

Threat Mitigation in ED Design

Michael P. Pietrzak, MD, FACEP

Objective:

To develop an understanding of the need and the design approach of incorporating threat mitigation features into Emergency Department design.

Introduction

Modern hospital design has been driven largely by well defined functional programs that describes the purpose of the project, the projected demand or utilization, staffing patterns, departmental relationships, space requirements, and other basic information relating to fulfillment of the institution's objectives. The functional program typically includes a description of those services necessary for how the facility will operate under normal conditions however it should also describe how critical areas will operate under different constraints such as natural, accidental or deliberate threats. In treatment areas the program should describe the types and number of procedures anticipated and address potential future expansion to accommodate increased demand during critical situations. Consideration for infrastructure (building service) equipment requirements, movement of materials (both clean and soiled), fixed and movable equipment, and circulation patterns for staff, patients, visitors, and the public need to be addressed. The functional program should describe how the facility is to operate in both normal and under stressed conditions if designed to accommodate critical situations. External constraints include the building site, zoning, fire and building codes, accrediting bodies and even local cultural acceptance. Financial constraints are ever present. These will all indeed continue to be major factors in hospital design and modernization. However, today's world environment has many threats- natural, accidental or deliberate (such as acts of terrorism). The notion that hospitals or Emergency Departments are "immune" or "protected" from such events is not tenable. The hospital must not only be able to function clinically and provide a healing environment, but should also provide reasonable protection from external threats. Furthermore, hospitals should be prepared and responsive to the medical consequences if those threats are successfully executed. This has historically been accomplished with make-shift or "parking lot" solutions after the hospital has already been built. Project *ER One* was conceived to consider and develop features and capabilities that would enhance medical consequence management and provide threat mitigation. This will enable facilities to address three goals; first, to better manage the medical consequences of disasters (natural or accidental), epidemics and

weapons of terrorism; second, to allow for robust scalability for large numbers of patients; and finally, to protect the facility and the people within (threat mitigation).

In order to most effectively achieve these goals in an operational setting, a number of general principles should be considered in the design process. The principle of daily routine promotes the concept that individuals best perform in critical situations if they are doing tasks similar to their daily work. The dual use principle recognizes that rarely used specialized or contingency spaces consume financial and space resources and either have been neglected during routine facility maintenance or their dual intent has been lost through staff turnover. In this design strategy, whenever feasible, spaces to be used for contingency operations will have a daily use that could be set aside during the contingency. For example a mass casualty triage area could be a lobby during normal operations and hallways could be pre-plumbed and wired to accommodate medical care if needed. Knowledge management is often never considered in hospital design. However, individuals cannot memorize and retain all the information and procedures needed to address any given situation. The facility design should ensure that appropriate responses occur when a given situation presents. For example smart intrusion detection systems could automatically contain an area of a hospital by locking the appropriate doors, and sealing the appropriate ventilation ducts or providing proper ventilation pressurization for the threat.

While Project ER One includes features for medical consequence management and scalability, this discussion will focus on threat mitigation concepts of design included in Project ER One.

There is no claim that all threats can be eliminated, or that any hospital could be designed to handle overwhelming numbers of casualties. Rather there is a fundamental premise that reasonable efforts should be made to mitigate the threats when possible. This, of course, must be achieved within existing external constraints and financial realities while preserving the foremost priority of providing optimal clinical care in a healing environment. Finally, threat mitigation cannot be accomplished by facility design alone. It needs to be an integrated solution with procedures, personnel training, and technology applications.

The Design Process

An appropriate design process should be developed before approaching any discussion of threat mitigation in facilities. It must be noted the elements of the threat mitigation design process do not encompass the entire design process of a medical facility. The elements listed below must be integrated into the “global” design process. The basic elements of the author’s process include:

Operational (clinical) needs assessment

Threat assessment

Vulnerability analysis

Establishment of threat mitigation features desired
Definition of constraints
Define the critical axis of the hospital or more specifically the ED
Selection of solutions via multi-objective optimization

The projected operational (clinical) needs assessment includes the definition of the procedures and practices likely to be executed, the projected volume, current technologies/equipment needed to achieve the mission and the definition of an environment suitable to these operations.

Additionally, today's world environment has many threats- natural, accidental or deliberate (such as acts of terrorism). A threat assessment matrix is essential in the planning process. The matrix of the American Society of Healthcare Engineers provides a useful tool to this end. Others may be equally beneficial.

After assessing the threat a vulnerability analysis should be undertaken. To which threats are the hospital or ED most vulnerable? Which threats may indeed exist, but the hospital does not deem itself vulnerable? For example the a hospital threat analysis may identify a high crime rate in the community, but the hospital itself does not feel vulnerable due to the number of police in the neighborhood. Which parts of the ED are most vulnerable to the identified threats? Most state licensing authorities have standards that require a level of security such as: Reception, triage, and control station shall be located to permit staff observation and control of access to treatment area, pedestrian and ambulance entrances, and public waiting area. The triage area also requires special consideration. As the point of entry and assessment for patients with undiagnosed and untreated airborne infections, the triage area shall be designed and ventilated to reduce exposure of staff, patients, and families to airborne infectious diseases.

The external and financial constraints will need to be defined. External constraints include the building site, zoning, codes, accrediting bodies and even local cultural acceptance. Some communities will object to a highly secure facility in their vicinity. Financial constraints are ever present. All these will need to be considered in the design solution

Due to the financial constraints it will often be impossible to include all threat mitigation features throughout the entire facility. It is useful for a medical facility to determine its critical axis in order to prioritize decisions on where to incorporate specific features.

Large medical centers are complex and often sprawling facilities with numerous functions and capabilities. Within any hospital there exists critical areas and infrastructure essential to maintain the mission effectiveness of the hospital. Basic mission effectiveness would be expected to continue providing essential services during contingencies. We refer to this concept as the critical axis of the hospital. The elements of the critical axis of a hospital generally include the following:

Emergency Department
Operating Suites

- Intensive Care and other designated special care units
- Imaging, lab and pharmacy capabilities (essential elements only)
- Critical Facility Resources
 - Water, gasses, power, ventilation systems
- Connectivity
 - Communications, Informatics
- Command and Control Center

These are the elements that permit the continued operability of the medical facility. Depending on the mission, operations and values of a given facility the elements of this axis will differ. For instance a cardiac care facility may determine that a cardiac catheterization suite is critical due to the number patients in the facility with cardiac conditions that might require intervention. Ultimately, only the facility management can determine what is critical to their operations. Even within the ED a critical axis for optimal protection applies. The planning staff should carefully assess which elements of the ED are most vulnerable and most critical to protect. Examples include the entry, communications center, triage area, critical care/trauma bays, etc. Administrative offices, break rooms, lecture rooms are generally not considered critical infrastructure unless they are designated to have a specific role in contingency situations such as casualty receiving area, command center or “safe room” functions.

Once the critical axis is established it can be followed by the prioritization of the security recommendations. A practical example would be the decisions to provide blast mitigation features. Higher priority could be the emergency department entrance (assuming it was determined to be critical) as opposed to the administration offices. This of course would be effected by other factors such as the vulnerability of the particular area. In some cases the critical infrastructure may already be relatively safe from threats. However, all other factors equal, the critical axis as determined by the facility should have the priority for security improvements. Some high-value resources such as ultra-high cost medical equipment may also require priority for protection (even though not part of the critical operating axis).

In the final analysis a multi-objective optimization process will need to be employed. Even if threat is determined to exist and the mitigation solution is affordable and acceptable, it may sub-optimize hospital operations. A deliberate decision will need to be made weighing the variables and advantages. This can be formally done with a matrix with some type of assigned-value scoring system. Despite scoring systems ultimately the process involves subjective decision making.

Design Concepts

Strategic Location/Configuration Decisions

ED planners are not given much choice in determining the location of their hospital. However, they may be given input into the location of the ED within a campus or facility. Standoff distance is one of the most useful mitigation strategies for blast, radiation and chemical. The ED should attempt to choose their location on campus with sufficient standoff distance from uncontrolled public access such as highways or a nearby government building. They should be positioned to minimize the serious congestion that occurs in rush hours or perhaps during contingencies. Additionally, open space and areas are ideal as security setbacks. The luxuries of having such options are rare. In reality planners usually have only the choice of orientation and configuration of the site given to them. Even within those constraints the same principals should apply to the extent possible

Traffic Access Management

The traffic management concepts should employ solutions proven in other venues to improve traffic management. Multi-lane unidirectional traffic patterns allow for easier access control and safer traffic movement. These have been well demonstrated at airport terminals. Access through multi-lane drive-through checkpoints should exist. These checkpoints can be vehicle portals designed to employ a variety of screening technologies as well as rapid external vehicle decontamination. Ambulances should be given priority and private vehicle will be directed to appropriate portals with automated traffic management signs. Landscape barriers prevent vehicle operators from attempting aberrant routes as well as excellent blast mitigation. Smart pop-up barriers with sufficient vehicle stopping can be strategically employed to control and divert traffic flow as needed. Back-in docking of ambulances typically used at most facilities has several disadvantages. Most important of these is that it creates a traffic flow choke point. But a second consideration is the increase security threat. A deliberate explosion or contamination at the ambulance loading dock can severely limit the functionality of that facility. The approaches to terminals at airports are configured to accept numerous vehicles simultaneously. Damage to any one area along the length could be by-passed for a more favorable arrival point. The planting of large trees and use of overhead signs along drives should be carefully assessed as they could easily block access of high-clearance height emergency vehicles.

“Immune” Building Technology

Hospitals have long struggled with the challenge of treating infected patients and keeping the facility “clean” and safe for other patients. Some biological and toxic agents of terrorism seem to be able to resist repeated attempts to successfully decontaminate the space in which they were released. Hospital rooms have surfaces, seams, equipment, and outlets that are difficult to decontaminate. For example, the typical lay-in acoustical tile ceiling is very porous and typically does not provide for an airtight seal. Once a contaminant infiltrates into the fissures and above the ceiling cavity adhering to all of the building service equipment it will be impossible to decontaminate. The consequences of having a key ED in a community closed for months due to anthrax contamination would create great strain on other medical resources.

Immune building enhancements include compartmentalized (non-central) air handling systems with high efficiency specialized filters providing clean air in and out. These individual units would permit the closing of units, floors, or wings without having to lose entire sections of the health care facility for the lack of ventilation. Systems could be designed to easily accommodate new technologies as they are developed. Seamless surfaces of non-porous materials allowing ease of cleaning and preventing the sequestration of spores, bio-agents or chemicals in cracks are recommended through out the ED. Corners can be “coved” for easier cleaning. These surfaces should be able to withstand degradation from repeated decontamination. Self-decontaminating materials and surfaces can be selectively applied to critical areas. For example drains are harbors for bacteria and when water is introduced in a high velocity fashion this bacteria may be dispersed. Metal impregnated with ionic silver can reduce bacterial counts on sinks, drains, and other metal surfaces significantly. Blister switches and controls can replace standard toggles and controls for ease of decontamination. Smooth covers for electrical outlets will prevent the entrance of contaminants into outlets.

The immune hospital facility will not only enhance the ability to handle a bio/chemical attack, it will enhance the facility’s ability to deal with hospital infections. These solutions will also have application in public restrooms.

Advanced Ventilation Systems Technology

Hospitals have long struggled with the challenges of provided “clean” air for their clients. The ability of some pathogens such a Legionella to be spread through ductwork is well documented. Many facilities have adopted hepa-filters to ensure a safer ventilation system. However when one considers all the threats, not only filters will be required. Hospitals should evaluate the advantages of “smart” vs compartmentalized ventilation systems. Highly compartmentalized ventilation systems ensure the effective “isolation” of any small section of the facility. Smart systems rely on the function of detector and automated actuation technology. Laminar or direction airflow strategies can be used in the public areas to force any contaminant to predominately one side or outside the facility. Negative air pressure with rapid air exchanges (6x per minute) in individual exam rooms can be used for standard isolation. Overpressure or positive pressure engineering provides hardening from external contamination. In addition to HEPA

filters, other filters using photo-catalytic processes can be applied where appropriate. Smoke evacuation systems are already available building technology and provide protection against inhalation injuries in fire and will also provide additional protection if a contaminant were released in the facility. Standard smoke evacuation systems can be augmented with purge capacity and additional sensors to allow removal of almost any type of airborne contaminant without requiring excessive new engineering and technology.

These systems will not only provide enhanced capability to deal with chemical and biological weapons but they will also provide significant improvement in the reduction of spread of airborne pathogens or toxic material in the daily hospital setting. These advances will have broad implications in the home building and airline industry where ventilation systems are often the source of infectious or allergic consequences.

Blast Mitigation

Hospitals could well be a strategic target for terrorist attack. While all major facilities serving the public are potential targets or could suffer collateral damage as a result of high yield explosive detonation, hospitals are of great strategic value in helping to maintain calm and manage the medical consequences of an attack. The public expects that hospitals will be safe-havens for those who have suffered injury or illness. The Emergency Department, due to its inherent need to have open access, is perhaps most vulnerable. While the first line of defense will always remain vigilant security and prevention measures, ultimately, even the best such measures can only reduce, not completely eliminate, the risk. Therefore could consider incorporating features that mitigate the consequences of blast effects.

Because emergency departments must function effectively on a day to day basis they cannot be built solely as a "blast-proof bunker." They must be welcoming and healing places. Fortunately, there are creative engineering solutions and technological advances exist that can be incorporated into Emergency Department design. One must explore the use of landscape barriers not only to control traffic but also as protection against blast propagation. External structure hardening and shields can be selectively incorporated- especially near vulnerable entrances. Specially treated and glazed glass materials can be used public areas to mitigate shard damage. Internal wall materials and coverings are to be chosen on the basis of strength and ability to reduce the effect of blast through principles of projectile energy reduction and baffling. Several internal wall coatings made of polymers have been demonstrated to dramatically reduce fragment projectile effects. Overpressure escape technologies such as blast panels and vents provide additional protection from blast effect. Additionally, lessons learned from progressive collapse of structures due to seismic can be applied to blast activity. This involves the use of expansion joints in the structure couple with floating base foundation isolation techniques. It allows significant movement of the structure without collapse or structural failure. The combination of such seismic strategies with direct blast hardening and the

use of radiation shielding techniques with heavy concrete comprise “nuclear hardening” strategies for the structure.

Ultimately the blast mitigation technologies and solutions incorporated in a hospital or ED setting will depend on the threat and vulnerability assessments as these threats are highly variable depending on the location.

Advanced Security Technologies

Emergency Departments are by their nature open, vulnerable facilities. They must allow visitors, patients, staff, suppliers, contractors and others to enter and leave the hospital repeatedly. During high security scenarios, ingress and egress limitations may impede hospital operations. Intrusive security measures would quickly make a facility undesirable from a customer standpoint. It is essential to employ non-intrusive technologies to enhance security and safety for all staff, clients and stakeholders. In addition to being non-intrusive the security measures should not cause significant delay.

Multiple entry/exit ports designed to accommodate security technologies would be ideal. These can feature non-intrusive walk-through screening. These ports will be architecturally integrated into the facility and have the ability to employ various screening and detection technologies as well the ability to accommodate new technologies. Detection sensors in the ports could check for explosives and toxic materials. Metal detection will be easily accomplished. Bio-metric identification such as facial recognition or iris scans are now being developed or already employed. These will uniquely identify the individual. They are relatively non-intrusive and require minimal cooperation from the individual as opposed to retinal scans. Iris scans are reported to have specificity similar to DNA testing. Even if an individual has presented false credentials, the scan will connect the individual with those credentials from that point on. An identification/access band can be attached to all entering the facility. The band will have the ability to track all movements of the individual. Similarly equipment can be tracked. Smart security doors will allow instant lock-down of specific areas as needed.

These technologies and design solutions will dramatically improve hospital security during critical and normal operations. Additional benefits to bio-metric identification would be reduction in transfusion errors as well as other medical mishaps resulting from misidentification.

Portal Concepts

People, vehicles, packages, food, water, air, and information all enter and exit major medical centers in large volumes daily. Any of those modes may provide a vehicle for intrusion into the facility with undesired consequences. The portal design concept implies functionality beyond simply ingress and egress. It involves determining all the processing that one would desire at the time of entrance and egress. First, identifying and categorizing all that enters or leaves the facility will need to be accomplished. Estimates of throughput requirements during normal and surge requirements will need to be

defined. Next one will need to decide specifically what needs to be accomplished in each type of portal. For instance irradiation used to mail/package handling portals should be not necessary in the personnel portals. Likewise biometric identification is not necessary for a package. The portal should to the greatest extent possible provide all the identification, control, security and mitigation interventions needed before anything enters the facility. An appropriate threat and vulnerability analysis will determine the specific measures needed to be accomplished. Projected volumes will determine the number of portals needed.

The specific design, appearance, configuration, number and location of portals will vary from facility to facility. However, several general principles will apply. The first principle is *standoff distance*. Most threats other than informatics threats are significantly decreased with distance. This is true of blast, radiation and chemical. Therefore designers/planners should give attempt to place traffic portals at sufficient distances from critical infrastructure of the ED such as the power supply or communications center. The definition of those critical areas will vary from facility to facility. In most cases, portals for emergency departments will, by necessity, be adjacent to the operational areas of the department. However, standoff distance for mailrooms, loading docks and vehicle control may be achievable depending on site constraints. Whatever the design configuration of the portal it should have the *flexibility* to accommodate what newer technologies that can be inserted or removed in a *modular* fashion. Ideally, the portal interiors for human use will appear pleasing, non threatening and *non intrusive*. The portals themselves should have surfaces that are easily *decontaminate-able*. The technologies applied should be *non-intrusive, automated* with little labor requirement and allow *rapid throughput* with high reliability. In some cases these technologies do not yet exist with acceptable efficacy. Relocate-able and portable approaches would be desired as well as fixed-site solutions. This would allow for scalability and adaptability in contingency situations. Fixed-site solutions should have significant blast mitigation features for the portal itself.

In order for the portals to be effective they must be integrated with other features in the master plan. Secure portals are of little use if other access is easily used. Effective measures to prevent entry via any method other than the designated portal will be necessary. The monitoring and detection technologies in the portals would need to be connected and integrated with an overall security/monitoring system. Appropriate data collected from proposed screening systems need to be transmitted to a control site separated from the portal site for interpretation and archival. Finally, the portal concept addresses external threats but not internal threats such as patient to patient violence or workplace violence. Appropriate internal security measures are needed.

The portal concept should not be limited to visible physical structures. In designing an informatics system for the ED the same approach can be used. What information comes in? How? Where? How much? -- Ultimately, how do we control it and protect it from threats?

Summary

In today's environment, hospitals and especially the Emergency Departments should be considered critical community infrastructure. In order to appropriately protect this critical asset, the design process should incorporate a systematic approach for threat mitigation and medical consequence management capabilities. An appropriate threat assessment and vulnerability analysis matched with the mission requirements of the facility can lead to optimized solutions. There are many existing and developing solutions some of which have important clinical benefits in addition to their threat mitigation capability. These should be identified and made available to hospital engineers and designers.

In the end few design changes may be ultimately incorporated to the facility design. However, those decisions should be based on an appropriate and deliberate analysis rather than omission of consideration.