CSIS 4495 Project Midterm Report

Title: Optimizing Emergency Department Throughput via Remote Digital Triage and Synchronous Telemedicine Interventions

Team Members

BRIGHT EKEATTOR (Team Lead)	300318200
AJ ENCINA	300381971

CSIS 4495-003

Video Link: https://drive.google.com/file/d/1ACR7gs1RazMB1XYDCsu_bp5OZ4-aqUKW/view?usp=drive_link

INTRODUCTION

Domain Overview and Background

Emergency departments (EDs) serve as critical access points within healthcare systems, providing immediate care for patients experiencing urgent and life-threatening conditions. However, ED overcrowding remains a persistent and well-documented challenge worldwide. Increasing patient demand, aging populations, and the growing prevalence of chronic illnesses have significantly strained emergency care capacity. As a result, prolonged waiting times, increased staff workload, and reduced quality of care have become common operational concerns.

In most healthcare systems, triage assessment begins only after patients physically arrive at the emergency department. This traditional workflow contributes to waiting room congestion and delays the prioritization of high-acuity cases. Patients with potentially serious conditions must compete for attention in crowded environments, increasing the risk of clinical deterioration while awaiting assessment.

Advancements in digital health technologies, including web-based systems and telemedicine platforms, have demonstrated the potential to improve healthcare accessibility and operational efficiency. While telemedicine has expanded in outpatient and follow-up contexts, its integration into emergency triage workflows remains limited. This research explores the feasibility of integrating remote digital triage and synchronous telemedicine into emergency department operations to support earlier patient assessment and improved prioritization.

Problem Definition and Research Question

Emergency department overcrowding is not solely a capacity issue but also a workflow inefficiency problem. The initial triage stage often acts as a bottleneck, delaying clinical prioritization and limiting proactive resource allocation. Physical congestion in waiting areas increases patient safety risks, contributes to patients leaving without being seen (LWBS), and places significant strain on nursing staff responsible for triage decisions.

Existing digital triage tools frequently operate independently of emergency department systems and rely heavily on automated decision-making without structured clinical oversight. This creates concerns regarding reliability, transparency, and accountability in high-risk healthcare environments.

This research addresses the following key questions:

1. How can remote, web-based triage be integrated into emergency department workflows without compromising patient safety?
2. To what extent can early remote triage improve patient prioritization and reduce waiting times and simulated LWBS rates?
3. How does incorporating human-in-the-loop nurse oversight impact the reliability and clinical acceptability of automated triage decisions?

These questions are critical for developing clinically responsible and operationally effective digital health solutions.

Literature Review and Knowledge Gaps

Research in emergency medicine consistently identifies delayed triage and overcrowding as major contributors to adverse patient outcomes. The conceptual model of emergency department crowding proposed by Brent R. Asplin and colleagues highlights input, throughput, and output inefficiencies as key determinants of congestion. Early prioritization has been shown to significantly influence patient outcomes, particularly for high-acuity presentations.

Telemedicine research, including work by Ronald Bashshur and colleagues, demonstrates the potential of remote consultations to improve access and patient satisfaction. However, these applications are largely focused on outpatient settings rather than emergency triage integration.

Digital triage systems such as those discussed by Andrew F. Dugas show promise in improving acuity-based patient distribution, yet many lack direct integration with hospital workflows and structured clinician override mechanisms.

The key knowledge gaps identified include:

- Limited integration of remote triage into actual emergency department workflows
- Overreliance on automated decision trees without clinician oversight
- Insufficient research on combining telemedicine and triage prior to physical arrival

This project seeks to address these gaps by developing and evaluating a web-based prototype that incorporates human-in-the-loop oversight.

Hypotheses and Potential Benefits

This research is guided by the following hypotheses:

- Implementing remote web-based triage will reduce physical congestion by enabling earlier assessment.
- Early remote triage will improve prioritization and reduce average waiting times for high-acuity patients.
- Human-in-the-loop nurse oversight will enhance reliability, safety, and clinical trust in automated triage outputs.

If validated through simulation-based evaluation, this system could improve patient flow, reduce simulated LWBS rates, enhance operational efficiency, and enable more proactive resource allocation in emergency departments.

Summary of the Initially Proposed Research Project

The initially proposed research project focuses on the design, implementation, and evaluation of a web-based remote emergency room triage and telemedicine system incorporating human-in-the-loop clinical oversight. The primary objective of the project is to explore how remote digital triage can be integrated into emergency department workflows to improve patient prioritization, reduce congestion, and enhance operational efficiency.

The proposed system enables patients to submit structured symptom information remotely prior to physically arriving at the emergency department. Based on predefined triage logic derived from established emergency severity frameworks, the system generates a preliminary triage level. Unlike fully automated triage systems, the proposed solution incorporates a nurse dashboard that allows qualified clinical staff to review, override, escalate, or confirm automated decisions. This hybrid model balances automation efficiency with professional clinical judgment.

The research adopts a mixed-methods design centered on the development of a functional academic prototype and scenario-based simulation. Two workflow models were proposed for evaluation:

1. A baseline model representing traditional in-person-only triage.
2. An experiment model incorporating remote digital triage prior to arrival.

Synthetic patient cases were to be used to simulate emergency department scenarios, allowing comparison of key operational metrics, including:

- Time to triage decision
- Waiting time for high-acuity patients
- Queue length

- Simulated Left Without Being Seen (LWBS) rates

The project integrates principles from data analytics, cybersecurity, and healthcare informatics. Supabase was selected as the backend database solution to manage patient records, triage date, authentication, and logging. Role-Based Access Control (RBAC) and JSON Web Token (JWT) authentication were proposed to ensure secure access for patients and nursing staff.

The Long-term objective of the project is to demonstrate that early remote assessment, combined with clinician oversight, can improve emergency department throughput without compromising patient safety. The proposal emphasized balancing technological innovation with ethical responsibility and healthcare data protection standards.

Changes to the Proposal

While the project's core objectives, architecture, and technology stack remain consistent with the original proposal, several refinements were made during implementation to ensure technical feasibility, system stability, and the timely delivery of a functional midterm prototype.

Feature Scope Refinement

Although the core remote triage workflow is fully functional, several advanced components are currently under refinement and scheduled for completion in the final phase of the project.

1. **Advanced Analytics and Machine Learning Integration**

   The original proposal included advanced analytics visualization dashboards. While the foundational logging and simulation mechanisms are fully operational, advanced visualization features are currently under development.

   In addition, the machine learning dataset required for predictive modeling has recently been acquired. This dataset will be used to train and evaluate a machine learning model to improve triage prioritization accuracy and support future predictive enhancements. Model training and integration into the triage decision pipeline are scheduled for the final implementation phase.

   The delay in full analytics deployment is intended to ensure:

   - Clean and validated simulation data
   - Stable triage logic before model training

- Proper evaluation of baseline vs. ML-enhanced performance

2. Extended Simulation Scenario Complexity

The simulation engine is fully functional and can process synthetic patient cases. However, expanded scenario complexity, including higher arrival variability, dynamic nurse allocation, and stress testing under peak-load conditions, is still being refined.

The current implementation successfully supports comparative workflow analysis, but further complexity will be introduced to improve realism and strengthen the quantitative evaluation component of the research.

3. Performance Optimization Improvements

The system is stable and fully operational; however, performance optimization is ongoing.

Planned improvements include:

- Database query optimization within Supabase
- Reduction of redundant API calls
- Improved state management in the frontend
- WebRTC connection efficiency tuning

These refinements are scheduled for the final phase to ensure scalability and smoother real-time interactions under simulated peak loads.

4. User Interface Refinements

The user interface is fully functional but undergoes incremental refinement to improve usability and clarity:

Planned enhancements include:

- Improved triage level visualization indicators
- Enhanced status tagging for patient cases
- Cleaner layout adjustments for dashboards

These changes are aesthetic and usability-focused and do not impact core system functionality.

5. Doctor Dashboard Completion

The Doctor Dashboard has been partially implemented but is not yet fully finalized.

Currently:

- Completed cases remain visible on the dashboard even after treatment.
- The intended behavior is that once a case is marked as treated, it should automatically transition to an archived state and no longer appear in the active case queue

This functionality is scheduled for refinement through improved state filtering and updates to the database status flag.

6. Nurse Dashboard Bug Fixes

The Nurse Dashboard is fully operational; however, minor bugs have been identified.

Including:

- Occasional state refresh inconsistencies
- Minor UI rendering alignment issues
- Edge case handling override updates

These bugs do not affect core triage functionality but will be resolved during the stabilization phase prior to final submission.

Project Planning and Timeline (Midterm to Final Submission)

Following the successful implementation of the core remote triage system, the remaining six weeks will focus on system refinement, machine learning integration, expanded simulation complexity, dashboard completion, performance optimization, and final research evaluation.

The project will follow an iterative development model with defined weekly milestones and individual responsibilities.

Overall Strategic Focus (Remaining 6 Weeks)

The final phase of the project will focus on:

- Completion of Doctor Dashboard functionality
- Nurse Dashboard bug fixes and stabilization
- Machine Learning model training and integration
- Extended simulation complexity and stress testing
- Performance optimization
- Advanced analytics visualization dashboards

- Final testing and validation
- Final report preparation and documentation

Week by Week Plan

Week 1: System Stabilization & Dashboard Completion

Deliverables:

- Fix Doctor Dashboards case removal logic (archive completed cases)
- Resolve identified Nurse Dashboard bugs
- Improve case status filtering logic in Supabase
- Validate role-based access behavior

Bright (Cybersecurity focus):

- Review dashboard access permissions
- Validate RBAC enforcement across dashboards
- Test secure case state transitions

AJ (Data Analytics Focus):

- Update database schema for case lifecycle states
- Implement archival logic for completed cases
- Begin exploratory analysis of newly acquired ML dataset

Week 2: Machine Learning Model Development

Deliverables:

- Data preprocessing and cleaning
- Feature selection and transformation
- Baseline ML model training
- Performance evaluation metrics (accuracy, precision, recall)

Bright:

- Ensure secure data handling during model training
- Review privacy implications of ML integration
- Validate logging of ML decisions

AJ:

- Train ML model on triage dataset
- Compare rule-based vs ML-based triage outputs

- Generate performance metrics

Week 3: ML Integration into Triage Workflow

Deliverables:

- Integrate trained ML model into backend
- Implement hybrid rule based + ML triage decision pipeline
- Log ML confidence scores
- Create a fallback mechanism to rule based triage

Bright:

- Secure API endpoints for ML predictions
- Validate audit trail integrity
- Conduct security testing of model endpoints

AJ:

- Integrate ML inference logic into API
- Implement performance logging
- Validate consistency of predictions

Week 4: Extended Simulation Complexity

Deliverables:

- Introducing variable patient arrival rates
- Simulate peak load stress conditions
- Expand acuity distributions
- Generate comparative datasets

Bright:

- Monitor system under load
- Validate secure logging during stress test
- Conduct system integrity validation

AJ:

- Expand simulation engine logic
- Run multiple scenario batches
- Collect quantitative performance metrics

Week 5: Performance Optimization & Analytics Dashboard

Deliverables:

- Optimize Supabase queries
- Improve API response times
- Implement analytics visualization dashboard
- Generate charts for waiting time, queue length, and LWBS

Bright:

- Conduct performance security audit
- Validate JWT expiration handling
- Finalize encryption validation review

AJ:

- Build analytics visualizations
- Optimize data aggregation queries
- Finalize statistical comparisons

Week 6: Final Testing, Documentation & Report Completion

Deliverables:

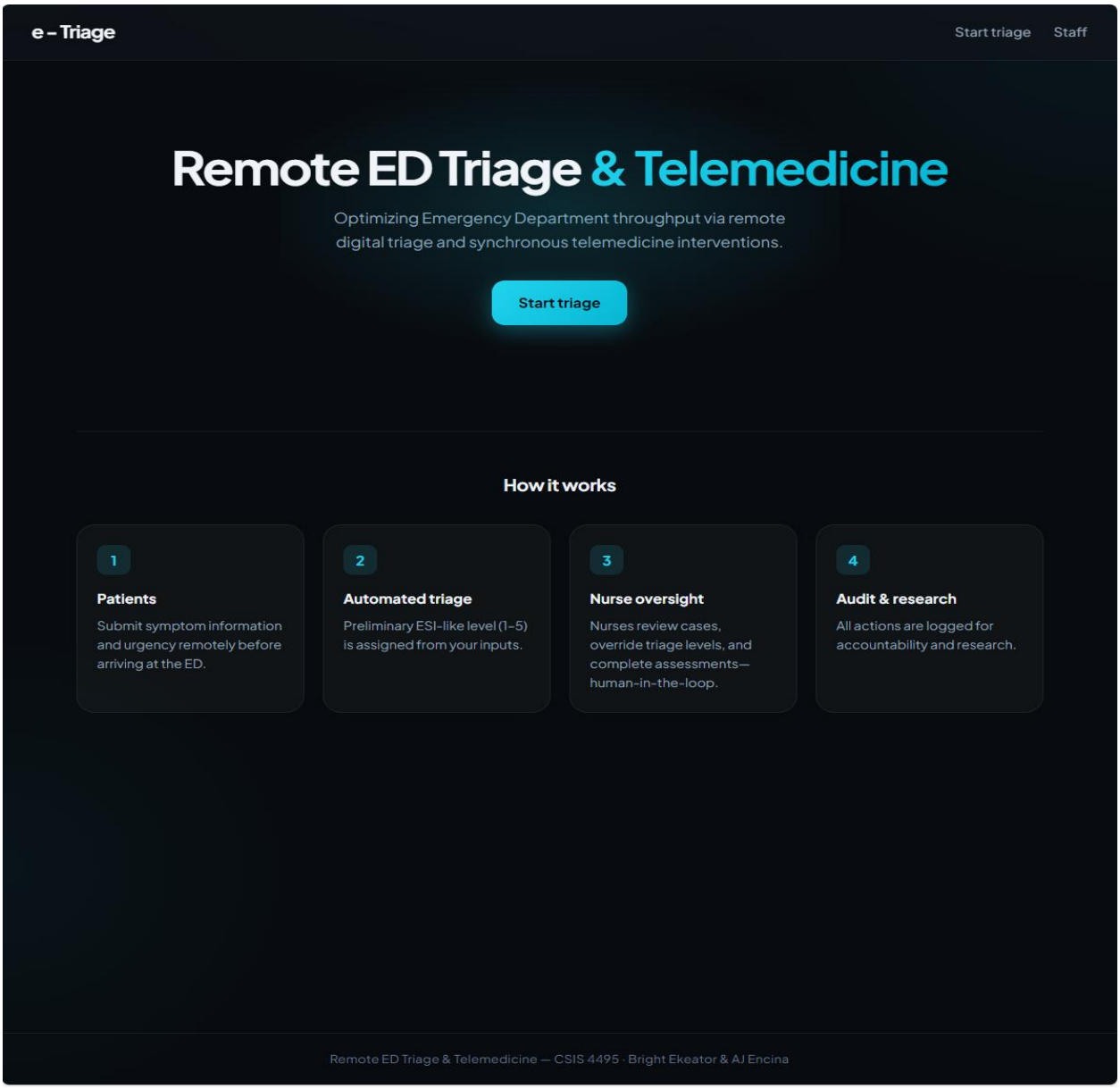
- Full system regression testing
- Validate Doctor & Nurse dashboards
- Final simulation runs
- Compile final quantitative results
- Complete final research report
- Preparing for the final Demo

Bright & AJ (Joint Work):

- Interpret results
- Finalize report writing
- Prepare presentation materials
- Final system validation

Implemented System Components and Individual Contributions

1) **E-Triage Home (Landing) Page (home.jsx) done by AJ.**
   The Patient Triage Interface serves as the primary entry point for patients to engage with the remote triage system before arriving at the emergency department. This feature directly addresses the research objective of enabling earlier patient assessment to reduce physical congestion in emergency waiting areas.
   The interface allows patients to submit structured symptom information remotely, capturing critical data points that feed into the automated triage engine

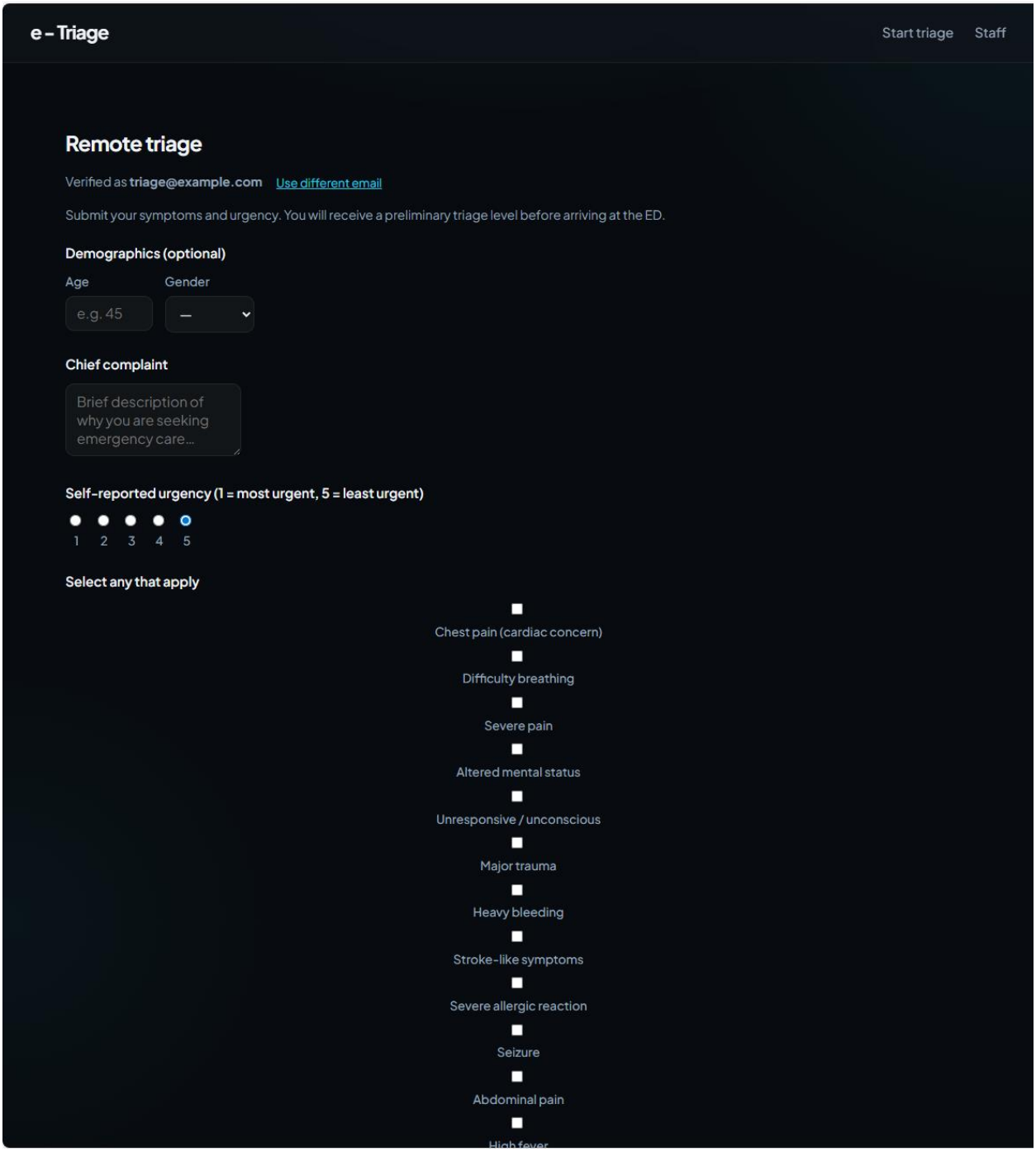


2) **Patient Triage Interface (NewTriage.jsx) done by Bright**

The Patient Triage Interface enables users to submit structured symptom information prior to physical arrival at the emergency department. The form captures:

- Patient demographic information
- Symptom descriptions
- Self-reported urgency indicators
- Timestamp of submission

Submitted data is securely transmitted to the backend API and stored in Supabase. The triage logic processes the input and assigns a preliminary acuity level.

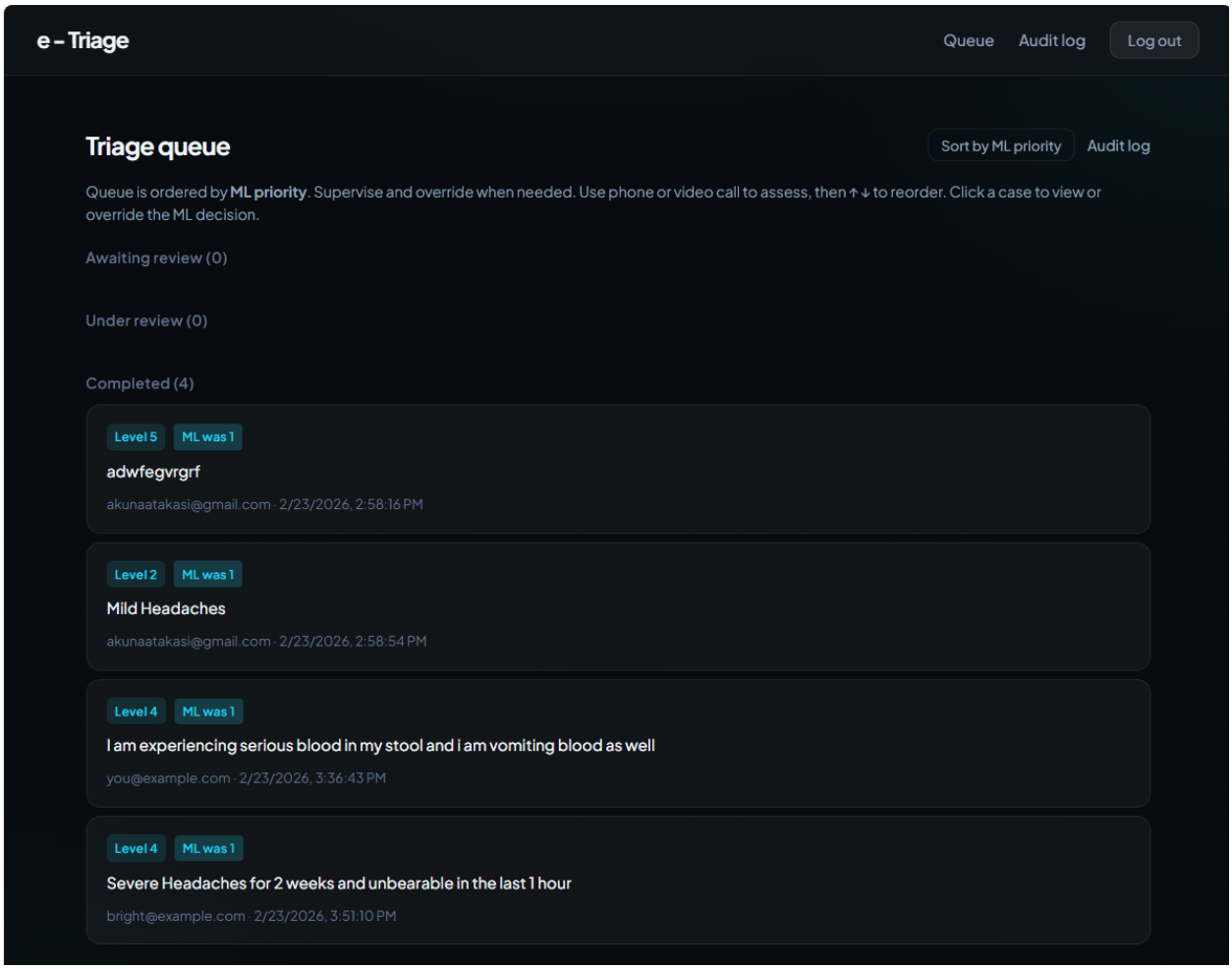


3) Nurse Dashboard by AJ

The Nurse Dashboard enables clinical staff to:

- View incoming triage submissions
- Review assigned triage levels
- Override automated decisions
- Escalate cases
- Update patient status

Role-Based Access Control ensures only authenticated nurse accounts can access this dashboard

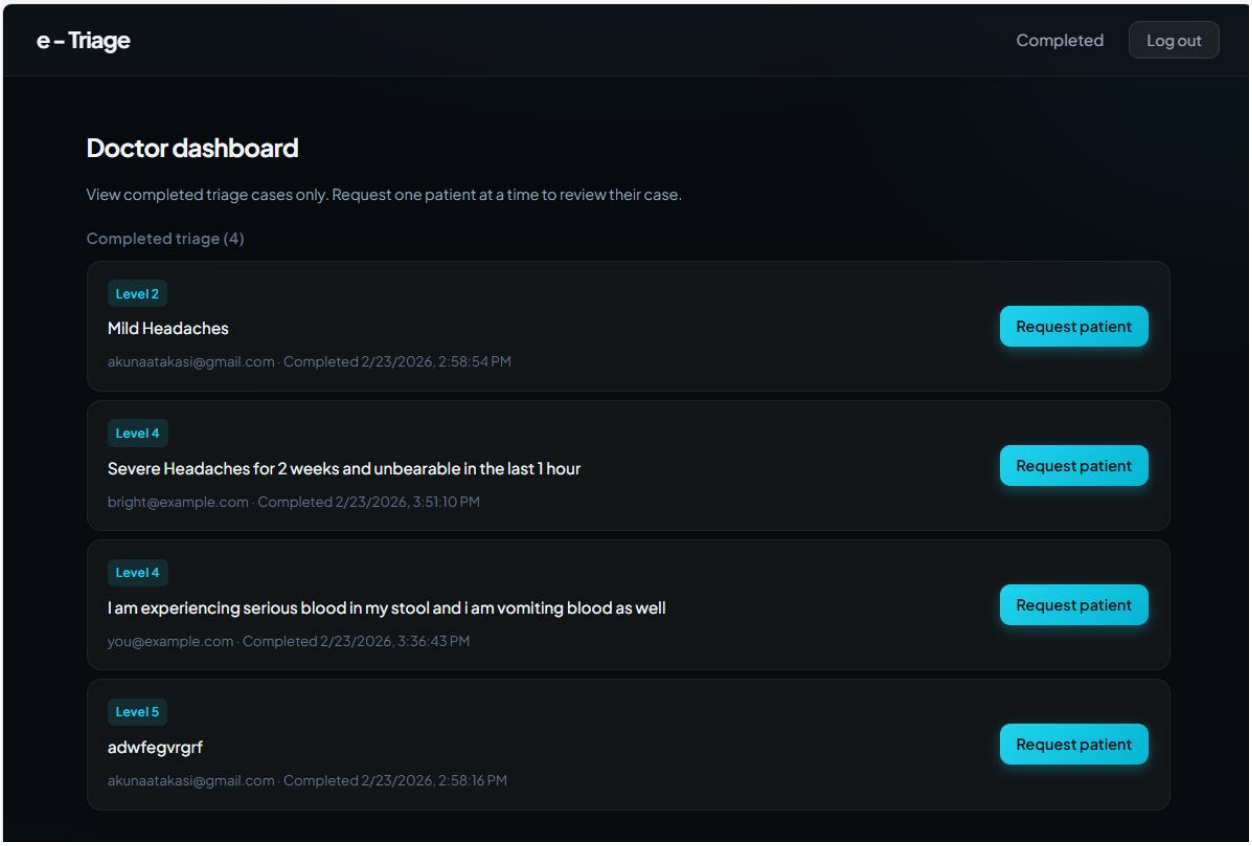


4) **Doctor Dashboard (DoctorDashboard.jsx & DoctorCase.jsx) by Bright**

The Doctor Dashboard provides case-level visibility for treatment workflow.
It allows doctors to:

- View active assigned cases
- Review patient triage data
- Mark cases as treated
- Transition case lifecycle states

Currently, completed cases remain visible and are being updated to automatically archive after treatment confirmation.



5) **Authentication and Access Control**

The system uses Supabase Authentication and JWT-based session management. Features include:

- User registration
- Login page
- JWT session tokens
- Role-based access (Patient, Nurse, Doctor)
- Protected routes

Individual Contribution

AJ: Implemented Login Page and Home Page

Bright: Implemented RBAC enforcement, secured protected routes, validated token-based access control, and tested session expiration handling

6) **Audit Logging System (AuditLog.jsx)**

The Audit Log component provides traceability of system actions.
Logged actions include:

- Triage submissions
- Nurse overrides

- Doctor case completions
- Authentication events

This ensures accountability and supports research data collection.

7) **WebRTC Telemedicine Integration**
   A real-time video consultation feature was implemented using WebRTC technology. This allows:
   - Secure browser-based video communication
   - Direct patient-nurse interaction
   - Real-time session handling

Summary of Individual Technical Contributions

Bright Ekeator

- Doctor Dashboard design & implementation
- WebRTC integration
- RBAC enforcement
- JWT security validation
- Audit logging system
- Secure case lifecycle transitions

AJ Encina

- Nurse Dashboard implementation
- Home and Login pages
- Simulation engine
- ML dataset creation
- Data structure design for triage logic

AI Use Section

AI Tool Name	**Version/ Account Type**	**Specific feature for which the AI tool was used**	**Value Addition**
ChatGPT	GPT-5.2, Free Account	Brainstorming architecture design, debugging React state issues, JWT authentication clarification, and	Evaluated and verified all suggestions, rewrote code for integration with Supabase, tested

		simulation logic refinement	edge cases, ensured security compliance, and proper RBAC enforcement
Gemini	Pro (Free Tier	Academic structuring of proposal and report sections, refinement of research framing	Validated academic accuracy, aligned writing with the CSIS 4495 template, ensured technical consistency with the implemented architecture
DeepSeek	Free Model	Assistance with debugging specific React component rendering issues and performance optimization ideas	Adapted suggestions to project-specific structure, integrated into existing component hierarchy, validated behavior under simulation conditions
ChatGPT	GPT-5.2, Free Account	Guidance on WebRTC implementation flow and signaling concepts	Designed actual WebRTC session lifecycle logic, implemented secure integration with user roles, and tested peer connection handling
ChatGPT	GPT-5.2, Free Account	Machine learning model brainstorming and dataset preprocessing strategies	Cleaned and structured a real dataset, performed feature engineering, implemented actual training and evaluation metrics independently

Work Date/Hours

Work Logs Bright

Date	Number of Hours	Description of Work Done
10/2/26	1.5 hours	Team meeting to plan sprint for weeks 5-6; set up project board with tasks for nurse dashboard development
11/2/26	2 hours	Researched WebRTC implementation for secure video consultation; tested basic peer-to-peer connection examples
12/2/26	3 hours	Implemented authentication system using JWT tokens; set up role-based access control (RBAC) for patient vs. nurse roles
13/2/26	1 hour	Code review of AJ's patient triage form; provided feedback on data structure alignment with security requirements
14/2/26	1.5 hours	Implemented secure session management; tested token expiration and refresh mechanisms
15/2/26	3 hours	Weekend work: Set up Supabase database schema for nurse dashboard; designed tables for triage reviews and overrides
16/2/26	1.5 hours	Integrated encryption utilities for sensitive patient data; researched PIPEDA compliance requirements
17/2/26	2 hours	Began doctor dashboard frontend implementation;

		created patient queue view component
18/2/26	2.5 hours	Implemented nurse override functionality with confirmation dialog; connected to backend API for updating triage levels
19/2/2026	2 hours	Debugged authentication issues with AJ; fixed CORS configuration for local development
20/2/2026	2.5 hours	Added audit logging middleware to track all nurse actions (reviews, overrides, escalations)
23/2/26	3 hours	Midterm report preparation: Drafted Changes to Proposal section, compiled work logs, prepared video demo script

AJ Work Logs

Date	Number of Hours	Description of Work Done
Feb 15, 2026	2.5 hours	Reviewed project proposal and confirmed requirement to use real Emergency Department dataset instead of purely synthetic simulation.
Feb 16, 2026	2.5 hours	Located and downloaded NHAMCS 2022 Emergency Department Public Use dataset and reviewed technical documentation and codebook
Feb 17, 2026	2.5 hours	Explored dataset structure using Python and pandas; inspected variables related to waiting time, length of visit, admission, and discharge outcomes.

Feb 18, 2026	2.5 hours	Developed data loading script to import Stata dataset, identify relevant ED workflow variables, and verify dataset integrity.
Feb 19, 2026	2.5 hours	Implemented data cleaning process including handling NHAMCS missing-value codes and exporting cleaned ED workflow dataset to CSV.
Feb 20, 2026	3.0 hours	Generated visualization comparing baseline versus remote triage metrics for inclusion in progress report and presentation.
Feb 21, 2026	3.0 hours	Debugged script execution issues (Pythonenvironment, variable naming, missing column errors) and validated final analytics outputs.
Feb 22, 2026	2.5 hours	Prepared outputs for GitHub repository, verified generated CSV files and charts, and documented analytics workflow for midterm report.
Feb 23, 2026	3 hours	Midterm report preparation: Drafted Changes to Proposal section, compiled work logs, prepared video demo script

Reference

Asplin BR, Magid DJ, Rhodes KV, Solberg LI, Lurie N, Camargo CA Jr. A conceptual model of emergency department crowding. Ann Emerg Med. 2003 Aug;42(2):173-80. doi: 10.1067/mem.2003.302. PMID: 12883504.

Bashshur RL, Shannon GW, Smith BR, et al. The Empirical Foundations of Telemedicine Interventions for Chronic Disease Management. *Telemedicine and e-Health*. 2014;20(9):769-800. doi:10.1089/tmj.2014.9981

Dugas AF, Kirsch TD, Toerper M, Korley F, Yenokyan G, France D, Hager D, Levin S. An Electronic Emergency Triage System to Improve Patient Distribution by Critical Outcomes. J Emerg Med. 2016 Jun;50(6):910-8. doi: 10.1016/j.jemermed.2016.02.026. Epub 2016 Apr 25. Erratum in: J Emerg Med. 2016 Aug;51(2):224. doi: 10.1016/j.jemermed.2016.08.004. PMID: 27133736.