# FAILURES IN VISUAL SIGNAGE SYSTEM FOR DISEASE TRANSMISSION PREVENTION

ENSE624 – Human Factors in System Engineering

Spring 2025

Josh Hochman
jhochman@umd.edu

# Contents

# Background

In the world of 21st century medicine, hospitals function as highly complex information systems, managing resources and data about hundreds of patients, visitors, and staff members every day of every week. To effectively track large volumes of data, hospital staff leverage many different types of information systems, ranging from complex digital databases and visual human-machine interfaces to simple pen-and-paper charts and signs.

Among the many different metrics tracked in a hospital setting, medical care providers need a way to keep track of a patient's latest diagnosis and potential risks to other humans. As each patient follows a path from their initial intake into the emergency room to their placement in different rooms in the hospital, digital systems track a property known as the patient *isolation precaution status*. Isolation precautions serve as a warning that a patient's health conditions make them contagious to others and indicate a need to wear appropriate PPE (personal protective equipment). The three types of precautions include *contact*, *droplet*, and *airborne*.

- ***Contact Precautions*** indicate a risk of infective transfer from a patient to another person via touch. It serves as the lowest of the PPE-required precaution levels, necessitating use of gloves and/or a gown to prevent transfer via hands or clothing.
- ***Droplet Precautions*** indicate a risk of infective transfer from a patient to another person via small particles, typically through coughing or sneezing. Protections for droplet precautions include a medical mask and potentially eye protection, in addition to all requirements for contact precautions (gown and gloves).
- ***Airborne Precautions*** indicate the highest risk of infective transfer. Airborne transfer means that the disease can spread through the air via the smallest of particles. Effective measures for preventing spread of airborne diseases include N95 masks or a PAPR protective suit.

At ABC Hospital[1], the Epic patient management system digitally tracks each patient's isolation precautions automatically based on the specific diagnosis entered into the patient's medical chart. However, individual patient holding rooms are not equipped with digital screens that make this information visually available at a glance. Instead, the hospital relies on nursing staff to make use of physical signage, posted at the entrance to each room or point of use. Patient charts act as constantly evolving records; as staff receive additional diagnostic information and testing results, the chart automatically adjusts the precautions level to include the appropriate PPE. Nursing staff bear the

[1] The actual hospital name has been anonymized for this report.

responsibility of updating the precaution signs outside each patient room as the system gathers additional information.

Unfortunately, the system of physical signage often fails in its goal of human protection. An exploration of multiple areas of the hospital reveals that signage is frequently ignored or entirely missing from areas where patient information indicates a need for personal protective equipment. As a result, this increases the risk of accidental and preventable disease transmission between the patient and medical staff or visitors.

This human factors study explores the root causes of signage noncompliance, examining a variety of potential contributing factors. Key questions include the following:

- What inputs does the signage process require to function properly?
- What factors contribute most to failed efficacy of the signage process?
- How do hospital digital systems generate precaution statuses, and how is that information transmitted between points of use?
- How do digital HMI layouts communicate precaution status, and how might they be improved?
- How does the design of physical precautionary signs contribute to their effectiveness?
- How does the layout of the hospital help or exacerbate potential exposures resulting from failures of the precautionary signage system? What areas pose a greater exposure risk?

## Methodology

To understand why the signage system fails, I wanted to first map out the entire journey that patients take. For the purposes of this study, this journey begins when the patient first enters the emergency room, and ends when they have been settled into a ward room with proper signage installed.

Upon entry into the hospital, new patients are seated in a waiting room until being called into one of three triage rooms for initial evaluation. Each triage room has two doors, with a front room connected to the waiting area and a rear entry leading directly into the emergency room. After triage, hospital staff move the patient into the ER.

The ER consists of approximately 50 rooms known as pods, which each hold one patient. Pods consist of a front and rear entryway, which may be either a glass swinging or sliding door or a retractable curtain. These pods will house the patient through their next round of consultation and evaluation. From here, patients will either be admitted to the hospital or discharged.

If the medical team opts to admit the patient to the wards, two scenarios can unfold. In the first scenario, the hospital has a ward room immediately available, in which case the nursing staff will transfer the patient from the ER floor to the upstairs wards. However, room availability fluctuates by the minute, and admitted patients may have to wait in a queue. In the second scenario, when no ward rooms are available, stable ER patients may be transferred to another zone of the hospital known as the ETCU, or *emergency transitional care unit*. This unit acts as a temporary holding ward until the hospital has available space in the upstairs wards.

To better understand how the different pieces move, I sought out a copy of the hospital floor plan from the facility's maintenance department. This allowed me to visually map out the patient routes for the facility. Approaching the map like a spaghetti diagram allowed me to start thinking about the points at which the paths taken by undiagnosed patients (who are potentially contagious) can cross the paths potentially taken by hospital visitors.

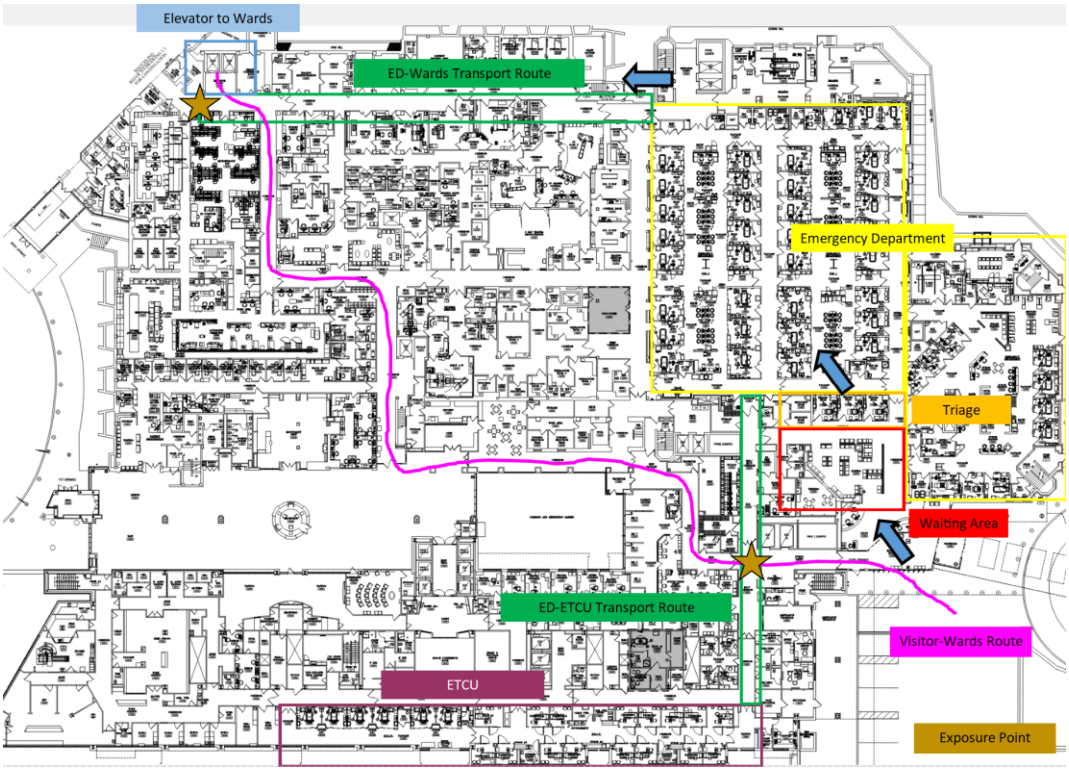



*Figure 1: Patient path from intake. New patients enter through the waiting/triage area (red) and are processed into the ED (yellow) along the route of the blue arrows. If put in a queue for an upstairs ward room, they may follow the lower green path to the ETCU (maroon), and if being admitted directly to the floors, they follow the upper green path to the elevators (blue). Visitors entering the hospital to reach the wards travel to the same elevators via the magenta path. Gold stars represent crossover areas.*

## Digital Tracking of Isolation Status

ABC Hospital uses Epic, a digital platform for tracking patient data. When a user opens the Epic dashboard and enters the patient view, two visual indicators provide information about precautions.

- The “Infection” field tracks the patient’s known diagnosis. If a condition is suspected but not confirmed (for example, if diagnostic testing for a condition is pending), the condition will be prefixed with the phrase “Rule Out”.
- The “Isolation” field contains information about the required precautions, which Epic automatically populates based on the code in the Infection field. Isolation precautions are populated regardless of whether the Infection is in Rule Out status.

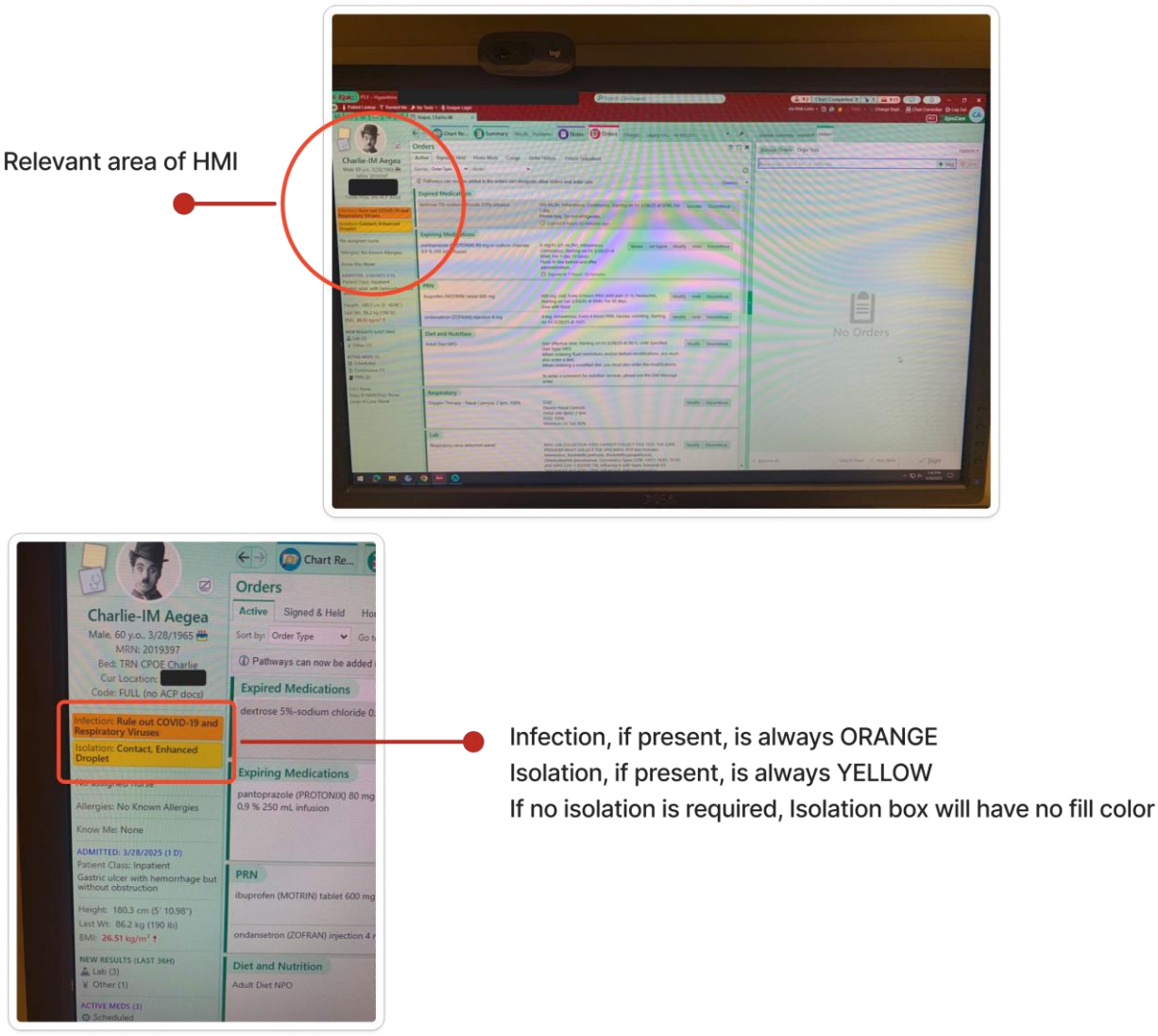
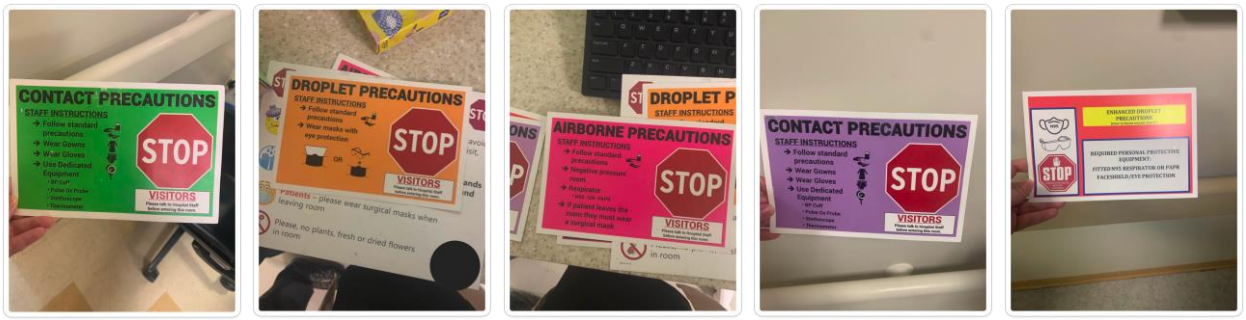



*Figure 2: The Epic GUI uses an orange text box for Infection status and a yellow text box for Isolation status. If no isolation precautions are active, the Isolation box is colorless. The Infection box is always orange.*

## Physical Signage

The hospital uses several types of physical signs to indicate the isolation precautions for each patient room. Each sign is printed on a roughly 8.5x11” laminated card and features specific information about the isolation type, along with instructions on how to use the proper PPE. Signs were typically designed with bright, noticeable colors and a large stop sign icon to grab recipients’ attention. However, sign design varied noticeably between different hospital units. For example, Contact precautions signs were green in some areas of the hospital and purple in others.




Nurse practitioners hold the responsibility of keeping posted signage up to date. Once a patient receives their initial diagnosis in the emergency department, nurses are supposed to post a sign outside the patient’s door that corresponds to the Epic Isolation status. Similarly, signage should be present outside patient rooms in the ETCU and upstairs wards.

# Data Collection

To collect data on adherence to proper signage, I worked with a member of the medical staff to identify and track patients as they moved between the ED, ETCU, and wards. Epic gathers timestamp data for many distinct process steps, including each time the patient sees a provider, times when diagnostic testing is ordered (and results received), and times when the patient’s Infection or Isolation status change. Throughout the day, I observed different zones of the hospital, noting whether precautionary signs were present and recording the time of each observation.

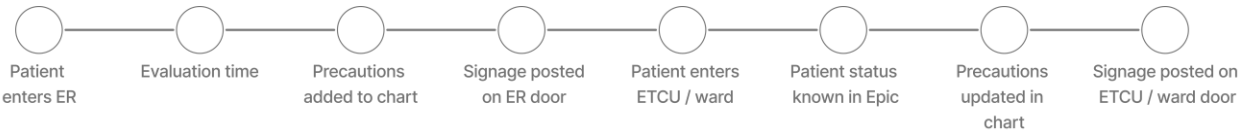



*Figure 3: Generalized patient movement path and information flow. Not all patients follow the complete path.*

By combining these timestamps together, I could identify the length of the period during which the patient was an exposure risk.

Over the course of 4 site visits, data was collected to track the movements of nine separate patients. Each patient's journey was mapped using a series of numbered time points, measured either from Epic or via direct observation.

- The initial time $t_0$ represents the patient's admission time into the emergency department.
- Time $t_1$ represents the timestamp for the first evaluation at which enough patient information is known to generate an initial possible diagnosis, and thus, the time at which rule-out precautions can theoretically be generated. Since patients are triaged and then further evaluated in the emergency department, this study assumes that $t_1$ represents the time of the evaluation by a healthcare provider in the ED pod, not the evaluation in the triage room.
- Time $t_2$ represents the timestamp after the ED evaluation at which a health care provider enters the initial diagnosis into the patient's electronic medical record. If the patient entered the emergency department with unknown medical status, then $t_2$ would occur after $t_1$. However, in some cases the patient entered the hospital with a known diagnosis. For these data points, it was assumed that the patient's $t_2$ value was equivalent to their $t_0$ value (i.e., the patient's complete diagnosis and thus their required isolation precautions were known at the time of entry into the emergency department).
- Time $t_3$ represents the point at which a sign is posted outside of a patient's ER door(s). Since the physical signs are not directly linked to the electronic medical record, it was expected that there would be a short delay between $t_2$ and $t_3$, though no hypothesis was made regarding the average length of the delay.
- If the patient was transferred from the ED to the ETCU over the course of an observation, then $t_4$ represents the time at which the patient entered their ETCU room, $t_5$ represents the time at which signage was posted outside of the ETCU room, and $t_6$ represents the time when the patient was discharged from the ETCU.
- For patients that were moved from the lower level of the hospital to an upstairs ward, $t_7$ represents the time at which the patient entered their ward room. $t_8$ represents the time at which the patient's test results were posted to Epic, meaning that diagnosis and isolation precautions would both be known/no longer on Rule Out status. Finally, $t_9$ indicates the time at which a sign was posted outside the patient's ward room with their relevant isolation precautions.

# Data Analysis / Interpretation

The main objective of tracking timestamp data for each patient was to ascertain the length of the time window for potential human to human disease transmission. For the purposes of this study, the potential exposure window was measured regardless of whether the patient ultimately tested positive or negative for disease. The study uses the final testing result only to distinguish between potential exposure and actual exposure.

Patient 1 was treated in both the ED and the ETCU before being discharged. In both environments, no physical signage was ever seen during the period from $t_0$ to $t_6$. The patient's chart indicated they were under evaluation with contact isolation precautions. The patient was discharged positive for contact illness.

Patient 2 was tracked from their entry at time $t_0$ and was still in the ED at the end of the collection period. Though it was known that this patient was going to be admitted, no data was collected beyond time $t_3$. Signage was properly posted outside this patient's room, and the patient ultimately tested positive for airborne illness.

Patients 3, 4, 6, and 7 were all treated in the ED and discharged during the observational period. No precautions signs were posted outside their ED rooms. All four patients ultimately tested negative for droplet illness.

Patient 5 was a known positive for contact precautions at the time of intake into the emergency department. Due to capacity constraints, she was moved to the ETCU shortly after triage and her initial evaluation ($t_1$) occurred in the ETCU. No signage was observed on this patient's ED or ETCU doors over the course of the study.

Finally, Patients 8 and 9 were evaluated in the ED and moved to the upstairs wards. No signage was posted for either patient in the ED. Proper signage was observed outside Patient 8's ward room, but no signage was observed outside Patient 9's ward room by the end of the data collection period. Both patients tested positive for droplet precautions.

## Calculation of Exposure Times

Across the entire dataset, only two instances were observed where signage was installed outside a room as expected. However, the exact timing of the installation was never directly observed, so an average was calculated to approximate the installation time. For example, if observations indicated that signage was posted on an ED door in the window of 3:00pm to 3:30pm, then the $t_3$ value was approximated as 3:15pm.

| Patient | Exposure Time | Result | Exposure Time (hr) |
|---|---|---|---|
| 1 | 4 hr 27 min | Positive - actual contact exposure risk | 4.45 |
| 2 | 2 hr 15 min | Positive - actual airborne exposure risk | 2.25 |
| 3 | 3 hr 52 min | Negative - no actual droplet exposure | 3.87 |
| 4 | 1 hr 59 min | Negative - no actual droplet exposure | 1.98 |
| 5 | 23 min | Positive - actual contact exposure risk | 0.38 |
| 6 | 3 hr 7 min | Negative - no actual droplet exposure | 3.12 |
| 7 | 1 hr 14 min | Negative - no actual droplet exposure | 1.23 |
| 8 | 8 hr 14 min | Positive - actual droplet exposure risk | 8.23 |
| 9 | 5 hr 30 min, minimum | Positive - actual droplet exposure risk | 5.50 |

*Table 1, exposure times by patient. Some data points indicate actual exposure of a contagious patient to others. Others were near misses, with signage not followed but the patient ultimately proving non-contagious.*

| Average Exposure Windows (hrs) | |
|---|---|
| Positive Cases | 4.16 |
| Negative Cases | 2.55 |
| All Cases | 3.45 |

*Table 2 – Among the observed patients, exposure windows were longer for the positive cases, on average.*

| Signage Used - Instances | |
|---|---|
| ED | 1 of 9 |
| ETCU | 0 of 2 |
| Wards | 1 of 2 |

*Table 3 – Consistently poor sign usage within the ED; not enough data points to draw conclusions for the ETCU and wards.*

The Epic database tracks and timestamps every interaction between a patient and a hospital staff member. Thus, it is possible to calculate the number of interactions that could have potentially resulted in disease transmission from patient to staff within each of the exposure windows. Unfortunately, Epic does not save interaction timestamp data beyond about 2 days, so I was only able to collect a limited amount of data on this metric during my site visits. For the four patients that tested positive, patients averaged about 10.5 staff interactions during the observation window which could have been potential transmission events.

| Patient | Exposure Time (hrs) | Patient-Staff Interactions | Diagnostic Result | Exposures per hr |
|---|---|---|---|---|
| 1 | 4.45 | 8 | Positive - contact | 1.80 |
| 2 | 2.25 | - | Positive - COVID - airborne | #VALUE! |
| 3 | 3.87 | 15 | Negative - droplet | 3.88 |
| 4 | 1.98 | - | Negative - droplet | #VALUE! |
| 5 | 0.38 | 3 | Known positive- contact | 7.83 |
| 6 | 3.12 | - | Negative - droplet | #VALUE! |
| 7 | 1.23 | - | Negative - droplet | #VALUE! |
| 8 | 8.23 | 16 | Positive - droplet | 1.94 |
| 9 | 5.50 | 15 | Positive - droplet | 2.73 |

*Table 4: Potential patient-staff transmission events*

## Additional Findings

While this study primarily focused on the challenges around proper use of patient isolation precaution warning signs, an analysis of the floor layout in the areas of study revealed some interesting results.

Prior to my first visit to the hospital, I wondered whether it would be theoretically possible to reorganize the ED layout in such a way that the area could be broken into distinct zones corresponding to the different levels of isolation precautions. The process flow from the ED waiting room to the ED pods is relatively linear, with patients passing through the triage rooms into the larger ED zone. However, assigning certain pods to be contact precaution areas and other pods to be airborne precaution areas would in practice likely be near impossible. The ED varies greatly in capacity, but based on discussions with hospital staff, this capacity most often exceeds 50%. As a result, new patients are typically assigned to whatever room is available first. Limiting the number of pods that could accommodate a particular isolation status would likely cause bottlenecks in the intake process, exacerbating the bottleneck already present from the limited number (three) of triage rooms.

Within the emergency room, the dual entryways into each pod also complicate the challenge of maintaining good adherence to the signage policy. Unlike patient rooms in the ETCU and upstairs wards, ED pods have two entrances. The rear entrance consists of a traditional swinging wood door, which I observed was typically closed. These doors often opened into larger hallways, making them the preferred exit route for moving the patient's mobile bed to another area of the hospital. The front entrances consisted of either sliding glass doors or curtains and opened into the center of the ED, where most of the hospital workstations were located. Medical staff typically use these entryways when moving from one patient room to another. With two doors to maintain, nurses using the precaution signs

have twice as many doors to keep up to date in an already hectic area of the hospital where other medical tasks take priority.

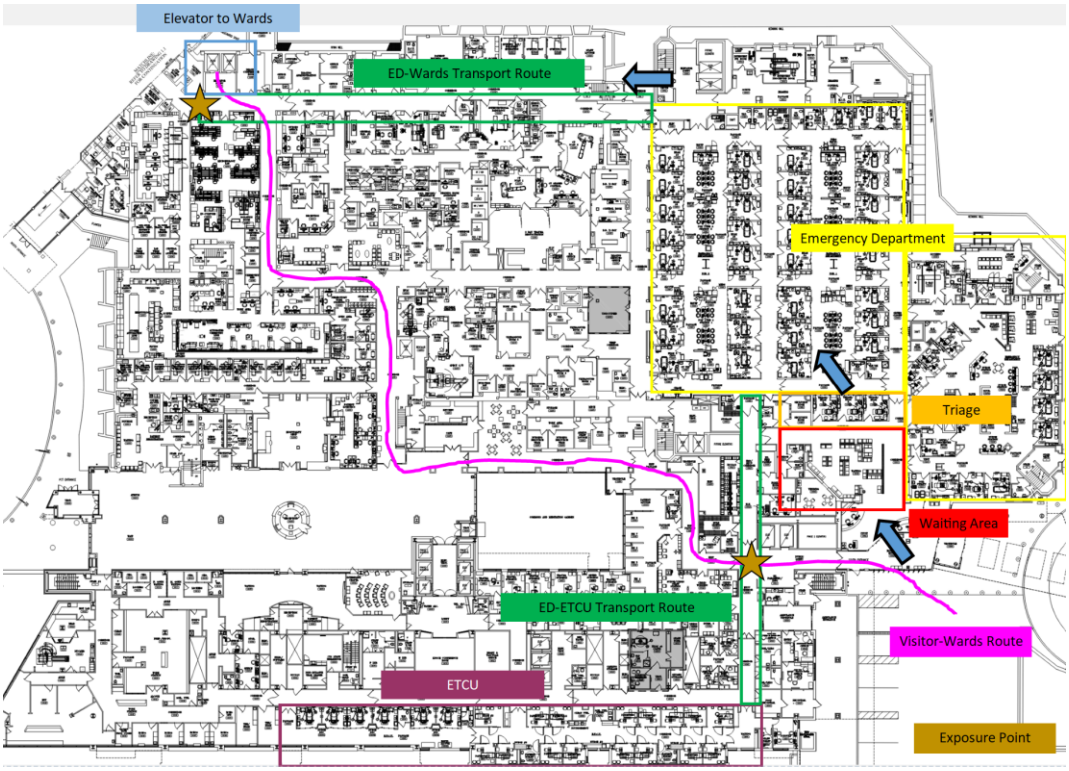



*Figure 4: The ED floor layout*

A review of the layout of the hospital also reveals several areas at higher risk of disease transmission. In Figure 4, we can see that new ED patients pass through zones in a red-orange-yellow order from intake to triage to the ED. The green zones represent transport routes connecting the ED to the ETCU or the ED to the elevators that lead to the upstairs wards. The magenta line shows the approximate route that civilian visitors would take on their way to the wards. By overlaying this route on top of the facility layout, we see two points of crossover: the lobby area near the ETCU, and the lobby in front of the elevators to the wards. To reduce the risk of disease transmission in these locations, the hospital would need to develop an alternate route for visitors to follow. For example, instead of having visitors and patients share the same elevator (as shown in Figure 5), these elevators could be designated for patient / staff use only, and visitors directed toward a different route to the upper floors.

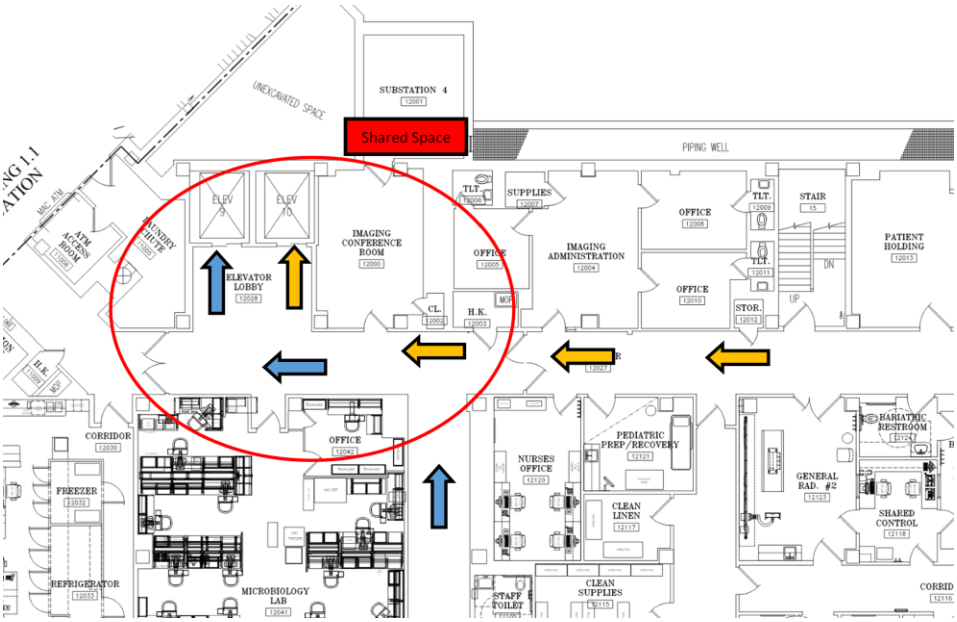



*Figure 5: The elevators represent an unprotected space that places contagious patients in close proximity with the general public.*

# Recommendations

The data collected as part of this study clearly supports the expectation that there would be gaps in proper usage of patient precaution signage. However, in addition to showing the frequency of process failures, the data also show that even when the signs are used, there are often gaps on the order of several hours during which disease transmission can occur. Exposure rates for the observed data typically ranged from 1-4 exposures/hour, with one patient exhibiting an hourly rate of nearly 8 exposures/hour.

As I explored the different hospital zones, a common observation I made was a lack of standardization. For the physical sign process to work, staff entering a room need

> (a) to know the most recently identified status of the patient through clearly visible and understandable signage;
> (b) to pay attention to / abide by the signage;
> (c) to have the required PPE readily available at or very close to the point of use.

In the Toyota production system, systems are often analyzed to reduce *muda*, a Japanese term meaning “waste”. One of the most common forms of waste is excess motion. In the hospital system, PPE availability varied by ward. In the ED, the hospital stored PPE on shelves at various locations across the ward. In the ETCU, teams used mobile carts to store equipment such as gowns and gloves; if someone needed PPE before entering a room, they would need to walk to the cart, gown, and then return to the room. Finally, the upstairs

wards used the most efficient process, with PPE receptacles mounted directly to the doors of each patient room. A simple improvement that could be made would be to standardize the supply locations in the ED and ETCU to match the layout used in the wards.

One of the key root causes of the problems with the physical signage system is its reliance on feedback control. In a feedback control process, a system takes action based on the observed outputs. If a detector senses that an output has deviated from its setpoint, it sends a message telling the system to adjust its inputs in response (Reddy, 2025). In the example of ABC Hospital, staff are supposed to enter each patient room (action) in a manner based on the posted sign (output), with the initial output state being "patient status is unknown". When the patient's status is determined (output deviates from the setpoint), the input is adjusted, with the nurse changing the sign and incoming visitors adjusting their PPE. Unfortunately, the physical signs will almost always lag behind the digital system. The process also requires two distinct steps: the nurse first interprets the digital chart, then travels to the patient room to post or update the sign. Medical staff, particularly nurses, regularly juggle multiple patient care tasks simultaneously, such as responding to call buttons or codes. As a result, the task of installing signs typically gets prioritized low on the list below a variety of more urgent patient needs.

Rather than using a feedback system, the hospital would benefit from designing a feedforward process. In feedforward control, corrective action is taken before any interruptions (commonly referred to as disturbance variables) have an opportunity to disrupt a process (Reddy, 2025). With this type of design, the patient status needs to be available before a human has the chance to be exposed to a potential hazard. When the patient's digital status changes, the result would be automatically fed to a system that displays that status at the point of use (the door), instead of passing it to the nurse who then has to react to it.

One potential moderate cost design option that could allow for feedforward control would be use of a series of andon indicator lights. This method would require integration of the digital Epic system with physical hardware. Outside of each room, the hospital could install a three-color stack light, with each light representing one of the three isolation precaution statuses. As soon as the patient's chart indicates they have been placed on isolation precautions, Epic would send a signal to the stack light based on the room number in the chart. Additionally, this type of system could also incorporate human hearing and tactile elements. To prevent someone from ignoring the light and entering a room with active precautions, the doors could be redesigned to require more attention upon entry. For example, you could wire each door to make a beeping sound upon opening if any of the stack lights are illuminated, and install a simple button or pull handle on the wall next to

the door. The visitor would need to pull the handle to stop the beeping, and in theory, this extra but brief task would help the individual remember to use their PPE instead of ignoring the light.

A second potential option to improve signage in the ETCU or patient wards could be a call-and-response framework. In this scenario, when the ED is ready to physically transfer a patient to the ward, they would send a signal to the staff in the new location indicating that signage should be installed. The nursing staff in the wards would then need to install the signage and send a signal back to the ED indicating that the room has been adequately marked, at which point the transfer would proceed. The downside of this approach is that it would slow the process of moving patients out of the ED, but it would be expected to improve the signage compliance rate.

If the hospital wanted to pursue a higher cost solution, another option could be to fully digitize the signage with monitors. For example, Sonifi Health offers a product called a Digital Patient Door Sign, which allows for the display of isolation precautions and other medical information on a small screen (SONIFI® Health, 2025). This type of technology would completely eliminate the need for the nursing team to maintain the paper signs.

Finally, another way to improve the system would be to standardize the design of the paper signs. If team members expect a blue precautions sign with a red Stop on it to indicate that contact precautions are in place, then the same design should be used throughout every ward. Additionally, hospital wards typically lower the ambient lighting at night to help patients sleep. At lower light levels, the darker colored signs, which feature black text, become harder to read and easier to ignore. While the stop sign graphic does help to grab the user's attention, it might be useful to use a design with greater color contrast for these situations.

## Conclusion

Patient isolation precaution statuses play an important role in helping hospital staff keep patients and each other safe. As shown in this study, the use of a manual system to track dynamically changing information poses a significant risk to healthcare workers and does not adequately protect them from disease transmission. By investing in improvements to this system, ABC Hospital can both reduce the burden on nursing staff and help protect patients, care providers, and visitors for years to come.

# Appendices

## Appendix 1 – Complete Process Flow Diagram

The complete process flow diagram can be found at the following URL:

https://www.figma.com/board/UzntSxdghWhG2LNy0VGnHi/ENSE-624-Hospital-Project?node-id=0-1&t=uQYzfBjnHb95Z8YA-1

## Appendix 2 – Raw Data Collection

| Patient No. | Patient Enters ER Room | Evaulation Time | Precautions Added to Chart | Signage Posted on ER door | Patient enters ETCU room | Signage posted on ETCU door | Discharge time from ETCU | Patient enters ward room | Patient results known in Epic | Sign posted on ward room door | Room | Diagnostic result | Approximate Exposure Time | Staff Interactions w/ Patient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | t0 | t1 | t2 | t3 | t4 | t5 | t6 | t7 | t8 | t9 | | | | |
| 1 | 10:13am | 10:18am | 10:13am | never posted | 1:01pm | never posted | 2:40pm | n/a DC | 10:13am | n/a | ETCU 84 / discharged | Positive - contact | 4.5 hrs | 8 |
| 2 | 12:59pm | 1:01pm | 1:03pm | posted between 3:00-3:30pm | tbd | Did not finish collection of data point | Did not finish collection of data point | Did not finish collection of data point | 2:58pm | n/a | ED 423 | Positive - COVID - airborne | 2-2.5 hrs | uk |
| 3 | 12:12pm | 12:20pm | 2:30pm | never posted | n/a | - | - | n/a DC | 4:04pm | n/a | ED 409 / expected to be admitted | Negative - droplet | 4 hrs | 15 |
| 4 | 1:11pm | 1:35pm | 1:44pm | never posted | n/a | - | - | n/a DC | 3:10pm | n/a | ED 431 | Negative - droplet | 2 hrs | uk |
| 5 | 3:27pm | 4:00pm | 3:27pm | never posted | 3:50pm | - | - | n/a DC | 3:27pm | n/a | ETCU 95 | Known positive-contact | 0.5 hrs | 3 |
| 6 | 2:23pm | 2:23pm | 3:06pm | never posted | n/a | - | - | n/a DC | 5:30pm | n/a | ED 433(a) | Negative - droplet | 3 hrs | uk |
| 7 | 2:50pm | 2:51pm | 2:58pm | never posted | n/a | - | - | n/a DC | 4:04pm | n/a | ED 403 | Negative - droplet | 1 hr | uk |
| 8 | 6:01am | 7:18am | 7:18am | never posted | n/a | - | - | 2:05pm | 8:21am | 2:15pm | ED 433(b) | Positive - droplet | 8 hrs | 16 |
| 9 | 9:00am | 9:10am | 9:15am | never posted | n/a | n/a | n/a | 1:01pm | 10:34am | None as of 2:30pm | ED 302 | Positive - droplet | 5.5 hrs + | 15 |

DC = Patient discharged

uk = Unknown

# Citations


Reddy, S. B. (2025). *Feedforward Vs Feedback Control*. Inst Tools. https://instrumentationtools.com/feedforward-vs-feedback-control/

SONIFI® Health. (2025). *Digital patient door signs*. SONIFI® Health Incorporated. https://www.sonifihealth.com/digital-door-sign/