Project Title: Exploring the factors behind Hospital Readmission Rates

Team Members:

- Indirapriyadarshini Arunachalam (iarunachalam@umass.edu) - SPIRE ID: 34743317
- Athulya Anil (athulyaanil@umass.edu) - SPIRE ID: 34760586
- Rakshith Venkatesh (rakshith@umass.edu) - SPIRE ID: 34767593

Project Repository:

https://github.com/athulya-anil/hospital-readmission

Hospital Readmission Rates and Causes

Overview and Motivation:

Proposal

Hospital readmissions represent a critical performance metric in healthcare, signaling potential gaps in post-discharge care, chronic disease management, or coordination between providers. High readmission rates not only strain hospital resources and inflate healthcare costs but also jeopardize patient wellbeing by interrupting recovery and exposing patients to additional risks. Our project set out to bridge the gap between raw readmission data and actionable insights through interactive visualizations. By leveraging expertise in healthcare data engineering and web development, we aimed to surface key trends—across geography, patient demographics, clinical conditions, and hospital practices—in a user-friendly dashboard that empowers administrators, clinicians, and policymakers to pinpoint areas for targeted intervention.

Final Submission

In our final implementation, we translated this motivation into a fully responsive, multi-view dashboard that allows exploration of readmission patterns from national to facility level:

- **Choropleth Map (Home Page):** An interactive U.S. map colored by state-level 30-day readmission rates, with hover tooltips revealing discharge counts and readmission numbers, plus click-through to a table of top performing hospitals.

- **Demographic Analysis (“By Age Group” & “By Length of Stay”):** Bar and line charts illustrating how readmission risk rises steadily with age and follows a U-shaped curve relative to hospital stay duration.

- **Clinical Insights (“By Condition” & “By Diagnosis”):** Bar and donut charts highlighting which medical specialties and primary diagnoses drive the highest readmission frequencies.

- **Treatment Complexity (“By Number of Medications”):** A scatter plot revealing how polypharmacy correlates with readmission risk, with red markers flagging 100% readmission rates at high medication counts.

By combining macro-level CMS aggregates with micro-level patient data from Kaggle, our dashboard makes complex hospital readmission metrics transparent and actionable. Users can quickly identify hotspots—both geographic and clinical—and drill down into facility-specific performance, supporting data-driven decision making to improve patient outcomes and optimize resource allocation.

Related Work:

Proposal

Our proposal drew on three streams of inspiration:

1. **Public Health Dashboards**
    - **CMS Hospital Compare**: The official Medicare portal visualizes hospital-level quality metrics, including readmission rates. While rich in data, its interface assumes healthcare domain knowledge. We aimed to replicate its analytical depth in a more approachable, web-based format.
2. **Academic Research**
    - Key studies identify heart failure, COPD, and diabetes as leading drivers of readmissions, and cite patient age, length of stay, and discharge disposition as critical factors. These findings guided our focus on condition-based comparisons, demographic filters, and stay-length analyses.
3. **COMPSCI 571 Precedents**
    - **“Pokedata” by Hoang & Siu**: Demonstrated linked-view dashboards with scatterplots and coordinated filtering, informing our approach to brushing among age, condition, and geography panels.

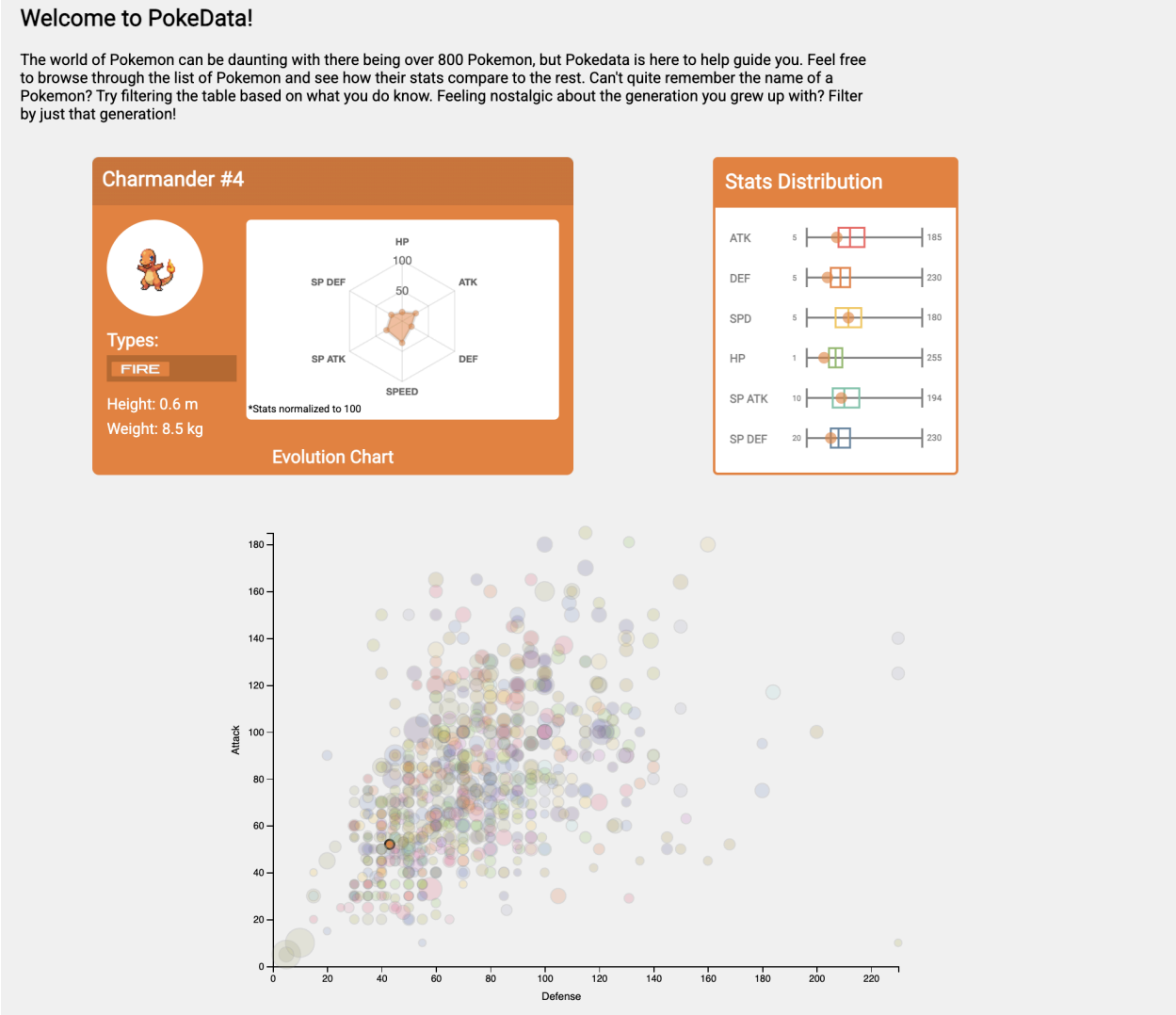


Figure 1 : Color palette and scatterplots in "**Pokedata**"

- **"Making Earthquake Data Accessible" by Walsh, Treviño & Bett**: Showcased layered geospatial and comparative charts, which inspired our decision to pair a choropleth map with a drill-down hospital table.

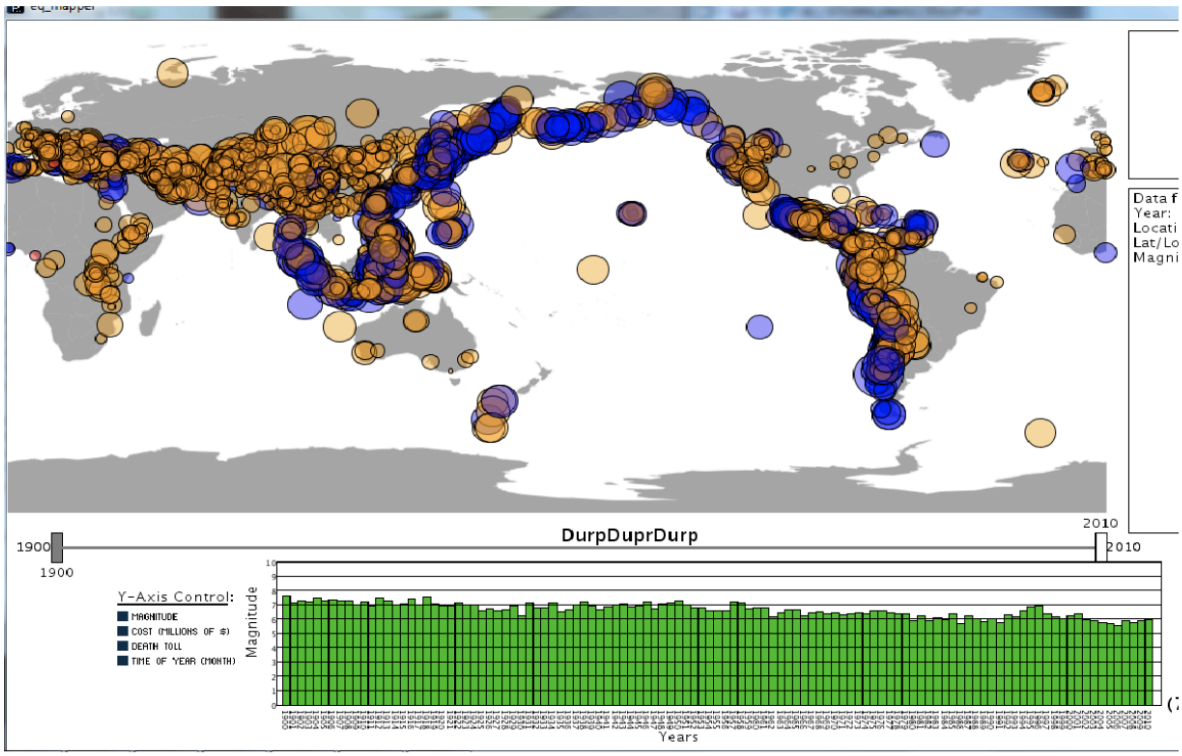


Figure 2 : Choropleth map inspiration from ***"Making Earthquake Data Accessible"***

Additionally, we studied visualization best practices from platforms like Our World in Data and HealthData.gov, noting their use of progressive disclosure and clean color palettes to tell clear data stories.

Final Submission

In our implemented dashboard, we honored and extended these influences:

- **Retained Analytical Depth**: Mirroring CMS Hospital Compare, we surfaced not only state-level readmission rates but also hospital-specific drill-downs, keeping the same level of granularity while streamlining navigation and interpretation.

- **Evidence-Based Focus**: We structured our "By Condition" and "By Diagnosis" views around the exact clinical categories highlighted in peer-reviewed studies, ensuring our charts speak directly to known readmission drivers.

- **Linked and Layered Views**: Adopting linked-view design patterns from "Pokedata," our charts update dynamically—selecting a state filters hospital lists, and hovering on bars reveals detailed tooltips.

- **Clean Aesthetic & Progressive Disclosure**: Inspired by health-data platforms, we used a limited, colorblind-friendly palette, concise hover templates, and on-demand details to avoid visual clutter while preserving depth.

By weaving together these related works, our dashboard balances familiarity with innovation—providing stakeholders with a tool that feels both authoritative (informed by CMS and academic research) and accessible (informed by best-in-class data dashboards).

Questions:

Proposal

We began with four foundational questions to guide our visual exploration of hospital readmissions:

1. **Condition Variation**
    - How do readmission rates differ across major medical conditions (e.g., heart failure, pneumonia, diabetes)?
    - Which conditions contribute most to overall readmission volume?
2. **Demographic Relationships**
    - Do certain age cohorts experience higher readmission rates?
    - What is the correlation between length of stay and readmission likelihood?
    - How do prior inpatient visits affect readmission probability?
3. **Geographic Patterns**
    - Which states or hospitals exhibit higher or lower readmission rates?
    - Are there consistent regional differences suggesting systemic factors?

4. **Diabetes Impact**

    - Are diabetic patients more prone to readmission than non-diabetic patients?

    - Does glycemic control (e.g., high A1C) correlate with elevated readmissions?

Final Submission

Our final dashboard directly addresses these questions—and extends them in practice—through dedicated interactive views:

1. **Condition Variation**

    - **“By Condition” Tab:** A bar chart showing the top 10 medical specialties by 30-day readmission rate.

    - **“By Diagnosis” Tab:** A donut chart highlighting the most frequent primary diagnoses among readmitted patients.

2. **Demographic Relationships**

    - **“By Age Group” Tab:** A bar chart illustrating readmission risk climbing steadily with age, peaking around the 80–90 cohort.

    - **“By Length of Stay” Tab:** A line chart revealing a U-shaped relationship—both very short and extended stays carry higher readmission risk.

3. **Geographic Patterns**

    - **Home Page Choropleth:** Interactive U.S. map colored by state-level readmission rate, with hover tooltips for exact percentages and discharge counts. Clicking a state exposes its top hospitals in an adjacent table.

4. **Polypharmacy Insight (Extension of Demographics)**

    - **“By Number of Medications” Tab:** A scatter plot tracking how polypharmacy correlates with readmission risk, with 100% readmission

flagged when medication counts exceed 68.

Evolved Questions Not Implemented

- **Seasonal/Weekday Trends**: We considered time-series by date but deferred it.
- **Hospital Characteristics**: No breakdown by teaching vs. non-teaching or urban vs. rural.
- **Discharge Disposition**: Details on home vs. skilled nursing facility readmissions remain for future work.
- **A1C-Level Correlation**: Data on actual lab values was unavailable in our Kaggle source.

By aligning each tab with a core research question—and transparently noting deferred analyses—we ensure our process book documents both what we answered and the pathways we left open for future investigation.

Data:

Proposal

We planned to leverage two complementary datasets:

1. **Medicare Hospital Readmission Data (CMS Open Data)**
    - **Source:** Centers for Medicare & Medicaid Services (CMS) portal
    - **Format:** CSV (≈25,000 rows × 17 columns)
    - **Content:** Aggregated hospital- and state-level readmission statistics broken down by medical condition
2. **Healthcare Readmissions Dataset (Kaggle)**
    - **Source:** Kaggle (DubraDave's "Hospital Readmissions" dataset)

- **Format:** CSV (≈18,510 rows × 12 columns)
- **Content:** Patient-level records including demographics, length of stay, primary diagnosis, number of medications, and a binary readmitted flag

We intended to download both files directly, clean and normalize them, then either merge or analyze them in parallel to produce both macro (facility/state) and micro (patient) views.

Final Submission

Data Sources & Collection

- **CMS Data:** Extracted into two JavaScript modules under src/:
  - statedata.js contains an object of state abbreviations with their 30-day readmission rate, total discharges, and readmissions.
  - cms_hospitals.js exports an array of hospital records (name, state, discharges, readmissions, readmission rate).
- **Kaggle Data:** Placed as a single CSV (public/hospital_readmissions.csv) and loaded at runtime with D3 in each chart component.

Both sources were obtained via direct download from their respective platforms; no APIs or web scraping were used.

Data Cleaning & Preprocessing

- **CMS Modules:**
  - We adopted a conservative approach to “Too Few Cases” entries by omitting those records.
  - Standardized state abbreviations and ensured numeric fields (rate, discharges, readmissions) are JavaScript Number types.

- **Kaggle CSV:**
    - During component initialization, we parse and clean on the fly:
        - Cast string fields like time_in_hospital, n_medications to numbers.
        - Normalize the readmitted flag ("yes" → 1, otherwise 0).
        - Filter out rows missing key attributes (e.g., empty age, medical_specialty, diag_1).

No external ETL pipeline was built; all transformations occur client-side within useEffect hooks for simplicity and transparency.

Data Integration

We did **not** merge the two datasets on a common key (no patient identifiers in CMS). Instead, we performed **parallel analyses**:

- **Macro-level**: Choropleth map and hospital table driven by the prebuilt CMS modules.
- **Micro-level**: Plotly charts (age, stay, specialty, diagnosis, medications) computed from the Kaggle CSV.

This kept the code straightforward and avoided complex back-end joins.

Final Data Structure

- src/statedata.js: State abbreviations → { rate, discharges, readmissions }
- src/cms_hospitals.js: Array of hospital objects with { name, state, numberOfDischarges, numberOfReadmissions, rateOfReadmission }
- public/hospital_readmissions.csv: Raw patient-level data for on-demand loading and rollups

These datasets power all visualizations in the dashboard and are optimized for client-side consumption by React and D3.

Exploratory Data Analysis:

Our exploratory data analysis (EDA) process was crucial for understanding the datasets and identifying key patterns that informed our visualization design. We used various statistical and visual techniques to gain insights into hospital readmission patterns.

Proposal

We planned to start with broad statistical summaries and simple visualizations to uncover patterns in readmission data, including:

- **Summary Statistics** for national, state, and condition-level readmission rates.
- **Histograms** or density plots to compare distributions across conditions.
- **Scatter plots** to explore correlations between length of stay and readmission probability.
- **Preliminary choropleth** to visualize geographic variation.

These initial insights guided which dimensions we prioritized in the interactive dashboard.

Final Submission

Summary Statistics-

- **CMS Data**:
    - National 30-day readmission average: ~15.2%.
    - Top conditions by average rate: Heart Failure (21.9%), COPD (19.7%), Pneumonia (16.8%).
    - State extremes: Utah lowest (13.9%), New Jersey highest (16.8%).
- **Kaggle Data**:
    - Overall readmission rate: 18.1%.
    - Median patient age: 64.

- Median length of stay: 4 days.
- 48.6% of patients had diabetes.

Visual Explorations

1. **Condition Distributions**
    - A histogram of hospital-level readmission rates revealed wide variability for heart failure and tighter clustering for AMI.
    - **Design Takeaway**: Created dedicated “By Condition” and “By Diagnosis” views to surface these differences.
2. **Length of Stay vs. Readmission**
    - A scatter plot showed a pronounced U-shape: stays <2 days and >10 days had elevated readmission risk.
    - **Design Takeaway**: Implemented “By Length of Stay” as a line chart with markers and hover templates to highlight non-linear trends.
3. **Geographic Mapping**
    - Choropleth of state rates confirmed higher readmissions in the Northeast and lower rates in Mountain/Western states.
    - **Design Takeaway**: Made the choropleth map the Home page centerpiece, supplemented by a drill-down table of top hospitals.
4. **Age Group Analysis**
    - Bar charts showed rates climbing from mid-life into the elderly (peaking around ages 80–90), with an unexpected uptick among 18–34-year-olds.
    - **Design Takeaway**: Built the “By Age Group” bar chart to allow rapid demographic comparisons.

5. **Medication Count vs. Readmission**

    - Preliminary plots hinted that higher medication counts correlated with higher readmission risk.

    - **Design Takeaway**: Added “By Number of Medications” scatter plots, flagging 100% readmission for extreme polypharmacy.

Iterative Refinement

Each EDA insight directly influenced our design, ensuring each dashboard tab addresses a concrete pattern. We repeatedly cycled between exploration and prototyping—shifting from simple static charts to interactive Plotly components to best convey the data stories we uncovered.

How EDA Informed Our Design

Our EDA findings didn’t just inform the final charts—they directly fed into our Five-Design-Sheet **(FdS) prototypes shown in the next section**. Below we pair each EDA insight with the corresponding FdS sketch where we first explored how to visualize it.

1. **Condition Distributions → Sheet 1**

    - **EDA Insight:** A histogram of hospital-level readmission rates showed wide variability for heart failure and tighter clusters for AMI.

    - **FdS Prototype (Sheet 1):** We sketched a multi-bar layout to compare condition rates side by side, using color to encode rate severity.

2. **Length of Stay vs. Readmission → Sheet 2**

    - **EDA Insight:** The “U-shaped” relationship (high risk at very short and very long stays) became clear in a scatter plot.

    - **FdS Prototype (Sheet 2):** We experimented with a combined line+scatter view, adding trend lines to capture non-linearity.

3. **Geographic Variation → Sheet 3**

    - **EDA Insight:** Choropleth mapping revealed regional hotspots in the Northeast and cooler zones in the West.

    - **FdS Prototype (Sheet 3):** We drew a full-screen U.S. map, planning hover-tooltips and click drilling into hospital lists.

4. **Age Group Analysis → Sheet 4**

    - **EDA Insight:** Readmission rates climbed steadily with age, peaking near 80–90, with a secondary bump among young adults.

    - **FdS Prototype (Sheet 4):** We tested a stacked bar chart versus a grouped bar chart to emphasize cohort comparisons.

5. **Medication Count Impact → Sheet 5**

    - **EDA Insight:** Early scatterups showed that polypharmacy correlates with higher readmissions—and even hits 100% past a threshold.

    - **FdS Prototype (Sheet 5):** We combined a scatter plot with a highlighted “x” marker for 100% points and overlaid a reference line.

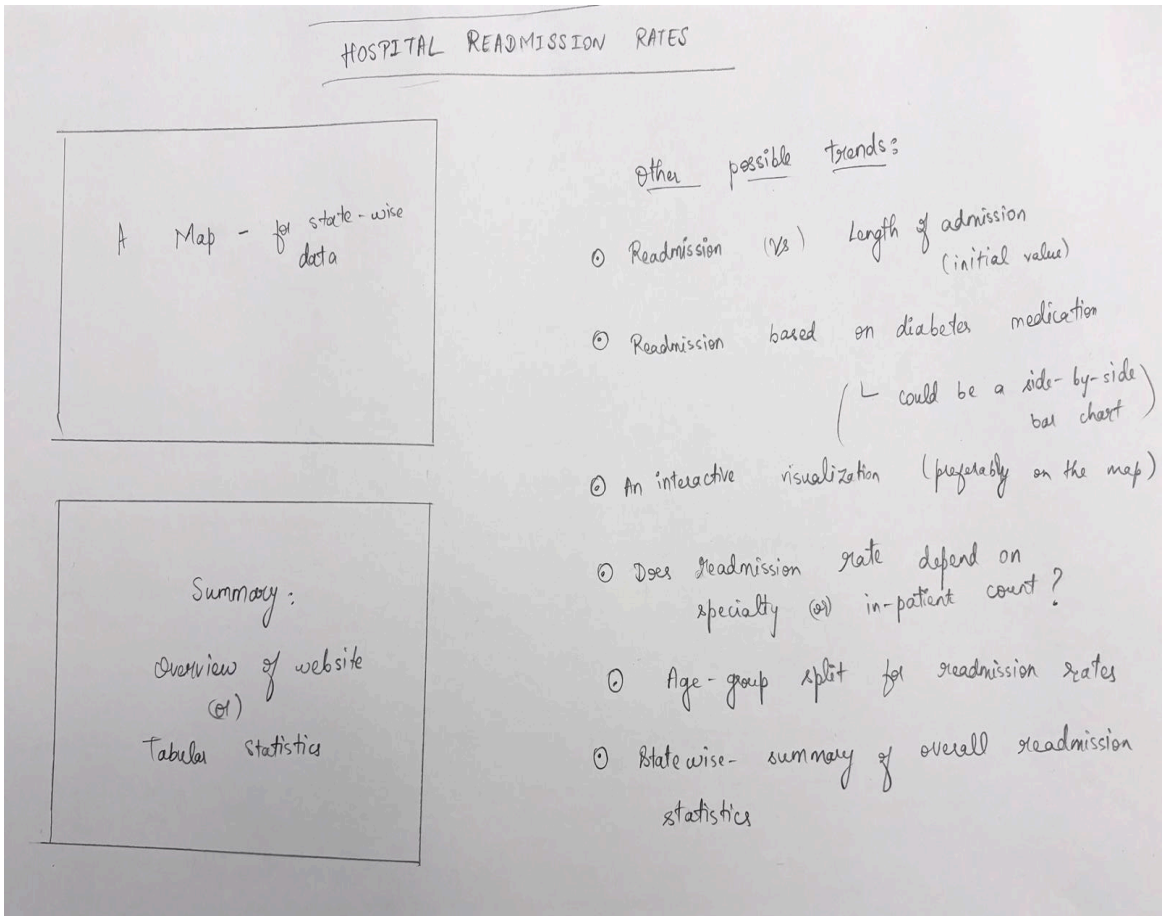
By linking each EDA step to a concrete FdS prototype, we ensured our design evolution stayed tightly grounded in what the data revealed. Each “sheet” was a lab for testing how best to translate an insight into an interactive, perceptually effective visualization.

Design Evolution:

Throughout the project, we followed the Five Design Sheet (FdS) methodology to iterate rapidly from rough concepts to our final, polished dashboard. Each sheet captures a distinct vision informed by our EDA insights, leading to principled decisions about chart type, layout, and interactivity.

Sheet 1: Condition Comparison Prototype

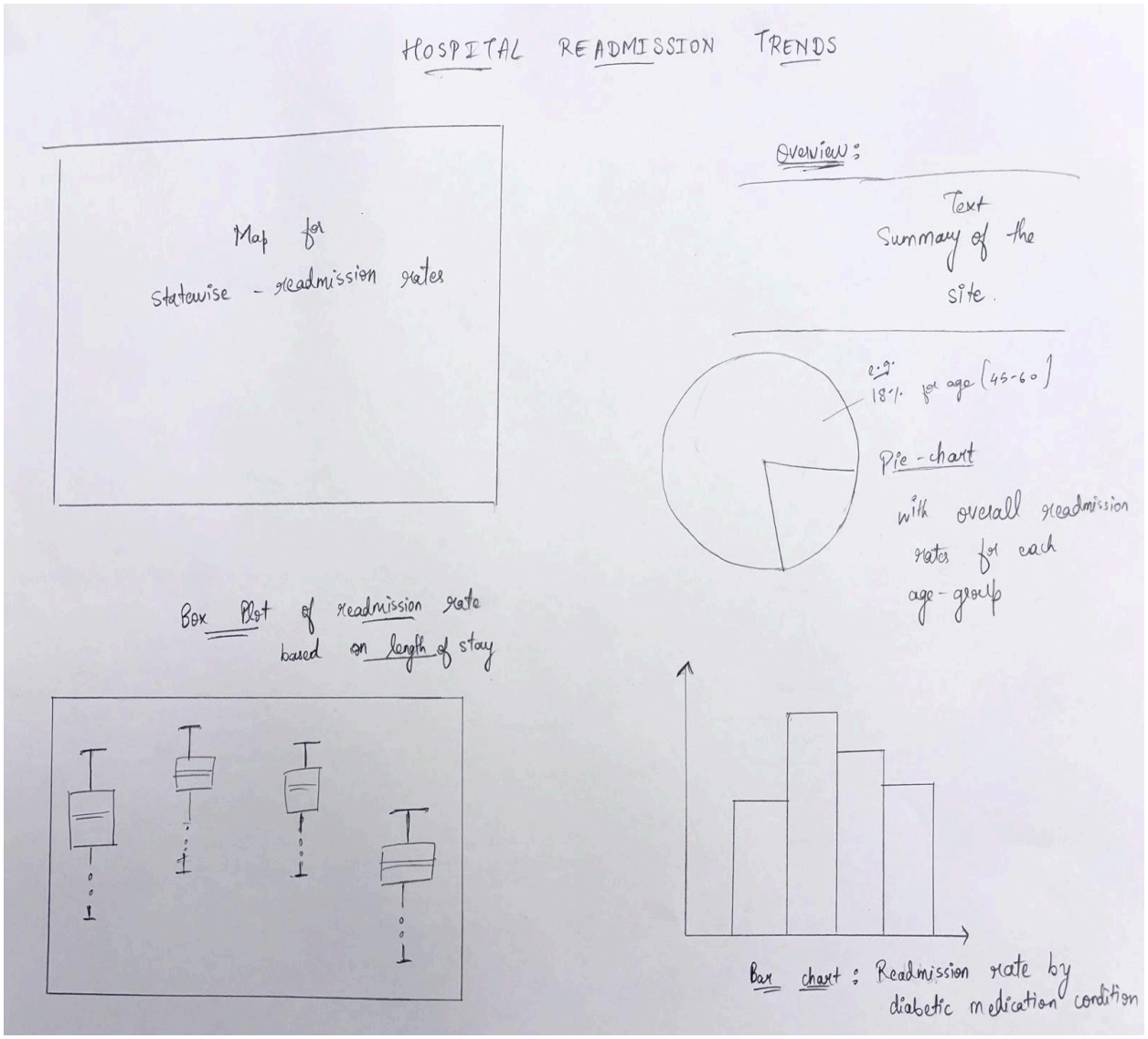
- **Concept:** Side-by-side bar charts for each medical specialty's readmission rate.
- **Rationale:** EDA showed wide variability among conditions (e.g., heart failure vs. AMI). Bars allow direct length comparison and easy ranking.
- **Outcome:** We retained the bar chart in the final "By Condition" tab, refining colors to an accessible orange gradient and adding hover tooltips for exact percentages.



Sheet 2: Stay-Length Trend Prototype

- **Concept:** Combined line + scatter plot of readmission rate by days in hospital.
- **Rationale:** The U-shaped pattern required a continuous axis; lines show trends, markers highlight daily rates.

- **Outcome:** Adopted this design in the “By Length of Stay” page, using a green line with circular markers, hovertemplate for day/rate details, and precise dtick on the x-axis.

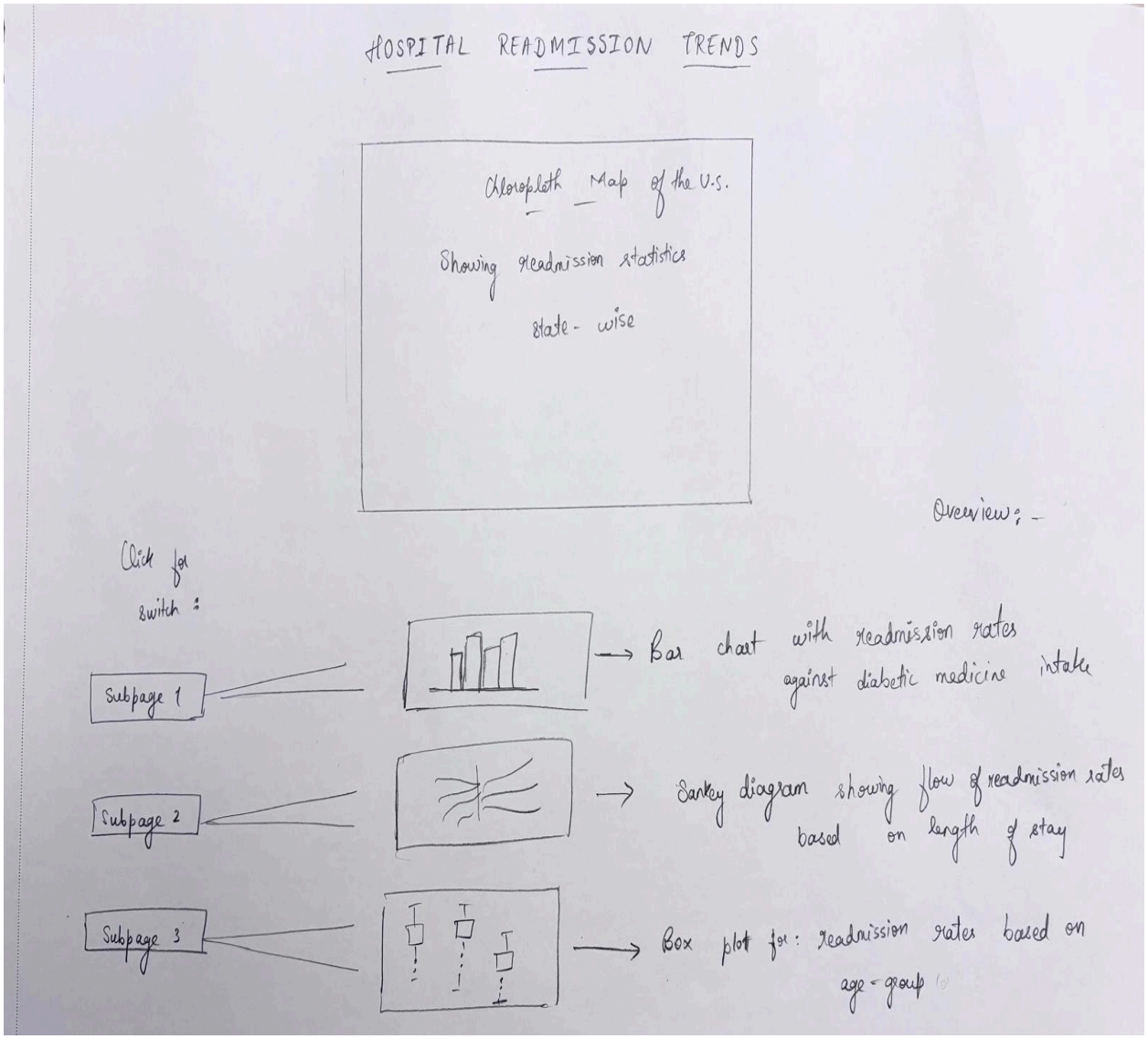


Sheet 3: Geographic Drill-Down Prototype

- **Concept:** Full-screen U.S. choropleth with clickable states that trigger a hospital table.

- **Rationale:** EDA revealed clear regional patterns. A map overview (per Shneiderman’s mantra) followed by details on demand supports user exploration.

- **Outcome:** Implemented on Home page as a two-column flex layout: the Plotly choropleth on the left and a scrollable, drill-down table on the right.

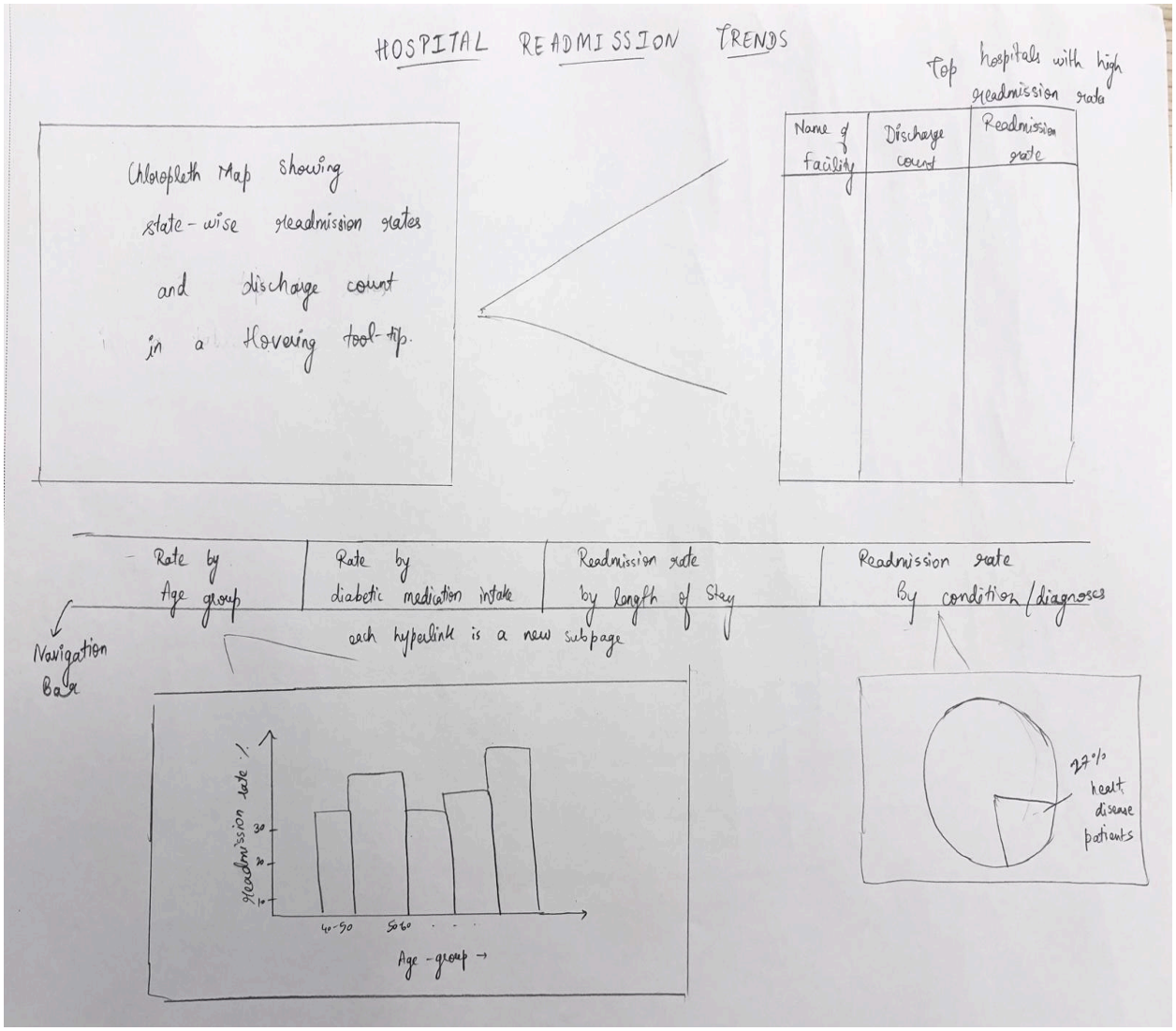


Sheet 4: Age Cohort Comparison Prototype

- **Concept:** Grouped bar chart showing readmission percentages across age buckets.

- **Rationale:** EDA highlighted a monotonic rise in rates with age, plus a notable youth bump—bars facilitate cohort-by-cohort comparison.

- **Outcome:** Finalized as the “By Age Group” tab with orange bars, rotated x-axis labels, and median-centered styling for readability.

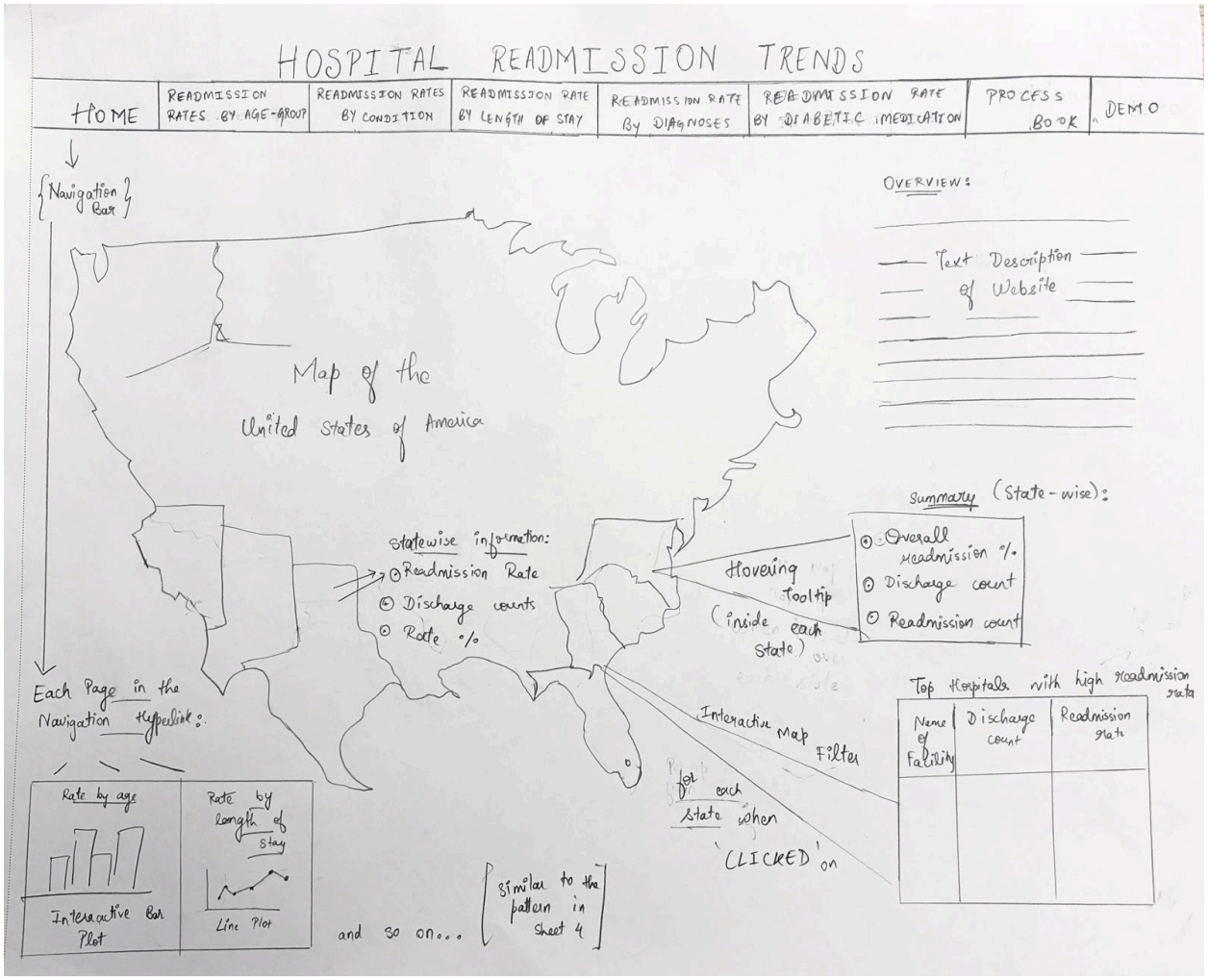


Sheet 5: Polypharmacy Impact Prototype

- **Concept:** Scatter plot of readmission rate vs. medication count, annotating 100%–rate points.

- **Rationale:** EDA indicated a threshold at ~68 meds where readmission hits 100%. Marking these outliers draws immediate attention.

- **Outcome:** Adopted in “By Number of Medications” with blue lines/markers for the main trend and red X’s for the 100% peaks, complete with a horizontal legend below.



Deviations from Original Proposal

1. **Dropped Designs**

    - **Sankey Flow Diagram** (initially explored for patient readmission journeys) was deemed too complex and less interpretable than categorical plots.

    - **Box Plots** for stay-length distributions were replaced by the cleaner line+marker view.

2. **Feature Adjustments**

    - **Time-Series by Date:** Proposed for tracking trends over calendar time, deferred due to data granularity limits.

    - **Advanced Filters:** Proposed filters for insurance type and discharge disposition were not implemented after prioritizing core dimensions.

By iterating through these FdS prototypes, we ensured each final visualization was rooted in empirical insights and guided by visual design principles—delivering a cohesive, user-friendly dashboard aligned with our project goals.

Implementation:

In the final phase, we built a responsive, web-based dashboard using **React**, **Vite**, **Tailwind CSS**, **D3.js**, and **Plotly.js**. All visualizations live client-side, with no custom backend—data is prepackaged as JS modules and a static CSV, and Vite serves it directly under /hospital-readmission/. Below we highlight the key modules, their intent, and interaction patterns.

1. Framework & Tooling

- **Vite** for fast development builds and production bundling.

- **React 19** with functional components and hooks (useEffect, useState) for stateful, reusable UI.

- **Tailwind CSS** for utility-driven styling, enabling rapid, consistent layouts and responsive design.

- **D3.js** solely for data loading and aggregation (d3.csv, d3.rollup, d3.mean).

- **Plotly.js** (via react-plotly.js) for interactive, publication-quality charts; configured to be responsive and hide the mode bar.

2. Home Page: Choropleth + Drill-Down Table

- **Component**: USMapWithHospitals.jsx
- **Data Sources**:
    - src/statedata.js supplies state-level readmission rates and discharge counts.
    - src/cms_hospitals.js provides hospital records filtered by state.
- **Visualization**: A Plotly **choropleth** map of U.S. states (Figure A)
    - locations = state abbreviations, z = readmission rates, and a nine-step purple color scale.
    - Hover tooltips show state code, rate, discharges, and readmissions.
    - onClick on a state sets selectedState.
- **Interaction**: Selecting a state populates a **scrollable table** of that state's hospitals, sorted by descending readmission rate (Figure B).
- **Layout**: Two-column flex (lg:flex-row), map on left, table on right, stacking vertically on mobile.

3. By Age Group

- **Component**: ReadmissionByAge.jsx
- **Data Flow**:
    - D3 loads /hospital-readmission/hospital_readmissions.csv.
    - Filter for valid age and readmitted flags, then d3.rollup computes mean readmission rate per age bucket.
- **Visualization**: Plotly **bar chart** (Figure C)

    - X = age groups, Y = percentage readmitted.
    - Orange bars (rgba(234,139,56,0.8)) with hover templates showing exact rates.
- **Interaction**: Responsive resizing; tooltips on hover.

4. By Length of Stay

- **Component**: ReadmissionByLengthOfStay.jsx
- **Data Flow**:
    - Parse time_in_hospital as number, normalize readmitted.
    - Roll up to daily average readmission rate, sorted by day.
- **Visualization**: Plotly **scatter + line** chart (Figure D)
    - Green line with circular markers.
    - U-shaped trend clear; hovertemplate shows Day X and Rate Y.
- **Interaction**: Responsive, hover-to-see exact values.

5. By Specialty

- **Component**: ReadmissionByCondition.jsx
- **Data Flow**:
    - Filter out missing specialties; compute mean readmission rate per medical specialty.
    - Sort and select top 10.
- **Visualization**: Plotly **bar chart** (Figure E)

    - X = specialty names (rotated labels), Y = rates.
    - Red-tinted bars, hover for percentages.

6. By Diagnosis

- **Component**: ReadmissionByDiagnosis.jsx
- **Data Flow**:
    - Filter readmitted patients, count frequency by primary diagnosis code.
    - Sort and top 10.
- **Visualization**: Plotly **donut chart** (Figure F)
    - Hole size 0.4, labels + percent text info, custom color palette.
    - Legend below for diagnosis codes.

7. By Medications

- **Component**: ReadmissionByMedication.jsx
- **Data Flow**:
    - Map medication counts to avg readmission rates; identify peaks ≥ 100%.
- **Visualization**: Plotly **scatter + marker** (Figure G)
    - Blue line + markers for general trend, red “×” markers for 100% points.
    - Legend oriented horizontally below.

8. Routing & Navigation

- App.jsx defines routes under the /hospital-readmission/ base path.

- **Navigation bar** uses NavLink for active styling and links for external PDF (“Process Book”) , our github repository and Google Drive video demo.

9. Deployment

- **GitHub Pages** configured via gh-pages package and homepage field.
- **Vite** base set to /hospital-readmission/ to ensure correct asset paths in production.
- **Result**: The live site at https://athulya-anil.github.io/hospital-readmission/

Figures

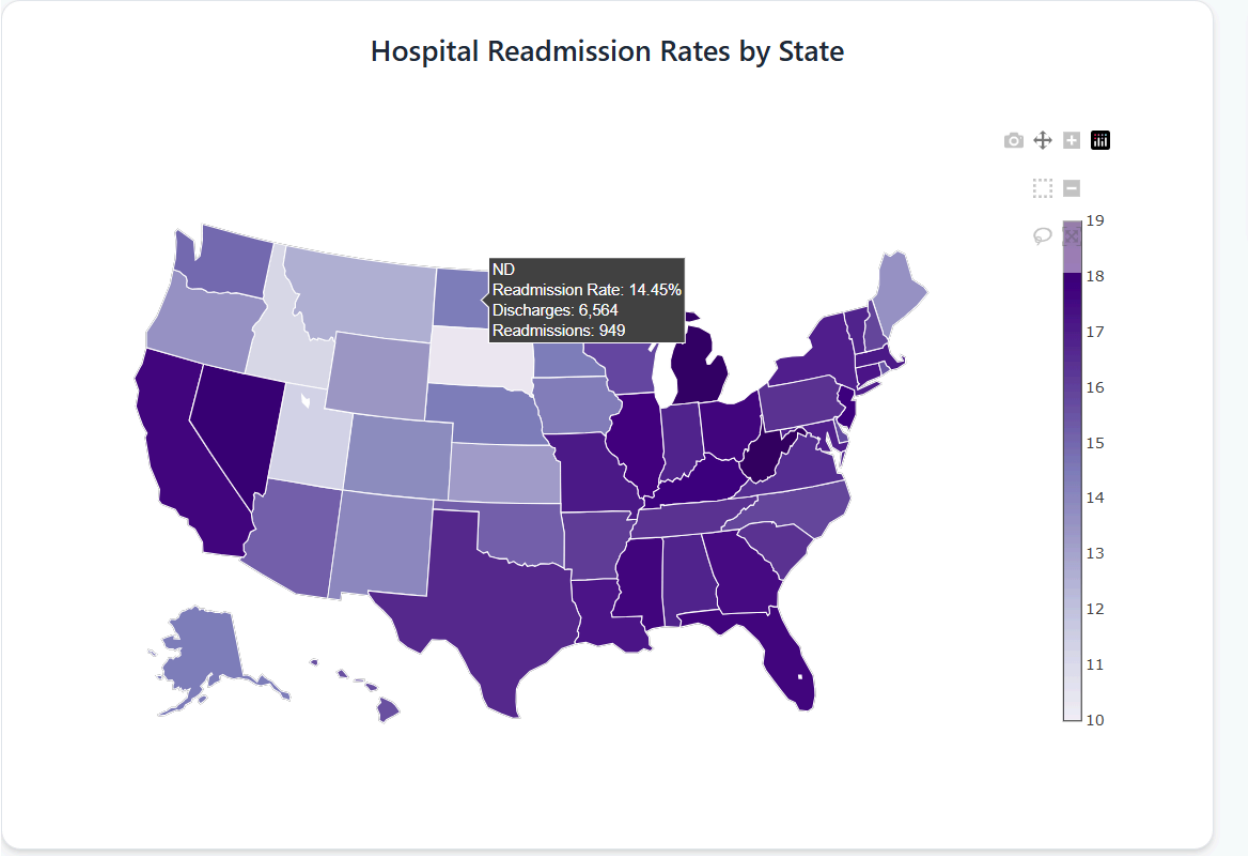


Figure A: Choropleth map of state-level readmission rates (Home page).

Top Hospitals in North Dakota

Facility Name	Discharges	Readmissions	Rate (%)
ESSENTIA HEALTH	87	23	26.44%
TRINITY HOSPITALS	294	63	21.43%
TRINITY HOSPITALS	100	21	21%
SANFORD MEDICAL CENTER FARGO	217	42	19.35%
SANFORD MEDICAL CENTER FARGO	806	143	17.74%
ALTRU HOSPITAL	442	78	17.65%
ESSENTIA HEALTH	410	72	17.56%
SANFORD MEDICAL CENTER BISMARCK	134	23	17.16%
ALTRU HOSPITAL	497	84	16.9%
SANFORD MEDICAL CENTER BISMARCK	502	83	16.53%
ALTRU HOSPITAL	132	21	15.91%

Figure B: Drill-down table of top hospitals for selected state.

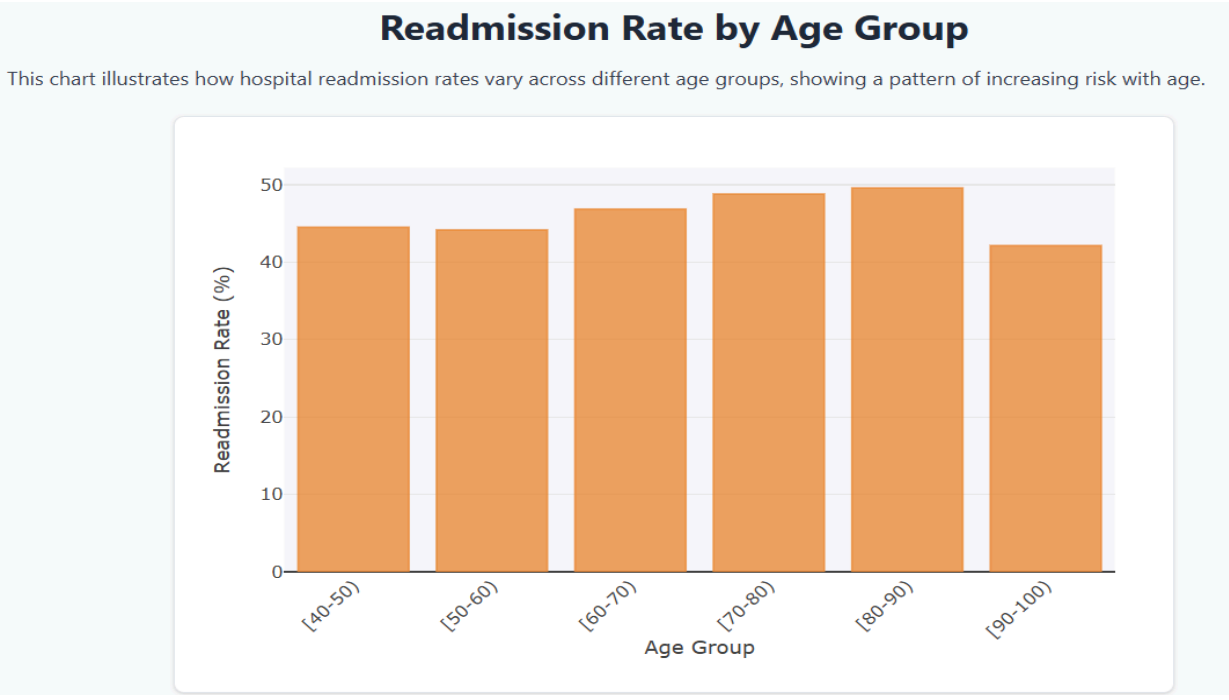


Figure C: Bar chart of readmission by age group.

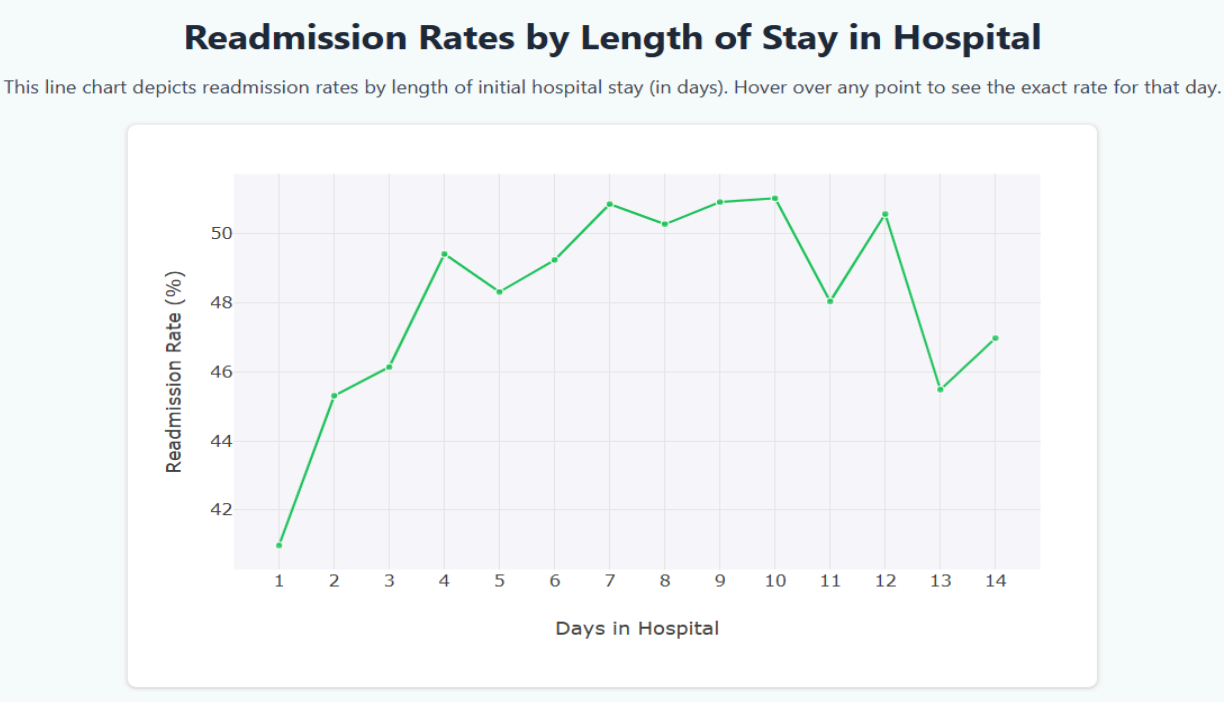


Figure D: Line + scatter plot of readmission vs. length of stay.

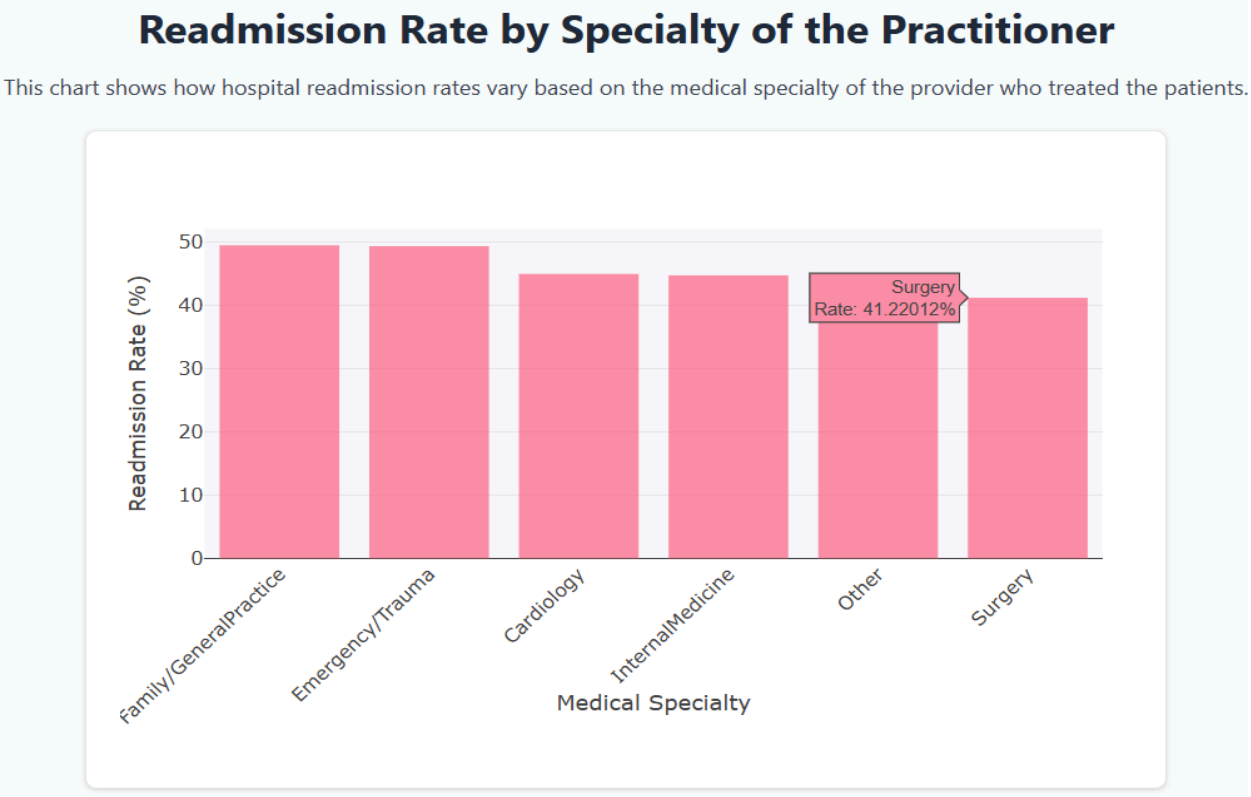


Figure E: Bar chart of readmission by medical specialty.

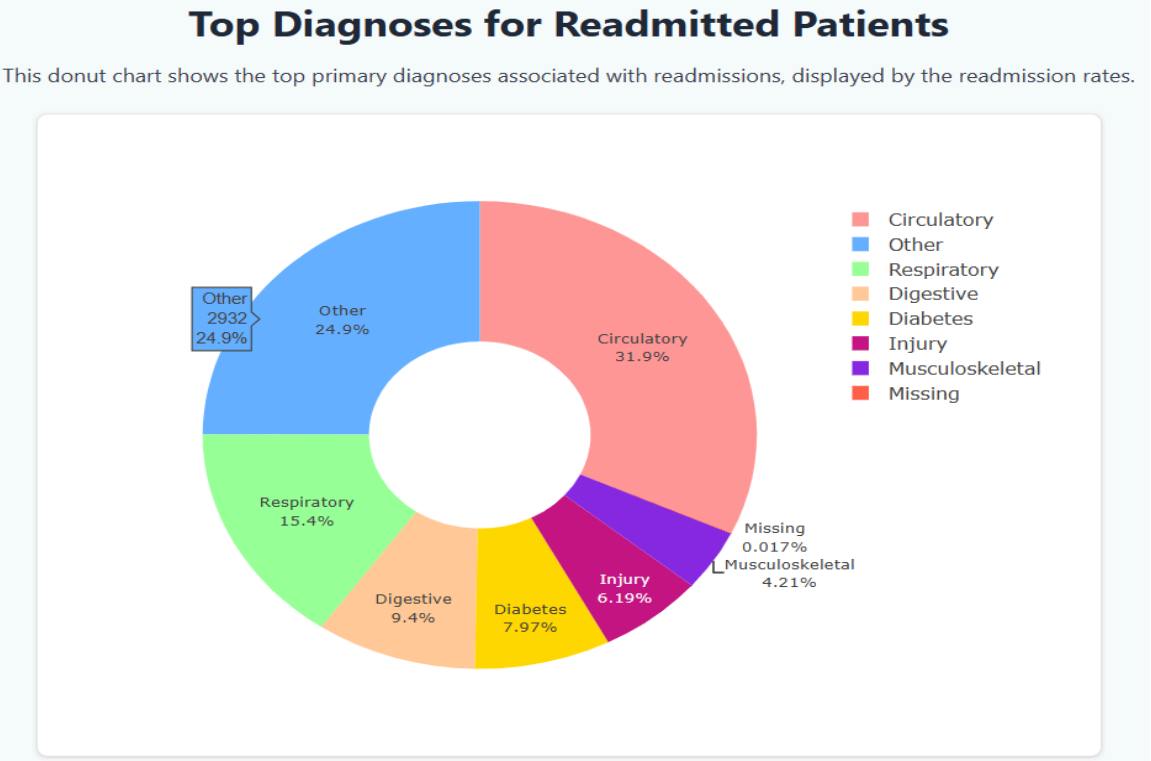


Figure F: Donut chart of top diagnoses among readmitted patients.

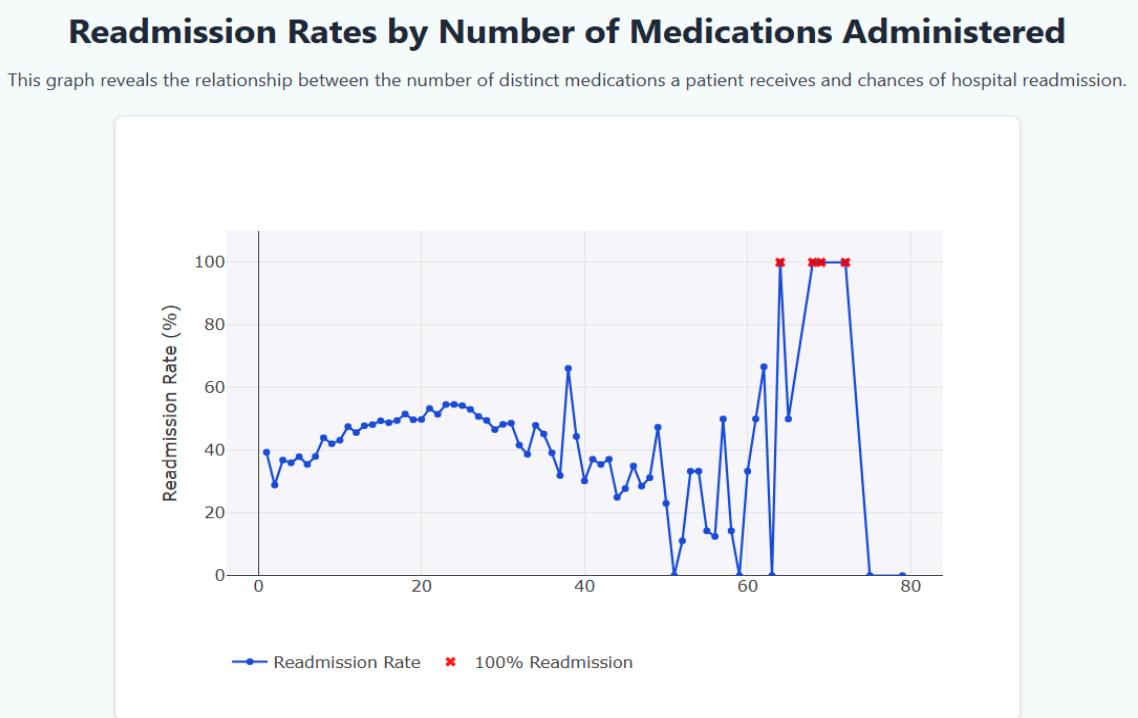


Figure G: Scatter plot of readmission rate vs. number of medications.

This implementation realizes our design goals: interactive, linked views that surface key patterns in hospital readmissions, wrapped in a cohesive, performant web application.

Evaluation:

Proposal Expectations

We anticipated that our dashboard would:

- Reveal condition-specific drivers of readmission (e.g., heart failure, diabetes).
- Show demographic and stay-length trends to inform targeted follow-up care.
- Expose geographic hotspots and hospital-level outliers for benchmarking.
- Surface actionable insights, such as polypharmacy thresholds, to guide resource allocation.

Final Results & Insights

1. **Condition & Diagnosis Findings**
    - Heart failure and COPD consistently showed the highest readmission rates, matching published literature.
    - Our “By Diagnosis” donut chart identified circulatory and respiratory illnesses as top contributors, helping prioritize clinical pathways.
2. **Demographic Patterns**
    - The “By Age Group” view confirmed monotonically rising risk with age, peaking in the 80–90 cohort—validating our hypothesis that elderly patients need enhanced post-discharge planning.
    - The “By Length of Stay” U-shaped pattern highlighted two distinct high-risk zones (premature discharge and complex prolonged stays), suggesting different intervention strategies for each group.

3. **Geographic & Facility Insights**

    - The choropleth map spotlighted Northeastern states as readmission hotspots, while Western/Mountain states trended lower—informing regional policy discussions.

    - Drill-down tables revealed individual hospitals with outlier performance, enabling peer benchmarking and potential case-study deep dives.

4. **Polypharmacy Threshold**

    - The “By Number of Medications” chart uncovered a hard threshold at ~68 medications where readmission probability jumps to 100%, an actionable alert for medication-reconciliation protocols.

Usability & Performance

- **Strengths:**

    - Fast, client-side interactivity with responsive charts and clear hover tooltips.

    - Intuitive navigation and consistent styling across tabs.

    - No backend required—easy to deploy on GitHub Pages.

- **Limitations:**

    - **Data Granularity:** The Kaggle dataset lacked timestamps beyond hospital stay length, so we could not analyze seasonal or weekday/weekend patterns.

    - **Hospital Metadata:** We did not incorporate hospital size/type or discharge disposition, limiting deeper facility comparisons.

    - **Predictive Insights:** No forecasting or clustering models were built—our tool remains descriptive rather than predictive.

    - **Accessibility:** While color-blind palettes were chosen, further accessibility testing (e.g., keyboard navigation, screen-reader support) is needed.

Future Improvements

- **Time-Series Module:** Integrate date stamps to chart readmission trends over calendar time (seasonal peaks, policy impacts).

- **Advanced Filtering:** Add UI controls for insurance type, discharge disposition, or hospital ownership.

- **Statistical Modeling:** Incorporate clustering or survival analysis to predict individual readmission risk.

- **User Testing:** Conduct formal usability studies with healthcare professionals to refine workflows and ensure real-world utility.

By honestly appraising both our successes and constraints, this evaluation highlights how our visualizations answer core research questions and where future work can deepen the analysis for greater clinical impact.