CASE STUDY

DESIGNING A BIOCONTAINMENT UNIT FOR THE CARE OF DANGEROUS, INFECTION DISEASES

Introduction
The recent threat of Ebola makes present an inconceivable thought: that a pandemic could occur in the United States without the proper infrastructure in place to care for its victims. The nosocomial infection of medical staff in American hospitals underscores the grave risk medical practitioners take in providing care for these patients, causing some to question whether the traditional hospital setting is ideally suited for the care of deadly infectious disease.

Infectious diseases present unique challenges to hospitals, with each one differing in its risk profile. Ebola, a hemorrhagic fever virus, is spread via contact with bodily fluids, whereas SARS is transmitted through the air. When a SARS patient sneezes, coughs, or talks, infectious particles attach to airborne dust, and can travel great distances to infect their next target. Whatever the transmission method, the seriousness of these diseases, and the fact that no vaccination exists for them, necessitates special precautions.

Problem
Facilities that treat these diseases must account for every particle of aspirated air; every scrap of clothing, waste, and linen; and every surface. This presents significant design and engineering challenges in terms of air handling, waste disposal, surface material selection, physical and environmental security, staff and patient throughput, and the handling of lab samples. Staff efficiency is potentially hampered by the many barriers that must be put in place to prevent infection. Furthermore, in such a secure, high-stress situation, measures must be taken to provide patients with an environment conducive to healing.

High-Level Solution
Biocontainment Patient Care Units (BPCUs) provide the highest possible level of protection against nosocomial infection. By applying the best practices of laboratory biocontainment design to the clinical environment, these meticulously designed and engineered environments minimize the threat of infection while facilitating staff efficiency and patient-centered care. Their distinguishing feature is an environmental control system that purifies all air entering and exiting the unit, and keeps the patient rooms at negative pressure. Likewise, systems are in place to apply rigorous sanitary measures to all waste, laundry, lab samples, and staff. Throughput is designed to be unidirectional, with processes, air flows, and personnel movements designed using “clean-to-dirty” principles.
Solution Details
There are currently only four BPCUs in the United States, with the largest being a five-room unit located at the Nebraska Medical Center. The unit is outfitted to appear much like that of a typical hospital ward, with added measures for the prevention of nosocomial infection.

Unidirectional Staff Throughput
Staff throughput is unidirectional, with a dedicated entrance leading to a “clean” changing room (see fig. 1). Changing booths and pass-through lockers are provided for staff convenience and privacy (see fig. 2). The changing room is only accessible from one direction, as there is no door knob on the opposite “dirty” side.

When exiting the unit, a pass-through shower lets staff “shower out” into the exit room, which is adjacent to the entrance room to allow them access to the same pass-through lockers via opposite-side doors (see fig. 3).

Patients and deliveries enter the unit via a set of air-locked double doors at the primary entrance. They are sequenced such that a second pair of doors into the vestibule will not operate until the first pair has closed (see fig. 4). A key card system denies access to any unauthorized personnel.
Soiled materials, Personal Protective Equipment (PPE), and lab samples leave the unit through a separate exit outfitted with a specimen “dunk tank” and pass-through autoclave (see fig. 5). All soiled linens, trash, and PPE are decontaminated before being taken off-site for incineration, and containers holding lab specimens are disinfected in the chemical dunk tank before going to the hospital’s central lab.

**Isolated Air Handling and Negative Pressure**

The outstanding feature of the BPCU is its unique air handling system, which is isolated from the hospital’s main system, and specially engineered to keep patient rooms at negative pressure (see fig. 6).

Incoming air is channeled via two redundant air handling units, one duty and one standby, with pre-filters and HEPA final filters. Exhaust air is HEPA filtered, and exits via two high-plume dilution exhaust fans mounted on the roof, and sized to provide 100 percent redundancy.

Negative pressure in patient rooms ensures that no air escapes except through its dedicated exhaust. Each patient room has a pressure monitor located between the wall of the patient room and the corridor. Should the negative pressure set point of the room be exceeded, an alarm notifies the staff (see fig. 7). Rapid throughput of air, at 15 changes per hour, enhances environmental safety.

Each patient room has a clean-to-dirty airflow, which protects the breathing zone of patient caregivers. Air enters the unit high, and exits low, six inches from the finished floor at the head of the patient bed.
Cleanability and Air-Tightness
The BPCU features washable walls and floor surfaces treated to withstand repeated cleansing with bleach solution. Light fixtures, electrical outlets, and light switches are sealed, as well as entrance and patient room doors. Washable subceilings are used for protection of adjacent non-containment areas. Sheet vinyl flooring is installed with welded seams, and an antimicrobial sealant applied to all wall and wall-to-floor seams. All exterior windows in the unit contain impact resistant glass for protection against violent weather.

Flexibility
Flexibility is an important feature of the design, as the unit functions as an inpatient ward when not needed for biocontainment. Depending on the specific disease being treated, patient rooms can be repurposed to meet changing staff needs. In the treatment of Ebola, for example, extra space is needed to stage the large quantity of soiled PPE and linens produced. Depending on the quantity of lab tests needed, a point-of-care lab can be installed. All of this is possible thanks to the size and flexibility of the unit (see fig. 8).

Patient Experience
In the sustained isolation of a BPCU, important measures are taken to attend to the patient’s mental health. Each patient room has one or two large windows, offering crucial daylight and a connection to the outside world (see fig. 9). A system of video phones allows the patient to “visit” with family despite actual distance, and allows consulting doctors to see the patient without entering the unit.

Summary
The design and engineering of BPCUs is a highly-specialized skill, requiring excellence in both biocontainment practices and patient-centered design. In creating the Nebraska Biocontainment Patient Care Unit, LEO A DALY demonstrated the best practices for delivering safe, effective care while minimizing threat to staff and community. Our application of rigorous design and engineering methodologies resulted in a first-of-its-kind facility for Nebraska Medicine, allowing it to deliver world-class care.

For more information on designing or commissioning a Biocontainment Patient Care Unit, contact LEO A DALY, the leader in healthcare design excellence.

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