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Research Article

A practical Digital Model for Real-Time Health Surveillance and Early Warning Systems During the Arbaeen Pilgrimage

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Abstract

The Arbaeen pilgrimage is one of the largest annual mass gatherings in Iraq, posing major challenges for health services due to high participant density and limited infrastructure, which may increase disease transmission. This article presents a digital design supported by a data governance framework for rapid response to serious health conditions during the pilgrimage. The electronic system uses Google Forms to systematically collect patient data, including age, gender, symptom onset location, therapy type, and clinical outcome. The system automatically converts this data into real-time readings displayed on a central monitoring screen. The paper discusses the technical architecture, data-quality assurance measures, early warning indicators for potential outbreaks, implementation, training, and risk management strategy. The electronic system is a low-cost, responsive technology designed to reduce response time and facilitate coordination among hospitals and medical units, with data as a key factor in delivering fast, effective health care during such events, thereby reducing morbidity and mortality.

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1.Introduction

Arbaeen is an annual religious mass gathering held in Iraq, attended by between 17 and 20 million participants [1]. These large-scale events present major public health challenges at both the local and global levels [2]. Several health conditions have been reported in relation to the Arbaeen walking pilgrimage, including infectious disease outbreaks (e.g., influenza), an inadequate integrated waste management system compared with the vast number of pilgrims who come to Iraq, and more walking-related injuries among pilgrims, such as burns, fractures, lacerations or wounds, and blisters. This, in turn, raises questions and concerns over both personal and public health behaviours [2,3].

Many facilitators have been identified as crucial in resolving the health issues linked with the Arbaeen pilgrimage. These include comprehensive pre-coordination, a health monitoring system, health facilities and other social services, pilgrim medical safety strategies, and pilgrim education and preparedness. The most crucial facilitator is customized pilgrim education on common health problems, especially regarding fundamental practices such as hand hygiene [4].

The healthcare system in Iraq has struggled to operate effectively and efficiently, particularly during public health emergencies and major gatherings such as the Arbaeen walk [4]. These challenges have resulted in resource waste, ineffective screening strategies, and underutilization of patient tracking systems [5]. Structural deficiencies and poor strategic planning have led to a shortage of adequate quarantine spaces and uneven access to critical medical equipment [6]. Moreover, limited capacity to detect high-risk populations and deliver comprehensive risk communication has left people at higher risk of emerging and re-emerging infectious diseases, requiring well-organized collaboration among mass-gathering stakeholders, including the ministries of health and relevant organizations, to use rapid syndromic surveillance systems to promptly identify and control communicable diseases [7]. Addressing these limitations requires leveraging the proven effectiveness of Early Warning Systems (EWSs) across diverse contexts and resource settings, in particular, by determining which data collection strategies are most effective. There is evidence that using pre-diagnostic information in EWSs enables faster, more proactive detection of epidemics than routine surveillance [8].

Bieh et al. [9] demonstrate how surveillance would improve timeliness and situational awareness of health events, including non-infectious threats, as applied during the 2019 Hajj. The Ministry of Health in Saudi Arabia implemented an early warning health system for the first time to rapidly detect and respond to health threats. An early warning system based on electronic information would enhance case detection, monitor the geographical spread of disease, and support control activities.

The study's goals are to create a real-time digital workflow that connects Google Forms, Google Sheets, dashboards, and geospatial analysis tools to design a standardized data model for collecting patient data in hospitals and medical units during the pilgrimage, and to establish early warning systems to identify unusual clustering of epidemic symptoms.

2. Proposed Methodology

2.1 Technical Architecture (Data Pipeline)

1. Unified Google Form, which consists of a concise, multi-page form with conditional questions and answers to reduce the risk of data input error.
2. Google Sheets for a convenient database application with data validation and cleaning layers.
3. Apps Script is designed for assigning case numbers by the computer, and automatic notifications if specific symptoms or location thresholds are surpassed.
4. Looker Studio Dashboards presenting heat maps, daily trends, and KPIs in real-time.
5. Google Maps Mapping of medical unit locations and service areas.

2.2 Form Design

Section A: Demographic Data

1. Case ID, which is auto-generated
2. Date and time are conducted automatically
3. Medical unit/hospital as a dropdown list
4. Recorder name or code
5. Age in years or categories such as (<5, 5–14, 15–49, ≥50)
6. Sex (male/female)

Section B: Symptoms and Vital Signs

1. Symptoms are listed in a multiple-choice format (fever, cough, breathlessness, diarrhea, vomiting, belly pain, looks dead/wakes up when shaken hard or shouted at, and eyes sunken)
2. Symptom onset date/time
3. Other clinical parameters (temperature, pulse rate, blood pressure, SpO_2) were optional.
4. Triage protocol gathered severity classification (ie, mild/moderate/critical)

Section C: Location and Epidemiological Data

1. Destination of symptom onset (station, street processional, district) selection or typed into the map.
2. Patient origin (province/country)
3. Existence of similar cases /procession (yes/no/unknown)

Section D: Diagnosis and Treatment

1. Preliminary diagnosis or clinical syndrome
2. Treatment given (oral/IV rehydration, antipyretics, antibiotics, oxygen, cooling therapy, wound care, and so on).
3. Referral status and destination hospital
4. Outcomes at the time of discharge (improved, stable, deteriorated, discharged from facility)

Section E: Medical Unit Services and Supplies

1. Estimated waiting time
2. Access to medicines and commodities (yes/no)
3. Number of on-duty staff
4. Operational notes

2.3 Data Quality Assurance

1. Age, sex, medical unit, and symptoms, as well as the date, were mandatory to complete. Certain fields (age, sex, medical unit, and symptom) had to be completed.
2. Normalized symptom and diagnosis dropdown lists.
3. Range Verification (e.g., age 0–110 years; temperature 34–43°C).
4. Conditional logic for showing extra fields if you choose certain symptoms.

5. Informative error messages for unrealistic values.

2.4 Analytics and Dashboards:

1.Cases by hour, average time between arrivals, and symptoms.
2.Spatial Analysis for Maps of symptoms clustering by street or procession in a heat map.
3.Epidemiologic measures of interest included disease rates per 10,000 or rates of referral (for those with available population estimates), as well as proportionate syndromic distributions (respiratory, gastrointestinal, heat-related) and risk ratios (attack rates).
4.Operational performance, such as response time, shortages of supplies, and personnel per case.

2.5 Early Warning and Detection of Abnormal Clusters

1.Establishment of baseline levels for each symptom and location during the first 24–48 hours.
2.Application of simple rules, including:
- Simplified CUSUM alerts for cumulative deviations beyond set thresholds.
- Three-hour moving averages triggering alerts at ≥2 standard deviations above baseline.

Operational Threshold Examples:

1. ≥5diarrhea cases within 1 hour and in a 500-m radius→ Yellow alert.
2. ≥2 critical heat syncope events in the same location within 30 minutes → Orange alert.
3. Suspected cholera, measles, or nationally notifiable disease → Red alert and immediate notification.

2.6 Supply Chain and Logistics Monitoring

Reported shortfalls written in the form are automatically displayed on the logistics overview, and if any reported stock is projected to run out within ≤8 hours, place an immediate replenishment order.

3. Implementation Plan

3.1 Governance and Roles

1. Provincial Health Operations Room contains dashboard management, alert monitoring, and decision-making.
2. Sector Coordinators for data quality monitoring and technical support.
3. Medical Unit/Hospital Leads for data entry, preliminary verification, and reporting shortages.
4. IT Team to design forms, dashboard, and script development.

3.2 Proposed Timeline (14 Days Before Peak)

1.Days −14 to −10: Complete final form design, variable dictionary, internal testing.
2.Days −9 to −7: Develop the dashboard and service area map.
3.Days −6 to −4: Conduct training of trainers and preparation of visual training materials.
4.Days −3 to −1: distribution of QR code, load testing, and conduct alert simulations.
5.Peak days: Provide continuous technical support and hold coordination meetings every eight hours.
6.Post-peak (1 week): Data cleaning, final analysis, and lessons-learned report.

4. Key Performance Indicators (KPIs)

1. Record completeness should be at least 95%.
2. Data update latency should not exceed 5 minutes.
3. Referral rate should be monitored by unit, location, and hour.
4. Frequency of supply stock-outs should be tracked daily.
5. Alert response time should not exceed 60 minutes.
6. Average waiting time should be measured for each medical unit.

5. Information Security and Ethical Considerations

1. Minimal personal data collection; no full names or phone numbers except when necessary for follow-up.
2. Restricted access with view-only permissions for non-authorized users and two-factor authentication for administrators.
3. Anonymization through random case identifiers.
4. Daily backups and secure CSV exports after the event.
5. Simplified informed consent via on-site signage explaining data use and protection

6. Statistical Analysis

Descriptive statistics will be utilized to summarize demographic, clinical, and operational data. Categorical characteristics, such as gender, symptoms, referral history, diagnosis categories, and geographical location, will be reported as percentages and frequencies. Continuous variables, including age, waiting time, and condition, will be reported as means and standard deviations (SD) for normally distributed data, or as medians and interquartile ranges (IQR) for non-normally distributed data. The surveillance system will include automated epidemiological analyses, such as hourly case counts, syndromic distributions, referral rates, and illness incidence per 10,000 people, when background data is available.

For early epidemic detection, simplified cumulative sum (CUSUM) surveillance and 3-hour average movement analysis will be used. Alerts will be sent if observed case numbers exceed predetermined thresholds or are ≥2 standard deviations above baseline values established during the first 24-48 hours of monitoring. Whenever analyses across groups are needed, a Chi-square or Fisher's exact test will be utilised for categorical variables. In contrast, the Student's t-test or the Mann-Whitney U test will be used for continuous variables, depending on their distribution. Statistical significance will be determined at $p < 0.05$.

All patients who present to participating medical units during the surveillance period will be added to the database in sequence. Because the suggested model is intended as a feasibility and operational surveillance framework rather than a hypothesis-testing study, no formal power analysis will be performed. However, sample size calculations may be performed in future large-scale implementations based on predicted illness incidence and surveillance sensitivity needs.

7. Estimated Cost (Approximate)

Connectivity and data SIM cards are market-specific. Printing of QR codes and informational materials is considered low-cost. The cost of training materials and sessions is moderate to low. App Script development is attainable in-house with no licensing costs.

8. A Simple Data Collection Model from one Medical Unit in one day only as an Example:

A data collection strategy was established in partnership with a single private medical unit. Workers in the unit were provided with the link to the electronic form. It was created to register relevant patient data, including demographics (age and gender), symptoms at presentation, the anatomic location of symptom onset, treatment administered, presence of chronic comorbidity(s), and whether hospital admission was required.

A licensed practitioner entered data over 24 hours corresponding to the day before Arbaeen Day on 20 August 2025. Meanwhile,

clinical information was obtained from 99 patients who presented to the medical unit with various health issues.

9. Results:

1.Analysis of age and gender distribution indicated that the 18–35-year age group constituted the largest proportion of Arbaeen visitors attending the medical unit (Figure 1). Male participants predominated, accounting for 68.7% of the total sample. Figure 2.

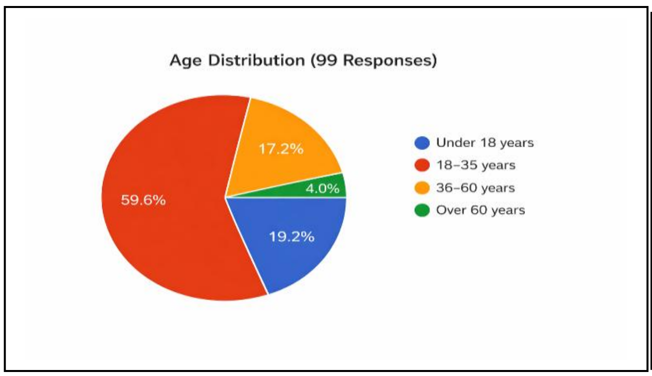

Figure 1: Age distribution of Arbaeen visitors attending the medical unit

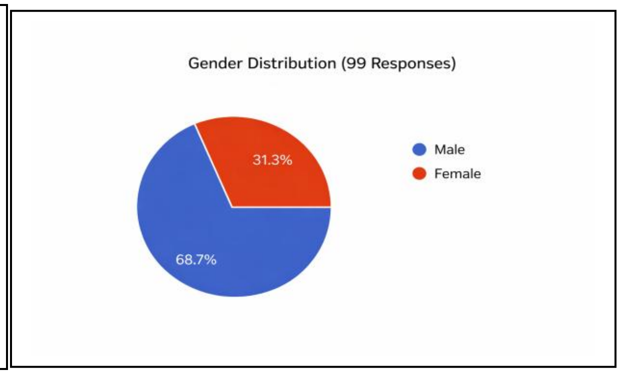

Figure 2: Gender distribution of Arbaeen visitors attending the medical unit

2.Analysis of reported symptoms indicated that fever and cough were the most commonly observed clinical manifestations. Diarrhea was the third most frequent symptom, reported by 24 patients. Figure 3

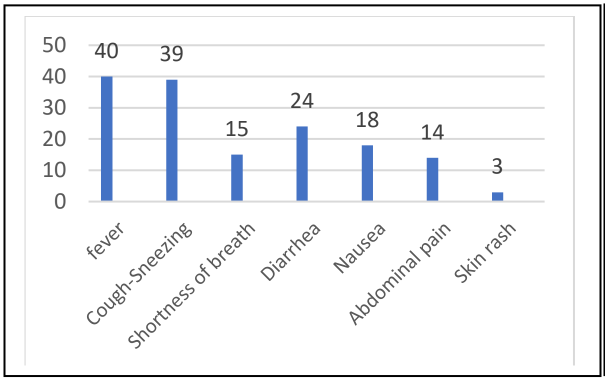

Figure 3: Types of symptoms of Arbaeen visitors attending the medical unit

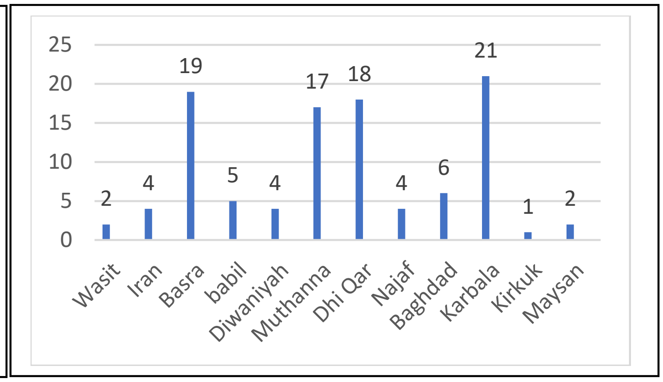

Figure 4: Countries, Governorate distribution of Arbaeen visitors attending the medical unit

3.Analysis of visitors' countries and governorates revealed that, excluding Karbala Governorate, the highest number of individuals attending the medical unit within a single day originated from the southern governorates, particularly Basra, Dhi Qar (Nasiriyah), and Al-Muthanna. In addition, four visitors were identified as originating from the Islamic Republic of Iran. Figure 4

4.It was found that most symptoms appeared in patients while they were resting at the service tents, with some symptoms emerging upon arrival in Karbala. Figure 6. Additionally, the majority of affected individuals were treated within the medical unit, while 16% were transferred to hospitals. Figure 5.

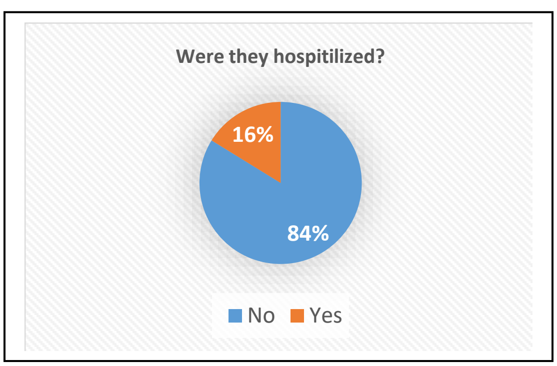

Figure 5: Number of Arbaeen visitors who are transported to hospitals

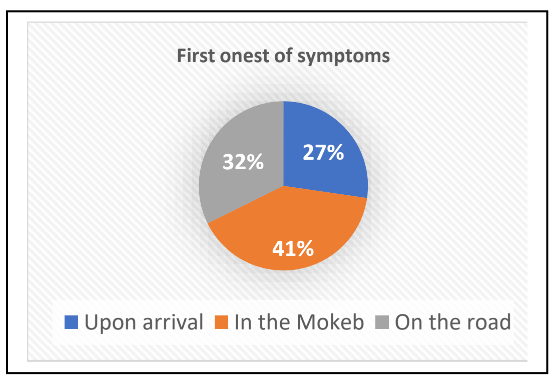

Figure 6: Places where the first onset of symptoms of the disease appears in visitors

5. The most important medication given to patients was:

Paracetamol 1 g v +N/S 500 ml + Flagyl 500 mg v + Amoxil 500 mg + Flagyl 500 mg tab. + Brufen tab.

Decadron, paracetamol, fulout

Brufen, Flagyl, Paracetamol tab, Decadron amp., Flagyl tab.

6. The other information collected was the name of the medical unit, its geographical location obtained via Google Maps, and the nearest hospital to the unit.

10. Discussion:

Mass gatherings, including the Arbaeen pilgrimage, pose significant challenges for healthcare provision due to high participant density and limited infrastructure during the event. Quick, efficient healthcare in these situations is crucial for reducing morbidity and mortality. There may be an answer in practical virtual models that offer real-time access to patients' data and can be transported anywhere [10].

Clinical data from 99 patients were harmonized and analyzed concurrently using a streamlined digital data collection method, organized under a single medical unit for one day. Influenza-like illness, defined as fever and cough, was the most frequently diagnosed acute disease, underscoring the prevalence of respiratory conditions during Arbaeen. These results align with those of Al-Ansari et al., who found that fever and cough are the most common symptoms, emphasizing the heightened risk of respiratory illness transmission in overcrowded settings with prolonged close contact. The presence of fever and cough may serve as a significant syndromic indicator, underscoring the need for ongoing surveillance during large gatherings and increased public health awareness of threats such as the recent COVID-19 pandemic [11] .Diarrhea was identified as the second most significant symptom. The primary causes of diarrhea among Arba'een pilgrims included contaminated water sources, unsafe food, and inadequate hand hygiene. The data suggest that the potential for epidemics, particularly waterborne and foodborne infections such as watery diarrhea, could signal a cholera outbreak [12,13].

Innovative digital technologies are frequently utilised to enhance existing public health monitoring systems, enabling the documentation of health events, risks, and services to support disease response.

The effectiveness of these technologies is determined by their timeliness, sensitivity, specificity, predictive value, and accessibility. While traditional processes, such as contact tracing, can be extremely challenging during large-scale outbreaks, systems built on these technologies can support early detection and prompt responses [14]. Furthermore, such data provided insight into the spatial spread of symptoms, the number of patients requiring hospital referral, and the sorts of therapies used. Taken collectively, this strategy provides a quick, efficient, and scalable solution for disease surveillance and case tracking during large gatherings [15].

11. Limitations

Dependence on internet connectivity. Staff adherence to data completion during the pressure period.

12. Conclusions

The suggested digital surveillance strategy offers a feasible, cost-effective, and scalable solution to improving public health monitoring during the Arbaeen pilgrimage. The system is meant to collect, analyze, and visualize health data from medical units and hospitals in real time by combining through a cohesive workflow. The system is designed to improve disease cluster detection, communication between healthcare facilities and health organizations, and evidence-based decision-making during large-scale gatherings. Furthermore, the use of automated alarms, spatial analysis, and operational performance indicators may enable prompt responses to emergent public health hazards and resource shortages. The experimental application demonstrates the possibility of electronic data collection and continuous monitoring in a resource-constrained environment. A broader implementation across various medical units could result in a comprehensive surveillance network that improves outbreak preparedness, reduces response times, and produces high-quality datasets for future research and policy development.

Future research should assess the system's effectiveness, sensitivity, and operational performance during large-scale adoption, and its potential integration into routine public health surveillance in Iraq and other mass-collection locations.

13. Conflict of Interest

There is no conflict of interest

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