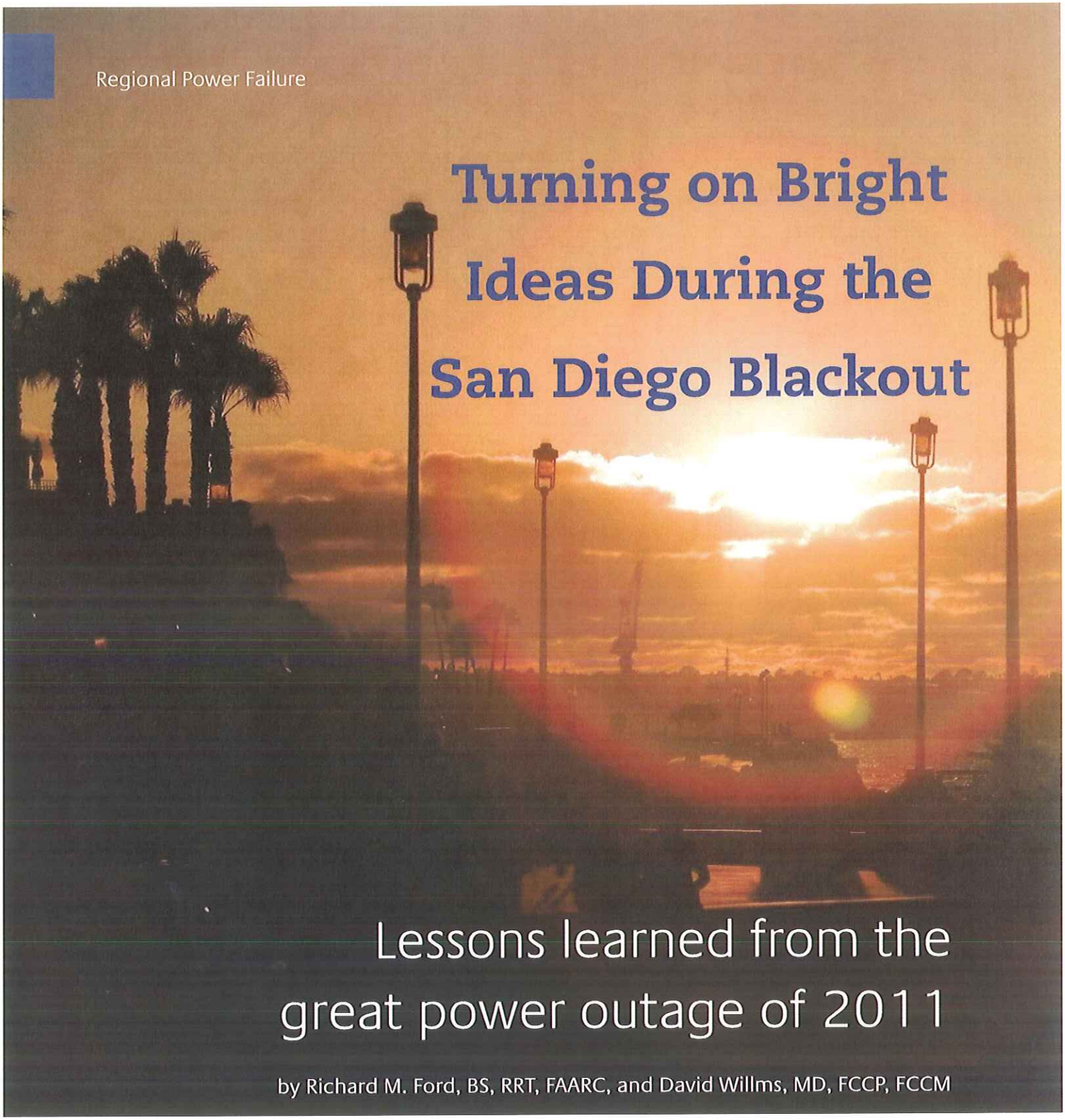

Turning on Bright Ideas During the San Diego Blackout

Lessons learned from the great power outage of 2011

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When the lights went out in San Diego last September, respiratory care departments made sure their patients remained safe and sound.

"We hope ideas continue to be
generated and shared so we can
be even better prepared for the next challenges."

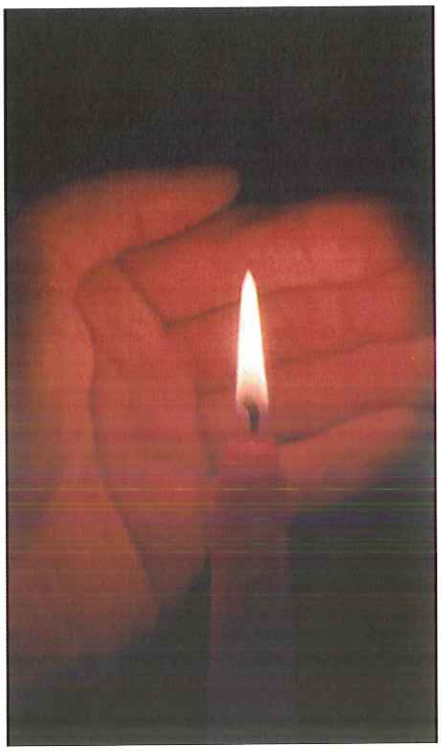
On Sept. 8, 2011, a sudden massive power outage in Southern California resulted in loss of electrical power to approximately 5 million people from Mexico to southern Orange County, including all of San Diego County. All residences, businesses, and public facilities were affected to a variable degree, the impact depending on whether or not the facility had functioning backup electrical generators.

Power was restored to most areas 12–16 hours later. Following the event, on Sept. 30, 2011, respiratory therapy department managers from multiple hospitals in San Diego County came together for a debriefing session, with particular focus on departmental function, mechanical ventilation, and medical gas delivery. Managers described their experiences, shared lessons learned, and talked about how we could assist each other within our San Diego respiratory care department community.

Through this format, we were able to identify a number of common problems that affected respiratory departments in particular, and hospitals in general. In addition, several suggestions were made for strategies to improve each facility's capacity to effectively respond to future disasters and protect patients receiving critical life support dependent upon electrical power. All attendees recognized the likelihood that the Sept. 8 power outage could represent a glimpse into the problems we may encounter in a much more extensive or prolonged regional catastrophe.

Problems and solutions

Managers from 13 area hospitals contributed to the debriefing, representing a wide range of the medical services provided in San Diego County, including general acute care, pediatrics, neonatal, maternity, trauma, and long-term ventilator care. Participants came from single-facility acute care hospitals, multi-hospital health care organizations, and a long-term acute care hospital. The number of patients receiving mechanical ventilation in these hospitals at the time of the power loss ranged from two to more than 30.



The following are some of the problems identified during our debriefing session and how managers and their hospitals coped with them.

Power generator failure: Although backup electrical generator capacity was in place at all the local hospitals and had been tested on a regular basis, the extreme and sudden power demand posed by the complete failure of the electrical power grid caused some hospital generators to experience excessive power demand, leading to generator shut-down and failure. In these cases, the usual "red plug" power outlets provided no power for a period of time, causing connected devices to shift to battery power if available.

Where this situation occurred, hospitals faced the potential for failure of invasive and noninvasive mechanical ventilators. All hospitals reported a primary ICU ventilator fleet that contained onboard batteries, with a variable expected duration of function. Noninvasive ventilation (NIV) was more problematic in those facilities with generator failure, as the most commonly used NIV ventilator in most hospitals in San Diego lacked an onboard battery. In some cases, battery-powered critical care ventilators could be adapted for patients requiring continuous NIV. Concerns were also raised about generators powered by gas or diesel fuel of limited supply, given the prolonged nature of the blackout. Our plan for replacement fuel sources became more of a concern with traffic gridlock and the inability to pump gas from stations, which virtually all depend on electrically driven pumps.

Loss of medical air: In several cases, the medical air supply was lost, as the compressor serving the storage tank lost electrical power and tank reservoir pressure dropped as gas was consumed. The drop in medical air pressure resulted in alarm conditions for low air inlet pressure and high inspired oxygen detection, as delivered gas came solely from the oxygen input. Facilities reporting loss of medical air adjusted the set FiO_2 to 1.0 for the duration to reduce the alarm conditions created. While adult ICUs did not see an FiO_2 of 1.0 as a significant issue for a short period of time, this was not the case in the neonatal intensive care units (NICUs). The one NICU represented in our debriefing session reported having a system in place to quickly isolate and back-fill the wall air outlets with medical air from a bank of cylinders stored for that purpose, avoiding the situation in which ventilators and other systems would

San Diego area (see red box) during the blackout.

deliver high fractions of inspired oxygen to neonates.

■ **Location of equipment and elevator non-function:** In most cases, only limited or no hospital elevator function was noted in the hospitals. As a result, some staff and visitors were trapped in elevators; and it was difficult to transport heavy equipment between floors, especially mechanical ventilators. At several of the hospitals, the primary storage area for ventilators was on a different floor than the ICUs or other high-acuity areas (ED, post-anesthesia care unit) where ventilation might be needed. In hospitals where elevators were operational under emergency power but generators failed, staff were unable to efficiently move ventilators in storage to the ICUs. This created challenges to providing equipment for new ventilator patients or accommodating the need to replace a ventilator in the event it lost battery power. Likewise, access to some of the hospitals' emergency supplies was impeded by lack of elevator function or lighting.

■ **Vacuum loss:** Similar to medical air, in some cases hospitals lost wall vacuum function during the electrical outage, necessitating the use of portable manual suction devices.

■ **Oxygen backup supply:** In at least one case, a hospital was unable to obtain additional oxygen cylinders from a local gas supplier, as the supplier's trucks were unable to obtain drivers or fuel for their delivery trucks.

■ **Communication breakdown:** Although most hospital landline telephones continued to work during the power outage, cellular service was spotty and intermittent. Voice, Internet, and text messaging were severely impeded in most of the hospitals reporting. This resulted in difficulty in contacting and instructing off-campus staff with regards to staffing needs and preparation, as well as staying informed on the local situation and expectations for recovery of electrical power. Most paging systems were down. Hospitals with staff carrying Sprint/Nextel radios had effective intra-hospital communication. The situation was compounded by reports of massive traffic jams on many area streets and freeways. In at least one case, a department relied on a hand-cranked radio to receive outside status reports on the disaster situation.

■ **Lighting:** In almost all cases, varying degrees of darkness resulted from the lack of electrical power. In those hospitals where generator failure occurred, many hospital areas were pitch-dark. In others, only "essential" lighting was powered by backup generators, leading to problems with providing care, using toilets, and other functions in cases where flashlights or lanterns were not readily available. Facilities reported cooperation from selected local stores (Food4Less, Wal-Mart, and Home Depot); while closed to the general public, the managers of these stores recognized the need to assist hospital facilities and provided escorted access to acquire flashlights, batteries, and food supplies as needed.

> *"Not one single adverse patient outcome due to the power outage was reported in the San Diego media or directly from any of the managers participating in our debriefing session."*

■ **Heat:** Air conditioning was lost in many areas of most hospitals. In addition to staff and patient discomfort, this caused significant concern in various departments over possible overheating and potential for malfunction of servers, blood gas machines, laboratory analyzers, and other sensitive electronic equipment. One facility reported that the overheating of lab equipment resulted in

a fire, which was quickly extinguished. In several instances ice and coolers were brought in to provide cooling measures for equipment or patients.

■ **Food:** Several facilities reported that lack of available food for patients and staff became a problem. Hospitals with insufficient stored/prepared food were unable to adequately meet the needs of patients and even staff, many of whom worked prolonged shifts due to the crisis. Most local grocery stores and restaurants shut down, so sending out for food was unsuccessful in most cases.

■ **Hygiene:** Sinks with electronic motion-activated faucets would not dispense water once electricity was lost. Only manual faucet sinks could be used for hand washing.

■ **Information systems:** Limited access to patient data was seen in some hospitals where a component of the system or network was dependent on power and an emergent power source was either unavailable or failed. Facilities reported the readiness to use backup paper systems and print out batch reports and patient data in anticipation data may not be available online if a critical component of the network failed. Department-based "fat clients" — in which the charting application resides on a battery-powered point-of-care charting device — ensured no respiratory care data was lost in hospitals with these types of systems. In most cases, the electronic medical records (EMRs) remained functional.

■ **Medication access with Pyxis® off-line:** Electronic control of drug inventory in most hospitals lies with the Pyxis medication dispensing system. With power off, medication access was initially limited. Where feasible, pharmacists were able to manually open Pyxis and allow drug dispensing without the usual electronic controls.

■ **Home care patients with ventilators, concentrators:** Local media communicated an erroneous message, saying that the use of oxygen cylinders at home during the power outage might cause a fire. Consequently, many patients came to the ED for help. Those with only oxygen concentrators at home, or nebulizers in regular use, also came to the ED for assistance. In many instances, staff accommodated these patients by using nasal cannula wall oxygen or portable generators to power or charge their equipment. Hospitals also provided access to power and a bed for patients on home care ventilation without formally admitting these patients in order to prevent shut down of home systems as batteries were depleted.

Preparing for the future

The members of our debriefing group came up with a number of measures they believe could help other hospitals prepare for a situation similar to the one we faced on Sept. 8:

- ☐ In anticipation of ventilator shutdown as battery power ceases, place standby ventilators with fresh batteries in ICU areas.
- ☐ In cases where "hot swappable" batteries can be used for ventilator power, move batteries to each bedside.
- ☐ Triage available staff to be at the bedside of ventilated patients and prepared to begin immediate manual ventilation using resuscitation bags if ventilator batteries fail. This is a top priority.
- ☐ Staff should not assume emergency generators will continue to run and have contingencies in place to support ventilation without any internal power. Alternately, they should have plans to move patients to a facility with equipment and/or systems that can provide support.
- ☐ When medical air becomes unavailable, adult ventilators can be switched to FiO_2 1.0 to avoid continuous alarm situations, although an FiO_2 of 1.0 will be delivered by most ventilators regardless of FiO_2 setting. This precaution is particularly important in the newborn areas.
- ☐ In the NICU, staff should back flush compressed air from cylinders into the air system to avoid the need for delivery of high FiO_2 to babies.
- ☐ When Internet access is still available, the use of Google's mass-texting function can allow communication to many staff at one time.
- ☐ Consider placing some or all reserve ventilators on the same floors as the ICU and ED to avoid the need for elevator transport.
- ☐ Use pneumatic-driven ventilators as backup for usual ICU ventilators if batteries fail; it may be necessary to increase available supply.
- ☐ Consider storing sufficient ice and coolers to apply near heat-sensitive equipment.
- ☐ Prepare disaster bags, stocked with lanterns, lights, gloves, and other emergency items needed in a power failure; adequate numbers of flashlights or battery-powered lanterns should be distributed throughout the hospital for ready access.
- ☐ Have battery or hand-crank radios on hand to get outside information.
- ☐ Consider distributing a list of landline numbers specific to respiratory departments to area hospitals in case the sharing of equipment is needed.
- ☐ Provide simplified paper forms for charting in the event of EMR outage.
- ☐ Keep available a sufficient manual suction device supply.
- ☐ Consider stocking multiple portable generators.