



Trauma medicine

Damage control

Lessons learned on battlefields are helping civilian doctors save victims of terrorism

BY 11.30pm on October 1st, 90 minutes after Stephen Paddock began firing out of a window at the Mandalay Bay hotel in Las Vegas, the floors of the emergency department at Sunrise Hospital and Medical Centre were awash with blood. The air smelled of iron. Staff slipped and slid as they moved from one patient to another.

Though experienced in treating gunshot wounds, they had never received dozens of patients with multiple injuries from semi-automatic rifles. Bullets from these can travel three times as fast as those from handguns. They not only pierce tissue on impact but produce shock waves that burst arteries and organs. Patients faced death from blood loss, asphyxiation or both. “It was like a war zone,” says one surgeon.

After mass-casualty incidents, comparisons to the battlefield typically refer to the scale. Paddock killed at least 58 people and injured more than 500, in America’s worst mass shooting of modern times. Since the Vietnam war the only battle with a heavier toll of Americans was in the Iraqi city of Fallujah in 2004. That battle lasted for 48 days, however; Paddock’s barrage lasted only ten minutes.

There is another way in which, after major attacks, trauma hospitals such as Sunrise resemble war zones. In recent years, as they prepare for and respond to

these events, civilian medical teams have drawn on the experience of their military peers. That has enabled them to save more and more patients with critical injuries.

The best way to measure medics’ success in treating victims of mass incidents is “critical mortality”, the share of those admitted to hospital with life-threatening injuries who die. This is more meaningful than the ratio of fatalities to injuries, since different modes of attack cause wounds of different types and severity. A paper in 2012 co-authored by Christine Gaarder, a doctor involved in the response to the Oslo attacks, found that between 2001 and 2007 the typical critical-mortality rate after a ter-

rorist attack was between 15% and 37%.

So few of the victims of more recent attacks in rich countries have died in hospital that rates have been much lower. That has been true both for lone gunmen, as perpetrators so often are in America, and for Islamist terrorists using knives, bombs or vehicles, as recently in Europe.

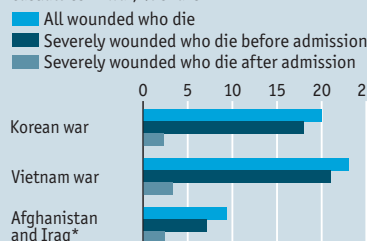
On June 3rd the driver and passengers of a hired van ran over pedestrians on London Bridge, then marauded through Borough Market, wielding knives. King’s College Hospital (KCH) typically admits three or four people with stab wounds on a Saturday night. In the hour after the first victims arrived it received one every five minutes. Eight people died at the scene, but all 14 admitted to KCH survived. So did all 34 admitted elsewhere. “The number of saves was truly remarkable,” says Chris Moran, the clinical director for trauma for England’s National Health Service (NHS).

No one died in hospital after the Boston marathon bombings in 2013. There was just one death among the 20 Norwegians admitted to hospital after the attacks by Anders Breivik in 2011. Hospitals in Paris saved all but two of the patients admitted after gunmen and suicide-bombers injured more than 400 people and killed 130 on November 13th 2015. The response to Las Vegas has not yet been audited, but of the 104 admissions to the University Medical Centre of Southern Nevada (UMC), another trauma hospital, just four died.

The improvement in critical mortality reflects the better treatment of trauma, in large part inspired by lessons learned on battlefields. In the second world war about 30% of wounded American soldiers died. In the Korean and Vietnam wars the share was about a fifth (see chart). By Iraq and Af- ▶▶

Making it back

Casualties in war, % share



*Operation Enduring Freedom and Operation Iraqi Freedom
Source: “A National Trauma Care System”, by D. Berwick et al, The National Academies Press

▶ghanistan it had fallen to less than a tenth.

The decline did not happen by chance, a report by the National Academy of Sciences concluded in 2016. Sturdier armour helped. But so did the “focused empiricism” of military medical teams who made incremental improvements to their treatment of the wounded. Civilian medicine has since embraced both clinical procedures developed in wartime and that way of thinking. Higher survival rates are mostly not about decisions taken by individual doctors, says Malcolm Tunnicliff, the clinical director for emergency and acute medicine at KCH. “It is the whole system that saves people’s lives.”

That system was, until recently, deeply flawed. In 2010 Britain’s National Audit Office (NAO), a government watchdog, published a report into trauma care noting that mortality rates in England had barely improved in two decades. Critically ill patients were brought to their nearest hospital, meaning few hospitals saw enough cases to gain expertise in urgent, complex and multiple injuries.

During major incidents British hospitals were overwhelmed. Joshi George, a neurosurgeon, did his first shift as a junior doctor on August 15th 1998, when Republican terrorists detonated a bomb in Omagh, Northern Ireland, killing 29 people. He remembers the smell of burnt flesh and mortar oil—and that “there was really no set-up.” The walking wounded took buses to the local hospital, filling beds needed for the critically ill. Communication between hospitals was poor, a failing also evident after the bombings in London on July 7th 2005. With phone networks jammed, medical students were sent running from site to site with messages on paper.

After the NAO report the NHS restructured its trauma care around 27 expert hospitals. Critically injured patients now travel to expert hospitals even if that means passing a local hospital on the way. That has improved the odds of surviving everyday traumas such as car crashes. (Trauma causes one in ten deaths globally and in many countries is the commonest cause of death for under-45s.) The NHS estimates that the change has saved 300-500 lives a year. The Netherlands and Germany have adopted similar “hub and spoke” systems.

Specialist trauma hospitals help save lives after major incidents. Partly this is because their doctors are more experienced. Between 30% and 50% of the critical injuries seen at KCH are from penetrative injuries, mostly knife attacks, often by gangs who inflict multiple wounds because they have learned how expert the hospital is in keeping their victims alive.

It is also because these hospitals are central to cities’ major-incident plans. London’s four main trauma hospitals (KCH, Royal London, St George’s and St Mary’s) must be prepared to receive patients with



Rehearsing for the worst in Paris

“injury severity scores” above 15; that is, on the verge of death. They must be able to clear at least ten beds within two hours and halt elective surgery. On-call staff must be able to turn up within 30-60 minutes. Enough blood for two to four hours, and surgical kit for 12 hours, must always be available.

Paris’s *plan blanc* gives the city the power to commandeer 40 hospitals and 100,000 health-care professionals. The scale reflects France’s disastrous response to a heatwave in 2003, when 15,000 people died. Israel’s hospitals must plan for dealing with 120% of normal bed capacity in case of emergency, and be able to increase that to 150% in times of war.

Emergency responses are regularly rehearsed. Medics at UMC carry out two large drills each year, and were briefed by doctors from Orlando after the Pulse nightclub shooting last year. A week before the attack on Westminster Bridge on March 22nd, in which an Islamist terrorist injured more than 50 pedestrians and killed four by driving into them, as well as stabbing a police officer to death, London’s doctors had done a run-through. Hours before the November 2015 Paris attacks the city’s doctors had practised their response to a mass shooting. Duncan Bew, the clinical director for trauma and acute surgery at KCH, is fond of the saying about no plan surviving first contact with the enemy. But planning and practice build in a “reflex”, he says, aiding medics to improvise when events do not go as rehearsed.

The medical response begins at the scene. The first ambulance arrived at London Bridge three minutes after the van attack was reported, as the stabbings continued in Borough Market. A three-day rampage by gunmen in Mumbai in 2008

had alerted European police forces to the need to plan for cordons to protect paramedics, says Cressida Dick, the head of London’s Metropolitan Police. On June 3rd the London Ambulance Service and the Met demarcated unsafe “hot” zones from “cold” zones, where paramedics treated patients and set up casualty-clearing stations to dispatch them to hospitals.

After a mass incident patients must quickly be triaged according to the severity of their injuries: P1, life-threatening; P2, serious; and P3, walking wounded. (P4 is dead.) The priority of medics on the scene is to get P1s to hospital alive. Labelling a P1 patient as P3 is of course dangerous but “over-triage” is also associated with higher mortality, since it can clog up wards.

Stopping heavy bleeding is crucial. Blood loss is the cause of 30-40% of deaths from trauma. Yet until around a decade ago tourniquets were not routinely used. Poorly applied they can destroy nerves or limbs. But going without is usually more dangerous. Between 2005 and 2011 in Iraq and Afghanistan tourniquets, including new versions that clamp big, hard-to-find vessels such as the femoral artery, which is buried deep in the pelvis, saved up to 2,000 American lives, according to the National Academy of Sciences. Simple steps can ensure that tourniquets are not left on too long. British soldiers write “T” on the forehead of anyone receiving one, so doctors are reminded to remove it.

Tourniquets are now commonplace in civilian medicine, as are haemostatic powders that clot blood. But there are not always enough. After Parisian medics used their belts as improvised tourniquets, many arrived at the hospital with their trousers falling down.

Precious moments

Another lesson from military medicine is to do the minimum to keep people alive, then get them to a specialist hospital as soon as possible. In the Vietnam war it took on average 45 days for a critically injured soldier to reach America. From Afghanistan and Iraq it took four. One soldier injured by a mortar attack in Balad, Iraq, was moved from the blast site to a field hospital, then to Germany, and finally to Virginia, all in under 36 hours.

Speed saved lives in Paris and London, too. The first two patients to arrive at hospital from the 2015 Paris attacks did so by taxi. They did not even realise they had been shot. Police officers took two colleagues hit by the van on London Bridge to St Thomas’ Hospital nearby using a makeshift stretcher. After they had been stabilised they were taken to KCH. Without this “scoop and ▶▶

▶ run” both would have died.

In the minutes before patients arrive doctors prepare for the surge. As the London Bridge incident unfolded, KCH set up its command structure. Switchboard operators alerted on-call staff, though most found out an attack was under way via Twitter or WhatsApp and set out unprompted. When they arrived at KCH they received a one-page “flash card” explaining their role. Senior doctors check supplies. Whole blood containing plasma, platelets and red blood cells is readied. Recent research has shown that transfusing this mixture rather than individual components improves survival rates. Some incidents require specific equipment. On his drive to KCH as fire engulfed Grenfell Tower in London on June 14th, Dr Tunnicliff told procurement teams to grab kits for cyanide poisoning, since this is caused by inhaling fumes from burnt upholstery.

Once a major incident has been declared, medics may take a moment to steel themselves. An anaesthetist working the night shift on May 22nd, when a homemade bomb placed by an Islamist terrorist in the Manchester Arena injured 250 people and killed 22, many of them children, says he tried to visualise what was coming, like a sportsman before a match. That helped, a little. The extent of the shrapnel injuries meant that several staff were crying as they operated on the injured girls.

Faster than a speeding bullet

As the surge begins doctors perform another triage, usually at the entrance of the resuscitation room. Patients may have deteriorated, especially if they have spent a long time waiting in the hot zone. Others may later decline in hospital. On June 3rd one patient brought to KCH from the London Bridge attack had been assessed as P3; despite being stabbed in the back of the head he was walking around. But soon enough he was reassessed as P1 because of a blood clot and whisked to theatre.

Once inside the resuscitation room Dr Bew started logging patients’ details in a notebook. In Paris patients were tagged with barcodes denoting their triage status. But keeping tabs on patients is more rudimentary in the NHS. As it is in Las Vegas: doctors in Sunrise wrote patients’ triage status and details of their injuries directly onto them.

Doctors are trying to make sure patients do not need to return to the resuscitation room. That requires senior doctors to treat individual patients at the same time as keeping tabs on what is happening in the rest of the room. At KCH, every 15 minutes the clinical directors shouted out situation reports. Radiology is often a bottleneck en route to the intensive care unit (ICU) or operating room. So hospitals are bringing scanning equipment closer to it. x-rays reveal lungs collapsed from stab wounds;

whole-body CT scans pick up the internal injuries from blast wounds. Bullets and shrapnel burrow into odd places.

Twenty years ago trauma doctors would “stay and play”, notes John Holcomb, a trauma surgeon and professor at the University of Texas. Now, rather than do everything a patient needs in one go, surgeons will do the minimum necessary to save life and move on to the next case. After the Paris attacks the first patient admitted to Hôpital Saint Louis spent just 30 minutes on the operating table. Surgeons removed two bullets from his abdomen and cut out 60cm of his intestine. They left three less life-threatening bullets to be removed later, and sent him to the ICU. This “damage control” approach is inspired by the armed forces. In emergencies surgeons at Camp Bastion, the British base in Afghanistan, aimed not to operate on any patient for more than an hour.

Most surgery has become highly specialised. “Even brain surgeons can’t operate on every part of the brain,” says Dr George. But trauma requires surgeons to operate across anatomical boundaries under extreme pressure. After the London Bridge attack doctors at KCH performed more than a dozen chest drains and “clamshell” thoracotomies, where the chest is cut open in an arc beneath the rib cage. Surgeons tied severed bowels and clamped vessels. They cleaned wounds thoroughly, fearful of contamination when the same knife is used on multiple people.

But they did not linger. Trauma medicine is not for perfectionists or mavericks. Teamwork is essential. One surgeon at KCH recalls draining a patient’s chest at the same time as cardiac, vascular and facial surgeons were operating. In Las Vegas’s hospitals, surgeons rushed to deal with the carnage wrought by semi-automatic weapons. Bodies were littered with bullets. Some had entered at odd, multiple angles as people crouched in an attempt to

protect themselves.

After the surge subsides, hospitals try to return to their normal schedule as soon as possible. But a major incident can be declared over too soon. Some hospitals in Manchester restarted elective surgeries a few hours after the bombing. Yet in the following ten days the injured required 139 hours of additional theatre time—about two normal weeks’ worth of surgery.

Saving more lives means a greater need for rehabilitation, both physical and psychological. Trauma hospitals are increasingly bringing physiotherapists and rehab doctors onto ICU rounds rather than referring patients later. In Paris a 35-strong team of psychiatrists and psychologists was called up as part of *plan blanc*. In Manchester a dedicated “bereavement service” counselled the parents of victims.

It is not just patients who need psychological support. One doctor involved in the Manchester attacks still hears the voices of injured parents who awoke screaming for lost children. In the resuscitation room after the Grenfell fire staff had allowed critically ill patients to use phones to speak to trapped loved ones for the last time. Hospitals such as KCH are using a peer-to-peer counselling method used by the British army for post-traumatic stress.

Each major incident is followed by efforts to learn lessons from how it played out. Professor Moran has overseen debriefs for the Westminster, Manchester and London Bridge attacks. It is vital, Dr Bew says, for trauma doctors to admit their mistakes and for hospitals to have an open and honest attitude towards error.

All of which will help trauma teams to keep improving. They will need to. The treatment of victims of terrorism has been transformed by lessons learned by trying to save injured soldiers. But as the attack in Las Vegas shows, those seeking to harm civilians will continue to test those who deal with the aftermath. ■



Heroes run towards danger