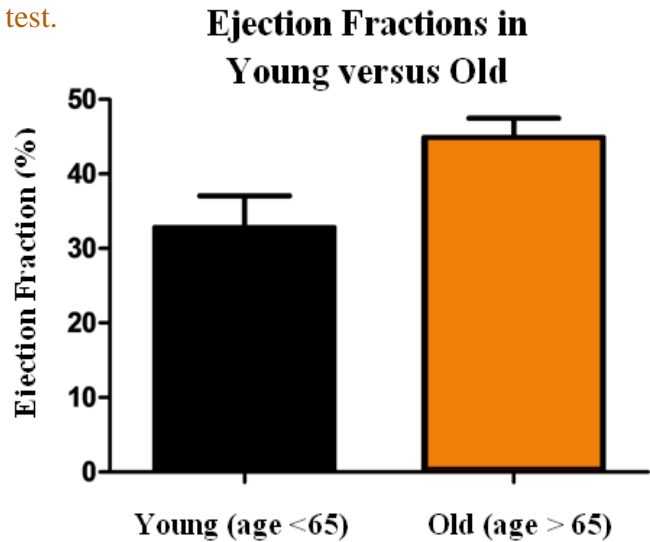
Figure 8: Average Ejection Fraction in Younger Patients and Older Patients. There was a statistically significant difference between these two populations, p = 0.0199, run as a two-tailed Student's T test.

Ejection Fractions in Men versus Women

Ejection Fractions in Young versus Old

ED LENGTH OF STAY

Figure 10 shows that heart failure patients spend a significant amount of time in the ED, whether they are admitted to a hospital floor or the ICU. There was an average ED stay of 430min (7.2 hours) for those admitted to the ICU at some point during their stay and 630min (10.5hours) for those only admitted to a hospital floor. This supports the hypothesis that the ED does have an effect on patient care since they spend a large amount of time in the ED for each heart failure admission. As mentioned earlier, recent national large-scale studies have found that ED length of stay can have large impacts on patient outcomes (Diercks et al 2007). As ED and hospital crowding becomes an increasingly common problem, critically ill patients spend longer in the ED as they await transfer. With the ED not intended to provide on-going care and reassessment, these patients often suffer from a lack of attention and care that could improved with shorter ED stays. It should be noted that this issue is not solely an ED problem. Part of the cause of ED crowding and prolonged ED stays are total hospital crowding; patients waiting in the ED for available beds on a hospital floor. A larger sample size and investigation into the causes of such stays area few of the next steps for this research.

Time Spent in the ED

Figure 9: Time Spent in the ED. The time spent in the ED between ED admission and transfer to a floor or ICU. (p=0.0167, run as a two-tailed Student's T test)
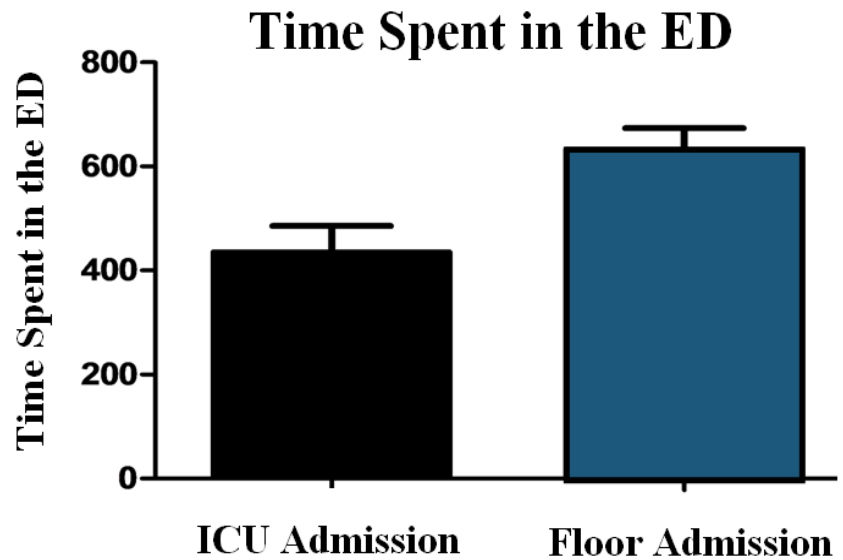
EARLY DIURETIC ADMINISTRATION

Figure 11 shows the effect of early diuretic administration on patient length of stay. This comparison yielded p=0.330 with a one-tailed Student's T test (hypothesis: early use of diuretics in the ED for patients with heart failure will lead to a decreased length of stay). The results found that the length of stay was 0.29 days (6.96 hours) longer for patients who did not receive diuretic early in their ED stay. Diuretics are administered to most heart failure patients during

Figure 10: Length of Stay and Timing of Diuretic Administration. Difference not statistically different, p=0.330, run as a one-tailed Student's T test.
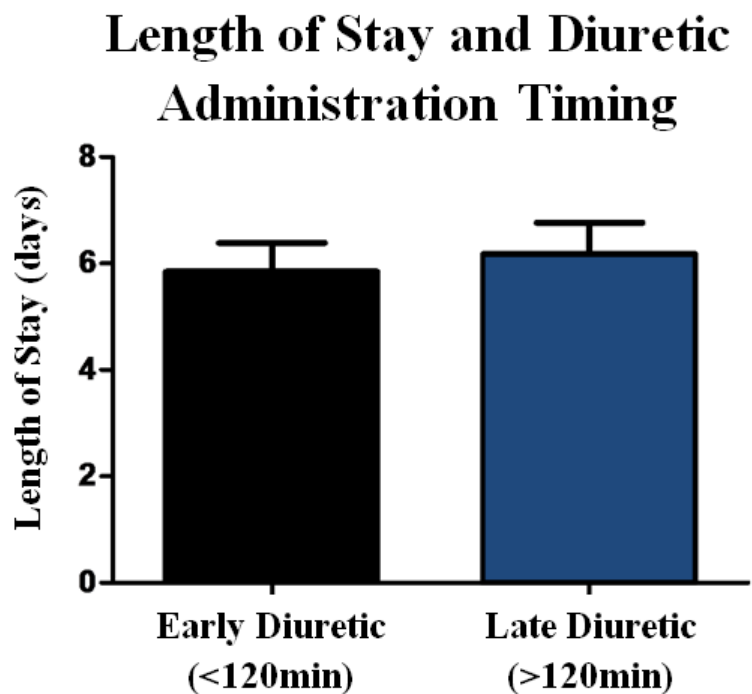
their hospital stay. Although certain aspects of diuretic administration have been analyzed, timing of administration remains understudied. This study compared the outcomes in patients that received diuretic earlier in their ED stay (<120min after ED arrival) or later in their ED stay (>120min after ED arrival). Although there is a slight decrease in LOS for patients who received early diuretic, there is currently no statistical difference. However, the somewhat low p value (p=0.330) indicates that there might be statistical significance for this comparison in a larger population size. If the difference between the two groups remained the same with the addition of another 500-600 patients in each group, the results would likely become significant. Large sample sizes can find significance in very small differences where this small sample size cannot. Small differences in hospital stay can have large impacts on patients and hospitals. For hospitals it frees up beds for additional patients and reduces cost for each patient. With the high volume of heart failure patients, small differences can add up to big savings. For patients, less time in the hospital may have positive impacts on their physical and emotional well-being.

The limitations of studies that involve length of stay should be noted. Because of the many confounding variables, length of stay is a hard outcome to analyze. First, length of stay (as used in this study) is based on the number of calendar days that a patient's stay spans, not their total hours divided by 24 hours/day. Therefore, the length of stay can be somewhat inaccurate. Second, patient length of stay is affected by many other variables. Patient discharge can be determined by ambulance or family availability for pick up, meal times, infection or other illness acquired after the hospital admission, etc. This means that length of stay is not simply a function of patient health. Hopefully larger sample size would help to eliminate the effect of some of these variables. Continuing research in this area should also attempt to exclude patients whose length of stay is definitely affected by these variables.

Despite its labeling as the new epidemic of the 21st century, heart failure remains understudied. This has led to a lack of understanding of how heart failure occurs, what treatments are most effective, and which patient outcomes are most important. Because of this type of confusion and uncertainty, it has been recommended that more studies be completed to develop more effective care strategies (O'Connell 2000). This study attempted to answer some of the questions about heart failure treatment in the ED. Future studies can build off of these methods and improve them with increased patient enrollment, expanded investigation, and tightened control of confounding variables.

Possibly the most obvious flaw in this research was the small population size of 85 patients. This research needs to be expanded to enroll many more patients. To find significance in very small differences between groups, this study would need to enroll at least 1,200 more patients. Other heart failure studies such as the ADHERE study have enrolled upwards of 100,000 patients. Making this study a large-scale, multi-center study could improve its accuracy and representativeness of the nation's heart failure population as a whole.

Future research in this area might expand the research and look into different variables of emergency care as well. For example, although this study looks at how long patients spend in the ED waiting for transfer to a hospital floor, it does not take into account the length of their pre-hospital ride or the length of their symptoms prior to hospitalization. These might be variables to look into, either to study specifically, or to control in order to diminish their effect on the results.

Future studies could also analyze the ED treatment methods more intensely. For many of the current treatment options, timing, dosage, and dosage frequency remain debated issues (Butler et al. 2004; Philbin, Cotto, Rocco 1997; Gheorghiade, 2005; Sackner-Bernstein et al. 2007; Peacock et al. 2006). Drug administration time was investigated to determine time sensitivity, however drug dosage was not. Perhaps giving larger or smaller dosages of some medications could have an effect on short term outcomes. Similarly, the frequency of such doses could also have an effect on patient outcome. The collective affect of timing, dosage, and dosage frequency could be studied together in future research as well, to see how the three factors are inter-related. The use of supplemental oxygen, non-invasive ventilation, and endotracheal intubation are other factors that were recorded during this study but could be investigated more deeply.

One issue with this study was poor documentation in the ED notes. Treatment, vital signs, urine output, and ED diagnoses were sometimes illegible or undocumented. This can yield results that are not truly representative of the study population. This was especially true for urine output records. For many patients there was no recorded urine output, despite ED stays surpassing 8 hours and administration of diuretics. This is likely the result of poor documentation, rather than a lack of urination. Future studies should keep the impact of poor documentation in mind and try to minimize its effect, possibly through exclusion of patients with incomplete documentation or

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through prospective studies that monitor patient care in real time. It might also be of interest to perform a study that looks at the effects of poor documentation on patient care in the ED.

Considering the effects of ED and hospital crowding discussed earlier, future studies might consider its effects on care of heart failure patients. Crowding leads to a decreased nurse to patient ratio and can decrease quality of care. Another step, in the future, might be to look at how crowding effects heart failure patient outcomes. Do patients treated in the ED hallway have poorer outcomes than those that receive immediate care in an ED room? Do patients that wait for a hospital room in "ED inpatient waiting" experience poorer results? Do patients treated in overburdened EDs suffer the consequences of a lack of attention? These issues could be investigated as additional variables affecting short term outcomes such as length of stay or readmission.

Patient initial condition was a problem encountered during data analysis. Patients receive different treatment courses depending on how they present to the ED. By the laws of triage, it is often the case that the sickest patients receive more attention and earlier treatment. This could lead to a correlation of early drug administration with poor outcome simply because those patients that receive the drug early are worse off to begin with. In the same sense, the research might find that patients that receive ventilation (invasive or non-invasive) tend to have worse outcomes. Again, these patients are usually sicker upon arrival, and therefore have poorer outcomes. In the future, controlling for patient condition could be helpful to minimize this problem. Using a standardized system to determine a patient's condition at various times throughout their stay could control for this. A scale like the APACHE II score (which uses a 71 point scale to calculate a severity of disease score based on 12 physiologic measurements) calculated for ED arrival, hospital admission and discharge is one way to accomplish this. With this score, patients could then be compared to themselves or analyzed as groups of patients with similar disease severity. In addition to further controlling confounding variables, this adds an interesting dimension to the research. Researchers could investigate whether certain aspects of ED care affect patients with varying disease severities differently.

Lastly, in addition to changing some study aspects and controlling for confounding variables, future research could look at other outcomes as well. This study focused on short term outcomes, yet long term outcomes may be just as, or even more important. Patient readmission or death over long post-discharge periods (such as over the following few months or years) may be other important outcomes to investigate.   Other outcomes to consider include: ejection fraction, stable blood pressure, reduced edema/congestion.

The hope of this study is that it will serve as an initial investigation into ED care of heart failure. This study has significant flaws yet can serve as a step towards a greater understanding of ED heart failure treatment. It highlights some successful and unsuccessful clinical research methods while underscoring the need for further study in the area of ED management of heart failure.

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