Notable Cases

The St Marys fragmentation grenade explosion

Antony Nocera

The accidental explosion of a fragmentation grenade in a munitions factory at St Marys injured four workers, two critically. The prompt response by ambulances and physician-staffed helicopter emergency medical service prevented deaths, but the incident suggests lessons for the future handling of urban explosions. ***(MJA 1997; 166: 545-548)***

On 14 November 1995 an F1 fragmentation hand grenade exploded in a grenade testing facility in a munitions factory on a 1600 hectare site at St Marys, NSW. Seven employees were in the room. The grenade exploded at 8:36 am on a work bench and injured four workers around the bench (Figure 1). None were wearing body armour and there were no blast shields in the work area.

The first ambulances arrived at 8:41, 8:44 and .47. The four injured workers were extricated from the factory building to an adjacent courtyard by other employees and ambulance personnel. NRMA CareFlight, a Bell 412 HP helicopter emergency medical service (HEMS) with a physician on board, was placed on standby at 8:45 and dispatched at 8:50, landing at the site at 9:06.

Two patients were transported by air to a trauma centre with full cardiothoracic facilities about 24 km (10 minutes' flying time) from the factory. Access to this centre by road would have encountered peak hour traffic flowing into Sydney via the major western arterial road routes. Two patients were transported by road to a local trauma centre (10 minutes' travelling time) which has limited cardiothoracic surgical facilities.

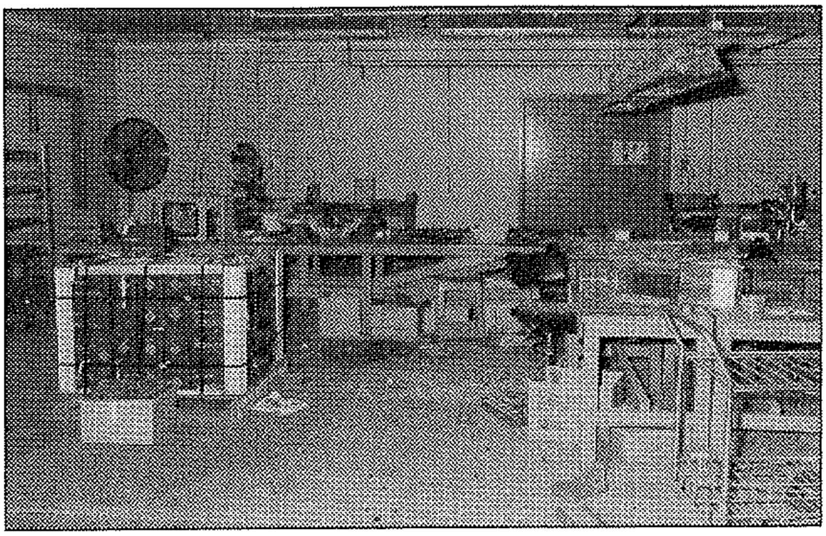

Figure 1: Immediate area of the explosion. Patient C was sitting in the chair in the foreground, with Patient A in the chair immediately behind, while Patient B was standing behind the two. Patient D was sitting on the other side of the bench, opposite Patient C. The pallet to the left carried 1000 live grenades and was 1.85 m from the grenade burst point. Forty-eight grenades were damaged in the explosion and represented an explosive hazard during recovery operations.

Photograph courtesy of the New South Wales Police.

Patient records

Patient A

tient A was a 44-year-old woman sitting 0.25 m from the grenade burst point. On arrival of the HEMS, she had a Glasgow coma score of 12–13 and no recordable blood pressure. Only carotid pulses were palpable after an infusion of 1.5 L of polygeline by ambulance personnel; an additional 500 mL polygeline and 500 mL normal saline were infused. The patient's conscious state began to fluctuate, and a rapid sequence induction and endotracheal intubation were performed before transport by helicopter. The patient received a further two units of O negative blood during transport.

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NRMA CareFlight, Westmead, NSW.
Antony Nocera, MB BS, Emergency Medicine Registrar.
No reprints will be available. Correspondence: Dr Antony Nocera, NRMA CareFlight, PO Box 159, Westmead, NSW 2145.
E-mail: tonynoce@ozemail.com.au

On arrival at hospital, Patient A had a heart rate of 100/min, systolic blood pressure, 118 mmHg; haemoglobin level, 79 g/L (normal range, 115–165 g/L); pH, 7.29 (normal range, 7.35–7.45); PO_2, 518 mmHg (normal range, 75–100 mmHg); PCO_2, 30 mmHg (normal range, 35–45 mmHg); HCO_3, 14 mmol/L (normal range, 22–26 mmol/L); and serum lactate, 3.04 mmol/L (normal range, 0.63–2.44 mmol/L). She was taken to theatre for thoracotomy and laparotomy, enucleation of left orbit, amputation of right ring and little fingers, debridement of right forearm and thigh, with internal fixation of her right forearm fractures. By the end of her first theatre session she had received (in addition to her prehospital fluids) 6.5 L of polygeline, 4 L of crystalloid, 24 units of packed red blood cells, 8 units of frozen plasma and 6 units of platelets.

Patient A's injuries were:

- Multiple puncture wounds to the face, neck, chest and abdomen
- Singed hair and eyebrows
- Grenade fragments in the right maxillary antrum and right side of the nasopharynx
- Multiple puncture wounds to the left eye

- Bilateral perforated tympanic membranes
- Multiple fractured teeth
- Subtotal traumatic mastectomies (Figure 2a)
- Bilateral haemothoraces, with contusions of the right middle lobe and both lower lobes of the lungs
- Perforation of the right ventricle and apex of the heart, with a 250 mL pericardial haematoma
- Perforations of the stomach, left lobe of the liver, and splenic flexure of the colon
- Haematomas of the head of the pancreas, lesser omentum and left perinephric region
- Comminuted compound fracture of the right radius and ulna, with major soft tissue disruption to the dorsal surface of the right forearm (Figure 2b)
- Subtotal amputation of the right ring and little fingers
- A large skin and muscle defect to the anterior aspect of the right thigh (Figure 2c).

After her initial surgery, Patient A required mechanically assisted ventilation for 11 days and underwent five additional operative procedures during her initial 39 days in hospital. In the next year she underwent another five operative procedures, with a further five reconstructive procedures scheduled for the following year.

Patient B

Patient B was a 45-year-old woman standing behind and to the left of Patient A, about 0.6 m from the grenade burst point. On arrival of the HEMS, she was in severe respiratory distress, with a heart rate of 105/min, systolic blood pressure of 60 mmHg, and Glasgow coma score of 10. Patient B was

What makes a grenade

Grenades have been in military use since at least the 15th century,[1] and became important weapons in the trench warfare of World War I. Early in the war, shrapnel balls were taped to the outside of some British grenades to improve their effectiveness. Shrapnel balls were used in the Shrapnel shell (invented in 1784 by Lieutenant Henry Shrapnel), an artillery round that exploded in flight, scattering shot and casing fragments along the shell's original trajectory.

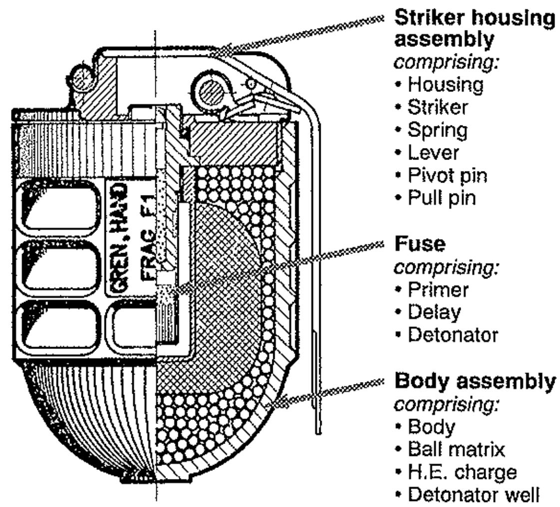
The development of high explosives rendered the Shrapnel shell obsolete by the 1940s,[2] and allowed the development of controlled fragmentation devices. A succession of grenade designs evolved, from fragmenting iron bodies and external fragmentation sleeves, to the use of preformed fragments within the grenade. The latter has proved to be the most serviceable design,[1] and is the design of the F1 grenade that exploded at St Marys.

Blast injuries are greatly influenced by environmental factors.[4-6] The fragmentation injury radius of controlled fragmentation devices exceeds the blast injury radius and thermal injury radius.[7] Casualties exhibiting blast or thermal injury generally sustain a fatal fragment load.[7] Body armour will mitigate fragmentation injury, but not the effects of blast.[8]

While non-metallic materials are used for the casings of some controlled fragmentation devices, fragmentation grenades generally have a metallic casing.[9] The function of fragmentation grenades is to release preformed fragments uniformly. Asymmetrical destruction of the device casing may change the normal distribution of fragments. The grenade casing base plug can be projected up to 250 m, producing injury well beyond the stated injury radius.[10] Fragmentation injury from grenades has a 10% mortality.[7]

At detonation preformed fragments have initial velocities of up to 1500 m per second. About half of the fragments are projected into the ground close to the grenade burst point.[10] The injury potential of fragments less than 0.5 g is lost within a few metres due to the exponential decline in fragment velocity and concentration.[9] Considerable differences in fragment mass, energy and lethal range occur with variations in fragment diameter as low as 1 mm.

Australian Defence Industries F1 high explosive fragmentation grenade



Mass:	*370 g*
Length:	*90 mm*
Diameter:	*68 mm*
*Lethal radius:**	*6 m*
Injury radius:†	*15 m*

The shape of the charge and its position in the body are designed to ensure even and predictable dispersion of fragments.

**Distance from the device at which a standing person will receive wounds to 80% of presenting surface area.*

† Distance from the device at which a standing person will receive wounds to 40% of presenting surface area.

(Photograph reproduced with permission of Jane's Information Group)

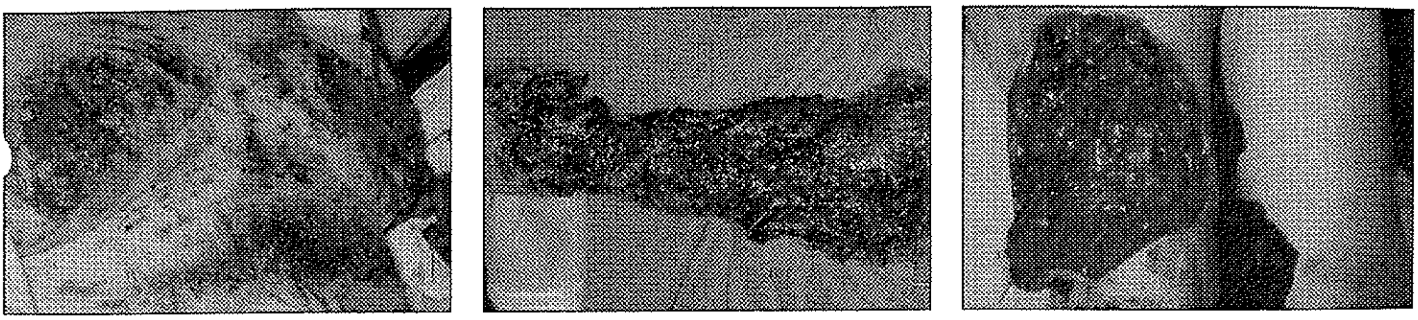


Figure 2: Injuries of Patient A.

a) Multiple fragment entry wounds over the upper torso, with subtotal bilateral traumatic mastectomies and gross disruption to the skin over the epigastric region.

b) Dorsal surface of right forearm, showing subtotal amputation of right ring and little fingers and major tissue disruption to the forearm and hand.

c) Right thigh wound of Patient A, showing major tissue disruption above the right knee.

Photographs courtesy of Westmead Hospital Audio-Visual Services Department.

treated by ambulance personnel with 1.7 L of polygeline and transported to hospital by road.

On arrival at hospital, Patient B had a heart rate of 88/min; systolic blood pressure, 140 mmHg; Glasgow coma score, 15; haemoglobin level, 83 g/L; pH, 7.30; Po_2, 331 mmHg; Pco_2, 36.6 mmHg; HCO_3, 17.8 mmol/L; and base excess, –7.2 (normal range, –3 to 3). Patient B was taken to theatre for laparotomy and cholecystectomy. Her injuries were:

- Multiple puncture wounds to the face, neck, thorax and abdomen
- Forehead laceration and fractured nose
- Grenade fragments in the ethmoid and sphenoid sinuses, plus a fragment in the occipital lobe of the brain.
- Contusion of the lower lobe of the left lung
- Multiple perforations of the liver and gallbladder
- Lacerated right kidney and retroperitoneal haematoma
- Fragments adjacent to the abdominal aorta and the right L3 nerve root
- Delayed third-nerve palsy.

She was discharged from intensive care after 1.5 days and discharged home after 18 days. She underwent six subsequent day procedures to repair soft tissue injuries and extract fragments.

Patient C

Patient C was a 54-year-old woman sitting to the right of patient A, 1.3 m from the burst point. On arrival of the HEMS, she had a heart rate of 80/min, systolic blood pressure of 130 mmHg and Glasgow coma score of 14. She was treated with 1 L of Hartmann's solution and 250 mL of polygeline and transported by air.

On arrival at hospital, Patient C's heart rate was 83/min; systolic blood pressure, 151 mmHg; Glasgow coma score, 14; and haemoglobin level, 125 g/L. Her injuries were:

- Multiple small puncture wounds to the left upper limb and left side of the thorax
- A chin laceration and left periorbital haematoma; there were no perforations of the tympanic membranes
- A closed fracture of the left ulna
- A small left retinal tear and preretinal haematoma
- A fragment in the medial rectus of the left orbit.

Patient C was discharged home after two days.

Patient D

Patient D was a 50-year-old woman sitting diagonally opposite Patient A about 1.6 m from the grenade burst point. On arrival of the HEMS, she had a heart rate of 105/min, systolic blood pressure of 70 mmHg and Glasgow coma score of 11. She was treated with 1 L of polygeline and transported by road. On arrival at hospital, Patient D had a heart rate of 90/min; systolic blood pressure, 150 mmHg; Glasgow coma score, 15; and haemoglobin level, 108 g/L. Her injuries were:

- Multiple fragment wounds to the right side of the face, neck, thorax and upper limb, including an intracapsular fragment in the right shoulder joint and a 4 cm scalp laceration
- Bilateral perforations of the tympanic membranes
- Right pneumothorax requiring drainage with an intercostal catheter, plus pulmonary contusions of the right mid and lower zones.

She was discharged after seven days and subsequently underwent two outpatient procedures to extract fragments.

Discussion

The injuries of the four accident victims demonstrate the capability of military weapons to inflict serious physical injury—but the potential psychological impact of these weapons extends well beyond their injury radius.

The grenade exploded on a bench top, which directed most of the blast and fragments onto the upper torso of the victims, but it also blew a hole in the bench top, producing the wound to the right thigh of patient A.

Any bomb or blast scene should always be considered dangerous until declared safe from the risk of secondary explosion by appropriate technical personnel. Specialist bomb disposal personnel were not part of the initial response to the St Marys incident, which contributed to the delayed recognition of a potential secondary explosion hazard from 48 damaged grenades at the site.

The size and shape of modern military weapons often belie their wounding potential. Explosive devices may contain fuse mechanisms that detonate in response to stimuli other than that of direct impact. The bodies of victims may conceivably hold unexploded devices that pose a threat to rescue, medical and mortuary personnel.[11,12] Major injuries and deaths occurred during the Gulf War among medical and service personnel handling souvenired battlefield ordnance.[13]

Injury from military weapons is uncommon in Australia. Army ammunition technical officers can provide expert advice on the composition and function of a particular device. This information is vital in the assessment of individuals wearing body armour, or who have been potentially exposed to either radiolucent fragments or items of ordnance which have become airborne.[11,12]

Early on-site specialist technical advice is critical to safe operations at the scene of an urban explosion.

Helicopter emergency medical services have been used in the primary and secondary transport of blast victims.[14,15] In this incident the HEMS rapidly provided a doctor on-site to assist in trauma triage. This allowed patients to be referred immediately for specialist surgical care, while dispersing casualties over a wider network of receiving hospitals (thus Patient A and Patient B were sent to different hospitals so that both could receive immediate surgical treatment; this would not have occurred under ambulance protocols). In addition, on-site medical care went beyond the scope of paramedic protocols[16] (e.g., in performing a relaxant-assisted intubation and giving a blood transfusion).

The NSW Ambulance Service Disaster Plan (December 1995) precludes the immediate dispatch of physician-staffed helicopter emergency medical services to potential multi-casualty incidents. This may introduce avoidable delays in delivering seriously injured patients to definitive surgical care, especially in incidents geographically removed from designated trauma centres.

Acknowledgement

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