HEART FAILURE

DATA ANALYSIS REPORT

Comprehensive Clinical Insights & Risk Stratification

Analysis of 2,008 Hospitalized Heart Failure Patients

Data Source:

PhysioNet Heart Failure Zigong Dataset v1.3

https://physionet.org/content/heart-failure-zigong/1.3/

Analysis Tools:

Python (Pandas, NumPy, Plotly) | Streamlit Dashboard

EXECUTIVE SUMMARY

This comprehensive analysis examines heart failure patient data across 2,008 hospitalized patients through four integrated analytical dimensions: cardiac complications, demographics and patient history, hospital discharge patterns, and laboratory biomarkers.

Critical Findings

- High-risk patients with **NYHA Class 4 + Killip Class 4** account for **64% of in-hospital deaths**
- Three-biomarker risk score (lactate, sodium, troponin) identifies patients with **40x higher mortality risk**
- Highest complication burden patients show **50% readmission rate at 6 months**
- ICU patients with impaired GCS account for **64% of deaths**
- Prolonged hospital stays (≥15 days) associated with **16.1% readmission rate**

1. CARDIAC COMPLICATIONS ANALYSIS

1.1 Overview

The cardiac complications notebook provides a comprehensive analysis of heart failure severity indicators including NYHA classification, Killip grading, left ventricular function, and combined complication burden

scoring. The analysis reveals critical patterns in ICU admissions, mortality risk, and readmission trajectories.

1.2 Key Clinical Findings

Patient Condition Distribution:

- 31% of patients have higher NYHA (New York Heart Association) classification.
- 93.2% had congestive heart failure (CHF).
- 74% had both systolic and diastolic heart failure.

Left Ventricular End-Diastolic Diameter (LVEDD) Analysis:

Higher ICU admission rates (1.9% vs 0.7% for normal LVEDD). Even with small absolute ICU counts, the percentage within dilated LVEDD groups is significantly elevated, indicating these patients present with more severe disease requiring intensive care.

NYHA Classification and Mortality Risk:

NYHA Class 4 represents the highest-risk group with the following characteristics:

- Most in-hospital deaths occur in NYHA Class 4 patients.
- NYHA Classes 3 and 4 have highest cardiology admissions and significant ICU utilization.
- Emergency admission proportions are similar across NYHA 2-4 with mild increase in Class 4.
- 60+ year old patients require careful monitoring as 3rd and 4^{th} Killip grades are prevalent.

Killip Grade Analysis:

Mortality increases significantly with Killip grade:

- 4th Killip grade shows increasing mortality during hospitalization
- Death within months is high among 3rd and 4th Killip grades
- Combined NYHA 4 + Killip 4 accounts for 64% of 11 deaths, representing the highest risk group

1.3 Complication Burden Scoring

A complication burden score was created based on three cardiac conditions: myocardial infarction, congestive heart failure, and Peripheral vascular disease. Patients receive 1 point for each condition (score of 3) demonstrate no excess mortality but show markedly higher 6-month readmission rates at 50%, compared to 36-42% for lower burden scores. This indicates they represent a chronic management challenge rather than acute lethal risk.

1.4 Combined Severity Risk Stratification

IV accounts for 64% of deaths from just 11 total deaths. Patients with NYHA 4 + Killip ≥3 represent 31.5% of the cohort and constitute the highest risk group requiring intensive monitoring and intervention.

1.5 Clinical Implications

1. *Immediate ICU Consideration:* Patients with severe LVEDD dilation require immediate assessment for ICU admission given 2.4x higher.
2. *High-Risk Identification*: NYHA 4 + Killip ≥3 patients (31.5% of cohort) require enhanced surveillance and aggressive therapeutic intervention.
3. *Readmission Prevention:* High complication burden (score 3) patients need comprehensive 6-month follow-up programs to address the 50% readmission rate.
4. *Post-Discharge Monitoring:* CHF patients require careful follow-up as they demonstrate 2.35% vs 9.56% mortality after discharge.

2. DEMOGRAPHICS , PATIENT HISTORY AND PATIENT PRESCRIPTIONS ANALYSIS

2.1 Overview

This comprehensive notebook analyzes patient demographics, comorbidity patterns, frailty phenotypes, and prescription medication patterns. The analysis reveals critical insights about age distributions, BMI

categories, chronic disease burden, and medication utilization across different clinical contexts.

2.2 Demographic Profile

Population Characteristics:

- Total patients: 2,008 (1,163 Female, 845 Male).
- Gender distribution: 58% Female, 42% Male.
- Peak age group: 79-89 years (21% of total population).
- Majority age range: 69-89 years for both males and females.
- Primary occupation: Urban residents (84%), followed by Farmer occupation.
- BMI distribution: Majority in Healthy Weight category.

Emergency Admission Patterns:

- Obese category, despite representing small percentage of population, shows significant emergency admissions.
- 69-89 age group demonstrates higher percentage of emergency admissions
- Urban residents have highest inpatient mortality (potentially due to highest representation in dataset).

2.3 Frailty Phenotype and Mortality Analysis

Underweight patients show significantly higher post-discharge mortality, indicating low physiological reserve and increased likelihood of destabilization after hospitalization.

Clinical implications:

- BMI paradox is broken here.
- Cardiometabolic obese patients show high long-term readmission burden reflecting chronic HF progression and metabolic/respiratory comorbidities.
- Younger adults (despite lowest readmission rates) still demonstrate 35% 6-month readmission rate, indicating systemic rehospitalization risk across all age groups.

2.4 Comorbidity Burden Analysis

Charlson Comorbidity Index (CCI) Distribution:

The CCI score quantifies comorbidity burden, with higher scores indicating greater risk. A score of 5 or more is classified as severe comorbidity. In this dataset, 16 patients have CCI scores ≥5.

Common Comorbidities:

- Diabetes: 23% of patients.
- Moderate to severe chronic kidney disease: 24%.
- COPD (Chronic Obstructive Pulmonary Disease): 12%.
- Rare conditions: Hemiplegia, AIDS, solid tumors (\<2%); Leukemia (absent).

Cerebrovascular Disease and CCI Stratification:

No cerebrovascular patients with CCI ≥5 died in hospital (small sample size requires cautious interpretation). Among cerebrovascular patients with CCI ≥5, approximately 91% admitted to cardiology (higher than overall 77% cardiology rate). Emergency admission rate of 27% in CCI ≥5 cerebrovascular group, indicating clinically vulnerable subgroup.

2.5 Respiratory Complications

COPD and Type II Respiratory Failure Correlation:

Among 2,008 hospitalized patients:

- 233 (11.6%) diagnosed with COPD.
- 114 (5.7%) had Type II respiratory failure.
- Among COPD patients: 30 (12.9%) developed Type II respiratory failure.
- Among non-COPD patients: 84 (4.7%) had Type II respiratory failure patients, indicating increased vulnerability.

Type II Respiratory Failure Clinical Profile:

- Admission pattern: 47% emergency, 53% non-emergency.
- Ward distribution: 65% cardiology, 17% general ward, 6% ICU.
- In-hospital mortality: 2.6%.
- Strong statistical association between Type II respiratory failure and ICU admission.

2.6 Diabetes and Mortality Trends

28-day mortality was low in both diabetics and non-diabetics (approximately 1.7-1.9%), but shows gradual increase over time. This suggests diabetes contributes to long-term mortality risk rather than

acute in-hospital outcomes.

2.7 Medication Prescription Patterns

Most Prescribed Medications:

Spironolactone tablet: 1,833 participants (highest consumption) - oral medication for heart failure, hypertension, fluid retention (25-100mg daily).

Furosemide tablet: High usage - oral diuretic for fluid removal (20-80mg morning dose).

Furosemide injection: High usage - IV/IM administration for rapid fluid removal in emergencies (20-40mg per dose).

Dobutamine hydrochloride injection: 22 participants (lowest consumption) - inotropic support for severe cases.

Department-Specific Medication Patterns:

- High usage: Aspirin, Atorvastatin, Deslanoside, Furosemide (tablet and injection), Spironolactone.
- High usage: Digoxin tablet, Furosemide (tablet and injection), Valsartan Dispersible tablet, Spironolactone tablet, Aspirin, Atorvastatin Calcium tablet.

Emergency Admission Medication Profile:

Medications with significant emergency use:

- Spironolactone tablet
- Furosemide injection
- Furosemide tablet
- Deslanoside injection (notable high percentage in emergency)
- Aspirin enteric-coated tablet (notable high percentage in emergencies).

3. HOSPITAL DISCHARGE AND PATIENT FLOW ANALYSIS

3.1 Overview

This extensive analysis examines hospital discharge patterns, patient flow through departments, length of stay correlations, readmission patterns, and mortality trends. The notebook includes descriptive

analysis, diagnostic evaluation, and attempted predictive modeling for 28-day readmission risk.

3.2 Key Outcome Distributions

- 67% of patients discharged home.
- 77% of admissions to Cardiology department.
- 52% non-emergency vs 48% emergency admissions.
- 85% discharged from Cardiology department.
- Respiratory support: 59.5% invasive mechanical ventilation (IMV), 40.5% non-invasive (NIMV).
- 94.5% received oxygen therapy.
- 94% alive at discharge.

3.3 Length of Stay (LoS) Analysis

LoS Distribution:

- 25th-75th percentile: 6-10 days
- Majority of patients (80-90%) were discharged within 14 days across all.

Department-Specific LoS Patterns:

- Cardiology and General Ward: Over 83% discharged within 2 weeks, following similar patterns.
- ICU: 73% discharged within 2 weeks, BUT 13.3% stay longer than 30 days (highest long-stay proportion) hospitalization represents significant resource utilization. This pattern should inform capacity planning for ICU beds, ventilation support, and specialized staffing.

LoS and Mortality Correlation:

LoS ≥15 days, though deaths also occur at shorter stays. Within Cardiology department, death outcome is more common in 15+ days LoS group, indicating prolonged stay patients represent higher-risk subgroup

requiring additional precautions and intensive management.

LoS and Readmission Risk:

readmission risk. Only 9.8% of non-readmitted patients had LoS ≥15 days, compared to 16.1% of 3-month readmissions and 14.1% of 6-month readmissions. This suggests either sicker patient requiring longer
stays or inadequate discharge preparation for complex cases.

3.4 Visit Frequency Analysis

Majority of patients are in first or second visit categories. This represents total number of hospital visits up to current admission.

- Cardiology handles highest volume of total visits (chronic disease/long-term care patients).
- ICU has very low total visit counts (critical short-term admissions) but HIGH repeat rate due to severity.
- Others and General Ward show lower repeat visit percentages requiring additional care coordination or discharge follow-up programs.

3.5 Mortality and Readmission Metrics

Mortality Timeline:

- Gradual increase in death observed from 28 days to 6 months post-discharge.
- ICU demonstrates highest 3-month death rate among all departments.

Readmission Patterns:

- Gradual increase in readmissions from 28 days to 6 months.
- Return to emergency department within 6 months: 39% (significant proportion).
- 28-day readmission highest in Others and Cardiology departments.
- Cardiology shows increasing readmission percentage over time (28 days to 6 months).
- Readmission within 28 days higher percentage in both 8-14 days and 15-30 days LoS groups and
  38.5% 6-month readmission, representing a transitional care crisis requiring intervention.

3.6 Patient Flow and Department Transitions

Admission Way to Admission Ward Flow:

- Most Emergency admissions flow to Cardiology and General Ward.
- Non-Emergency patients heavily utilize Cardiology, with minimal ICU.
- ICU admissions are rare (critical triage or capacity constraints).

Cardiology Self-Containment:

with only small fraction transferred to ICU, Others, or General Ward. This reveals Cardiology as a self-contained unit with minimal inter-department handoff.

Discharge Destinations by Department:

- Cardiology: ~80% discharged home, 2% died.
- ICU: Highest death rate at ~33%.

3.7 Respiratory Support and Outcomes

Invasive Mechanical Ventilation (IMV):

- 16% of patients with IMV respiratory support died.
- 60% of patients who had IMV support remained alive.
- IMV strongly correlates with ICU-level interventions and critical conditions

Non-Invasive Mechanical Ventilation (NIMV):

- Shows mixed outcomes, suggesting partial severity but often survivable and 0% mortality in NIMV group vs ~12% in IMV group.

No Respiratory Support:

- ~98% did not receive respiratory support (lower clinical severity for majority).
- 76.5% of these patients remained alive difference in outcomes between IMV and NIMV groups is significant. Respiratory support type should be considered a key risk flag for outcome prediction and triaging.

3.8 Oxygen Therapy Patterns

- Cardiology and General Ward: Highest percentage receiving oxygen therapy.
- ICU patients: Majority received oxygen therapy (consistent with critical care needs).
- Ambient air use: More common in Others and General Ward departments.

3.9 Emergency Department Returns

NONE were recorded as deceased in department within 6 months of discharge. Mortality cases occurred only among those who did not return to emergency care. This suggests patients who seek emergency care may receive life-saving interventions.

3.10 Predictive Modeling Attempt

- Dataset highly imbalanced (\~7% readmitted).
- Model achieved 92% accuracy by mostly predicting no readmission.
- Recall and precision for readmitted patients (class=1) both zero.

- ROC AUC ≈ 0.51 (no better than random guessing) imbalance and possibly insufficient predictive features.
- Next steps should include dataset balancing, additional clinical predictors, and alternative modeling approaches.

4. CARDIAC COMPLICATIONS:

- Null values are present in LVEF, left_ventricular_end_diastolic_diameter_LV,mitral_valve_EMS, mitral_valve_AMS , EA, tricuspid_valve_return_velocity,tricuspid_valve_return_pressure columns.
- Handling extreme outliers in biomarkers and converting them to null and no duplicates.

Biomarker	Normal Range	Datavalues-dataset	Action
LVEF	50-70%	5% (impossible)	<30% → NULL
LV end-diastolic diameter	42-59mm	0.3mm (catheter error)	<30mm or >80mm → NULL
Mitral E velocity (EMS)	0.6-1.3 m/s	0.03 (measurement error)	<0.3 or >2.5 → NULL
Mitral A velocity (AMS)	0.6-1.0 m/s	409 (artifact)	<0.3 or >2.0 → NULL
E/A ratio	0.75-1.5	21.3 (diastolic dysfunction max)	<0.5 or >3.0 → NULL
Tricuspid velocity	2.5-3.0 m/s	0.9 (too low)	<2.0 or >4.0 → NULL
Tricuspid pressure	15-30 mmHg	87 (severe PH)	>60 → NULL

- 31% of patients have higher NYHA.
- 22.5% PEOPLE COME UNDER higher killip_grade risk grade.
- 7.1% of the population had myocardial infarction.
- 93.2 had congestive heart failure.
- 5% had peripheral_vascular_disease.
- 74% both had heart failure.
- 79% of moderate/severe LV dysfunction have biventricular HF.
- Mild dysfunction equally split Emergency/NonEmergency.
- No ICU escalation despite severe systolic dysfunction.
- Zero in-hospital mortality among worst LVEF patients.

- Severe LV dilation patients had 2.4x higher ICU admission rates (1.9% vs 0.7% Normal).
- Abnormal TR velocity is common: about half of measured patients have elevated or severe pulmonary pressures.
- Biventricular HF link: ≈75% of elevated/severe PHTN cases have Both-sided HF, reinforcing the association between pulmonary hypertension and global cardiac failure.
- Pathway neutral: TR velocity does not materially change Emergency vs Nonemergency admission rates or ICU allocation in this dataset; these pathways seem driven by other factors (e.g., clinical instability, comorbidities).
- **Higher NYHA class (especially Class 4) represents more advanced heart failure, and in this cohort:**
- The proportion of emergency admissions is similar across NYHA 2–4, with only a mild increase in Class 4.
- NYHA class 3 and 4 have highest cardiology and significant ICU admissions
- Most in-hospital deaths occur in NYHA Class 4, supporting its role as the highest-risk group, although absolute mortality is low.
- Deaths that happened in NYHA class 3 and 4, they belonged to 69-79 and 79-89 age group indicating to closely monitor this group and BMI doesn't have a deep impact on deaths.
- Killip Grade I–IV is used in heart attack patients to describe the severity of heart failure and risk based on exam findings. Higher the grade, higher is the severity.
- The mortality is increasing during hospitalization for 4th Killip grade
- Death within months is also high among the 3,4th Killip grade
- 60+ year old patients have to be monitored carefully as, 3rd and 4th Killip grades are prevalent in that section.
- Significant readmission within 6mths, and visit times is small but significant and no major ICU and outcome as death, meaning good medication can control
- Emergency admissions: 25 out of 76 MI emergency admissions are readmitted within 6 months (~33%)
- Non-emergency admissions: 26 out of 67 non-emergency MI admissions are readmitted within 6 months (~39%)
- Both emergency and non-emergency admission types for myocardial infarction patients have substantial readmission rates within 6 months.

- Congestive heart failure has almost same emergency and non-emergency admissions. 1st and 2nd visit times are high. readmission within 6mths is significant. ICU admissions are prominent(~90%). has major impact on Death outcomes. both right and left heart failure is observed in majority of patients with congestive heart failure. Death within 6 mths is significant.
- In this cohort, patients with congestive heart failure had slightly higher mortality after discharge compared to patients without CHF (2.35% vs 9.56% in our dataset). Although the increase is modest, it indicates that CHF patients require careful follow-up and monitoring to reduce post-discharge risk.
- myocardial infraction has slightly high emergencies compared to non-emergency admissions. 1st visit is high and 2nd visit time is significant. readmission within 6mths is significant. icu admissions are non-prominent. has slight impact on Death outcomes. both right and left heart failure is observed in majority of patients with myocardial infraction. Death within 6 mths is significant.
- myocardial_infarction,congestive_heart_failure,peripheral_vascular_disease are considered as complicated columns and give a score of 1 when patients had them
- **Insights:** Patients with highest complication burden (3 conditions) show no excess mortality but markedly higher 6-month readmission (50% vs 36-42% for lower burdens), indicating they represent a chronic management challenge rather than acute lethal risk.

High Burden Patient Characteristics:

- Ward distribution: High-burden patients are predominantly Cardiology (70%) with modest increases in General Ward (19%) and Others (10%). ICU remains rare (~1%) regardless of burden.
- Admission pathway: High-burden patients show similar Emergency/Nonemergency split (50/50) as low-burden patients, indicating complexity is evenly distributed across admission types.
- Key takeaway: Complication burden reflects chronic cardiac complexity (Cardiology-heavy) rather than acute decompensation requiring ICU/Emergency care.
- Insight: NYHA IV + Killip IV = 64% of 11 deaths , Severity scoring validated

5. LABORATORY BIOMARKERS AND CLINICAL OUTCOMES

5.1 Overview

This notebook represents the most clinically impactful analysis in the portfolio. It examines laboratory biomarkers relationship with patient outcomes, creating a novel three-biomarker risk scoring system that demonstrates exceptional prognostic value. The analysis integrates cardiac markers, renal function, electrolytes, and neurological assessment (Glasgow Coma Scale) with mortality and readmission outcomes.

5.2 Three-Biomarker Risk Score Development

After evaluating 12 initial biomarkers, the analysis identified three critical markers with strongest prognostic impact:

5.3 Selected Biomarkers:

- Lactate (≥2.0 mmol/L abnormal) - indicates tissue hypoperfusion and shock physiology.
- Sodium (\<135 mmol/L abnormal) - indicates heart failure decompensation.
- High-sensitivity Troponin** (\>0.04 ng/mL abnormal) indicates myocardial injury (Score 0-3).

5.4 Risk Score Validation and Clinical Impact

Mortality Gradient:

mortality risk compared to Score 0 patients:

- 28-day mortality: Score 3 = 6.1% vs Score 0 = 0.15% (40x increase).
- 3-month mortality: Score 3 = 7.1% vs Score 0 = 0.3% (23x increase).
- 6-month mortality: Score 3 = 8.1% vs Score 0 = 0.6% (13x increase).

medications take effect, transitioning from acute instability to chronic management.

Readmission Gradient:

elevated readmission risk:

- 28-day readmission: 15.2%
- 3-month readmission: 33.3%
- 6-month readmission: 46.5%

indicating chronic disease burden requiring prolonged follow-up and management optimization.

5.5 Analysis of Deaths: Biomarker Profile

Among 11 total in-hospital deaths, biomarker analysis reveals:

Top Abnormal Biomarkers in Fatal Cases:

- Troponin \>0.04: 9/11 deaths (81.8%) - indicates myocardial injury.

- Lactate ≥2.0: 8/11 deaths (72.7%) - indicates tissue hypoperfusion
- Sodium \<135: 5/11 deaths (45.5%) - indicates HF decompensation

Combined Biomarker Pattern:

acute myocardial injury combined with shock physiology.

Cryptic Shock Phenomenon:

(traditional hypotensive shock criteria). This represents cryptic shock pump failure with preserved blood pressure. Patients appear hemodynamically stable by vital signs but have severe underlying cardiac dysfunction revealed only by biomarkers.

5.6 Emergency vs Non-Emergency Admission Patterns:

Emergency admissions demonstrate significantly higher rates of high-risk biomarker scores (≥2) compared to non-emergency admissions, validating the clinical assessment at triage.

5.7 Cardiac Evaluation and Ward Triage Validation

Cardiology Admission Patterns:

While clinical teams recognized heart failure crisis, they critically under-triaged acuity, missing the biomarker-driven **silent killer.**

ICU vs Cardiology Risk Profiles:

- Top3 Biomarker Score: 1.33 (vs Cardiology 0.96).
- 28-day mortality: 13.3% (vs Cardiology 1.4%).
- Slightly higher pulse: 88 vs 84.
- MAP 94.3, SBP 130.4 Stable appearance.
- BUT Top3 Score 0.96 indicates hidden high risk.
- 7.6% readmission rate

higher scores and mortality. Biomarkers confirmed doctors identified sick patients despite similar vital signs. The biomarker score adds nuance by identifying hidden risk in apparently stable patients.

5.8 Integration with Cardiac Complications

Killip Grade 3-4 Patients:

- 4.5x higher 28-day mortality (6.3% vs 1.4%).
- Higher Top3 biomarker scores (1.12 vs 0.96 overall).
- Killip 3-4 severe HF patients had Top3 Score 1.12 + 6.3% mortality.

5.9 Two High-Risk Groups for Targeted Intervention

GROUP 1: CHF + Killip 3-4 (412 patients)

- 6.3% 28-day death (4.5x overall average)
- Moderate biomarkers: Top3 Score 1.12
- Action Required: Aggressive early HF therapy - ICU consideration despite normal vitals, GDMT optimization (ARNI/SGLT2i day 1), close 28-day surveillance.

GROUP 2: MI + CHF (133 patients)

- 8.3% 28-day readmission (vs 7% CHF+Killip)
- Milder biomarkers: Top3 Score 1.16
- Action Required: Prevent post-discharge deterioration - extended clinic follow-up (weekly x4 weeks), telemonitoring for ischemia/HFsignals, dual antiplatelet + HF meds compliance.

5.10 Glasgow Coma Scale (GCS) and Neurological Assessment

The responsiveness table contains Glasgow Coma Scale components (eye +verbal + motor responses), scoring 3-15 with higher scores indicating better neurological function.

GCS Risk Categories:

- Normal GCS: 97.6% of patients.
- High-Risk GCS: 2.4% of patients.

GCS and Emergency Admissions:

non-emergency patients (1.9%), demonstrate they arrived in poorer neurological condition.

GCS and Heart Failure Biomarkers:

(low GCS) also show abnormal heart failure biomarkers. Heart stress (high HF biomarkers) increases sharply as consciousness declines - 74% in normal GCS vs 92-100% in impaired GCS. This indicates strong cardiac stress co-exists with neurological compromise.

GCS and Mortality:

small proportion of admissions but accounted for ~64% of all in-hospital deaths (7 of 11). This suggests neurological responsiveness at admission is a strong early indicator of adverse outcomes.

GCS and Type II Respiratory Failure:

normal vs ~25% in severely impaired patients.

High-Impact Findings:

- Three-Biomarker Score: 40x mortality risk stratification with $p<0.00001$ represents actionable clinical tool.

- Cryptic Shock Identification: Recognition of pump failure with preserved blood pressure - critical for preventing missed diagnoses.
- GCS as Early Warning: Impaired neurological status at admission predicting 64% of deaths.
- Readmission Trajectory: Identification of acute-to-chronic care gap (0.55% → 38.5% readmission).
- Ward Triage Validation: Biomarkers confirmed clinical judgment while revealing hidden risk in stable-appearing patients.

6. ACTIONABLE CLINICAL INSIGHTS AND RECOMMENDATIONS

6.1 Immediate Clinical Interventions

Priority 1: Three-Biomarker Score Implementation troponin score at admission.

- Automatic cardiology consultation within 2 hours.
- Consider ICU admission regardless of vital signs (cryptic shock concern).
- Initiate aggressive HF therapy (GDMT optimization day 1).
- Close monitoring first 28 days (40x mortality risk window).
- Mandatory 6-month follow-up program (46.5% readmission rate).

Priority 2: GCS-Based Early Warning System

- Immediate ICU evaluation.
- Comprehensive cardiac biomarker panel (92% have abnormal HF markers).
- Respiratory assessment for Type II failure (25% prevalence).
- Assume multi-organ deterioration until proven otherwise.

6.2 Department-Specific Interventions

Cardiology Department:

- Address 7.6% readmission rate through enhanced discharge education.
- Implement biomarker-guided triage despite normal vitals (hidden risk identification).
- Focus on patients with LoS ≥15 days (higher death risk in cardiology)

ICU Department:

- Resource planning for 13.3% with LoS \>30 days (prolonged mechanical ventilation).
- High repeat admission rate indicates need for post-ICU follow-up.
- 13.3% 28-day mortality requires palliative care consultation early.

6.3 Population Health Interventions

High-Risk Population #1: CHF + Killip 3-4 (412 patients)

- ICU-level care pathway regardless of ward assignment.
- Daily biomarker monitoring first 3 days.
- 28-day mortality surveillance (6.3% risk vs 1.8% overall).

High-Risk Population #2: MI + CHF (133 patients)

- Extended clinic follow-up (weekly x 4 weeks, then biweekly x 4.
- Medication reconciliation at every visit (dual antiplatelet + HF.
- Cardiac rehabilitation enrollment.

6.4 Transitional Care Program

- Phone call within 48 hours of discharge (medication reconciliation, symptom check).
- Clinic visit within 7 days (not 30 days).
- Home health nurse visit for high-risk patients (Score 3, impaired).
- Teach patients 'red flag' symptoms requiring emergency evaluation.

6.5 Resource Allocation Priorities

ICU Capacity Planning: 13.3% of ICU patients require \>30 day stays - plan for long-term ventilator capacity.

Cardiology Follow-Up Clinic: Expand capacity for post-discharge visits (39% return to emergency within 6 months).

Laboratory Automation: Implement automated three-biomarker score calculation and alert system

Staffing: Monday admissions peak (consider staffing adjustment), November seasonal pattern.

Home Health Services: Contract expansion for frail/underweight patients (highest post-discharge mortality).