

Battlefield Radiology: 2014 Update

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Abstract

A “Military Medical Revolution – the Military Trauma System”¹ has revealed the developments during the Middle East Area of Operations (MEAO) wars over the last decade showing survival rates of up to 98% of trauma patients brought to hospital alive. This significant improvement is due to the “combat care revolution”^{2,3} involving major multidisciplinary changes in health care with on site tourniquets and medic, rescue resuscitation teams, immediate aeromedical evacuation to a NATO Role 2E (basic field hospital with unspecified extra surgical and other capabilities) or Role 3 hospital (Role 2E with additional specialist tertiary level capabilities), improvements in blood product availability, Damage Control Resuscitation, Surgery and Radiology and later aeromedical removal to major hospitals. The changes in radiology have been the deployment of 64 slice CT (Computed Tomography) scanners situated adjacent to emergency casualty receiving areas, with clear access and space for the whole surgical /resuscitation team to work together with the radiologist and radiographer who can have the CT trauma examination completed in 2-3 minutes and have the interim CT report delivered verbally to the trauma team less than 2 minutes later. The final written report, including clearing of the spine, is usually available 60 minutes after the completion of all reconstructions and review thereof. Most patients who need immediate surgery for survival have a postoperative CT examination for completion of diagnosis and management planning.

The ADF (Australian Defence Force) has benefited from the NATO supply of radiology aspects of this service to provide best standard of care to its members. As the ADF regroups and plans for a new era, review of the decision to postpone acquiring the capability of its own deployable CT should be undertaken. The ADF should be able to provide current standards of care to members incurring ballistic and blast injuries on non-NATO or US supported deployments that may be required in Australia’s interests.

Description

the last decade has seen major change in the contribution of radiology to the battlefield trauma team as part of the combat casualty care revolution, with survival rates of up to 98% of trauma patients brought to the hospital alive.^{2,3}

This huge improvement in survival is due to major multidisciplinary evolution of health care, starting with self and “buddy” first aid, tourniquets, on site medics, use of rescue resuscitation teams, immediate aeromedical evacuation from the site of injury to NATO Role 2E or Role 3 Hospitals, improvements in blood product availability, damage control resuscitation and surgery and, later if necessary, aeromedical evacuation to major hospitals well outside the combat region for ongoing definitive care and rehabilitation.⁴⁻¹¹

The changes in radiology, now being referred to as Damage Control Radiology,¹² have been deployment of 64 slice or more CT scanners situated adjacent to the emergency casualty receiving area, with clear access and space for the whole resuscitation team to work together with radiologists and radiographers who can have the CT trauma examination completed in 2-3 minutes and have the interim CT report delivered verbally to the trauma team by the

radiologist less than 2 minutes later. The final written report, including clearing of the spine, is usually available by 60 minutes, after completion of all images reconstructions and radiologic review thereof. Any significant unexpected findings in the meantime are reported verbally to the trauma team. Back up teleradiology is available to assist with the workload if necessary, to audit the on site reports and to store the patients’ images and reports for future access.¹³⁻¹⁵

This evolution is, perhaps, best reflected in the experience of the UK Defence Forces over the last decade.

The UK Defence Forces have a central DMS (Defence Medical Service) responsible for all health matters, with a subsidiary JMC (Joint Medical Command) specifically in charge of operational policy and support of single service health delivery in a tri-service fashion. These provided for a central tri-service integration of radiological examinations, unlike in the US Defence Forces, which have separate radiology services for Air Force, Army, Navy and Marines with incompatible separate Picture Archival Communication System (PACS) across the forces.

Before 2004, the UK Forces were providing the then standard operational radiology service in Iraq with

mobile x-ray units, wet film processing and mobile FAST (Focused Abdominal Sonography in Trauma) ultrasound units. Shortly thereafter the Basra unit was re-equipped with direct digital X-ray units, bypassing wet film processing and CR (Computed Radiography), together with teleradiology and a PACS for timely image acquisition and reporting. A 16 slice CT unit was then deployed, again with teleradiology reporting back-up in the UK. A couple of years later in Afghanistan at Camp Bastion a pair of 64 slice CT units were installed with on site radiologist supervision, again with back-up teleradiology support.¹⁴⁻²⁰

The same progression to deployment of radiologists and fast CT scanners occurred with US Forces in Iraq (Balad) and in Afghanistan (Kandahar), as has been noted by ADF surgeons and other deployed health team members and our ADF patients. Folio in his now classic text, *Combat Radiology*,² details the challenges and changes faced in Iraq and how they were dealt with using earlier 16 slice CT, including a detailed review of ballistic and blast injury, Traumatic Brain Injury and CT and plain X-ray examination of the chest abdomen, pelvis and extremities. A later review confirms progression to 64 slice CT with radiologists incorporated into the multidisciplinary trauma care team.^{1,20-22}

Naval hospital ships from the US and the UK (USNS Mercy and RFA Argus) are equipped to function as Role 3 Hospitals which capability was in use during the Gulf War and Operations Desert Shield and Desert Storm. Both are equipped with CT but from that time of military involvement it was more that a decade later that the full impact of Damage Control Radiology became available as CT scanners became faster. These ships remain available to support military requirements but may be more active in their secondary functions of providing humanitarian care and disaster relief.

Damage Control Resuscitation and Surgery evolved from US urban civilian healthcare of multiple gunshot injuries associated with the increased availability of automatic pistols in the 1970s, together with the growing number of high speed motor vehicle accidents, leading to the ongoing development and spread of major Trauma Centres. As is usual under the pressure of war, military experience has led to better utilisation and outcomes compared to civilian trauma experience in many countries. Germany has also pioneered these principles together with Damage Control Radiology. In the UK, the Royal College of Radiologists has published Standards of Practice and Guidelines for Trauma Radiology in the Severely Injured Patient.²³⁻²⁸ Radiologists have documented their trauma radiology responses to

mass terrorism blast and penetrating injuries in Boston and Jerusalem.^{29,30}

Currently in Australia a major trauma centre is generally closed to new admissions if the CT scanner is not operational.³¹

Reasons

Why has CT examination become a central component of the management of penetrating or blunt polytrauma patients over the last 7 years?

Before CT, radiology trauma examination generally comprised FAST ultrasound and supine X-ray examination of the chest, abdomen, pelvis and spine. Its problems are that FAST, while accurate for free fluid in the abdomen, pelvis, pleura and pericardium and also for pneumothorax, is not reliable for liver and spleen injury. Supine chest X-ray is not reliable for pneumothorax detection and supine X-ray examination of abdomen and pelvis is not reliable for soft tissue injury. X-ray examination of the spine, especially the cervical region, is no longer regarded as reliable.

Initially, CT was known as the "tunnel of death" where haemodynamically unstable patients could perish in association with a CT examination that could take 20 minutes and a journey from the resuscitation bay to CT scanner that could be 100 metres or more, plus or minus lift transport. But it was quite useful for diagnosis in haemodynamically stable patients.

Under current policy, fast CT scanners (64 slice or more) are sited adjacent to the resuscitation area, separate from a general radiology department if it is present, and staffed by dedicated radiographers and consultant radiologists who are an integral part of the trauma team and captained by the team leader. The CT scanner can now be regarded as a "circle of life".

From the practical perspective, deployable CT scanners are supplied built into an expandable ISO (International Organisation for Standardisation) container / shelter, which is transportable by truck, C17 aircraft or by ship to the presumed tented hospital. Some units have been sited in hardstand deployed hospitals (Camp Bastion). An example of a deployable CT scanner is the Philips 64 unit adapted by Marshall.^{32,33}

CT is very accurate in the positive identification of head, neck, chest, abdominal, pelvic and spine injuries as well providing an angiographic review of the arterial system from the brain down to the toes if necessary. Limb trauma is also definitively demonstrated with review in multiple planes and tissue levels. However formal definitive assessment

of sensitivity, specificity and accuracy have not yet been reported.

CT is used to examine most polytrauma patients either immediately on arrival, or, if haemodynamically unstable, after Damage Control Resuscitation and Surgery in theatre so as to detect the full range of injury and exclude the presence of any unsuspected lesions.³⁴

Integration of Damage Control Radiology CT findings with Damage Control Resuscitation and Surgery and all the other components of the retrieval and trauma management systems have led to the current very major improvements in survival of injured service personnel.

Associated CT Utilisation

Apart from the use of CT for investigation of less severe injuries and for general medical and surgical indications that may come up in the military health care system on the deployment, a number of specific military areas of utilisation are current. These include:

General medical and surgical referrals, as above;

- Scout / scanogram views of patients or others to exclude the presence of hidden ordinance³⁴;
- CT ballistics calculations to determine from where the bullet was fired²;
- Analysis of injury patterns for improvement of body armour and for aircraft incident assessment^{2,35-37};
- Veterinary use for investigation of injury to and treatment of valuable working dogs^{2,16};
- Post mortem forensic CT including for use by the Coroner^{35,38};
- Post mortem injury assessment and for ongoing military review of causes and mechanisms of death.^{2,36}

Overview of Operational Radiology in the ADF

Operational radiology includes all radiology undertaken outside the Garrison Area. It has a long history.

Shortly after Roentgen's publication on X-rays in 1895, X-ray examination was undertaken in the Graeco-Turkish War of 1897.³⁹ Madame Curie,⁴⁰ better known for her work with radium, developed and equipped 18 mobile X-ray cars ("little Curies") for use by the French Army in World War 1.

The next 80 years has brought us to its more recent status, as noted above, in the UK Defence Forces prior to 2004.

In the ADF X-ray services are available for Role 2 military hospitals in the field for Army and Air Force and afloat for Navy for the ongoing health care of members as currently supplied in the ADF together with FAST diagnostic ultrasound. This capability may also be deployed for humanitarian or disaster relief missions.⁴¹

If required for military or other reasons, the capability of a Role 2 health facility can be upgraded to Role 2 E, but such has not been required by the ADF in the Middle Eastern Area of Operations over the last decade as ADF hospital requirements have been made available by our Coalition and NATO partners. The ADF does not have current capability to deploy a Role 3 Hospital.

At present, ADF operational equipment comprises now dated CR (Computed Radiography) units, replacing wet film technology with relatively old mobile X-ray units and a range of current and outdated SonoSite mobile ultrasound units.

Enoggera Health Centre X-ray facility is staffed on an augmentation basis by ADF radiographers from 2GHB (Army) and Amberley Air Force base and provides the only ongoing "hands on" experience for ADF radiographers. At all other sites where deployable X-ray capability exists, radiographers require rostering to work in the civilian sector on a regular basis to maintain their professional skills and registration.

Navy: While awaiting the commissioning of its first LHD (Landing Helicopter Dock) with PCRf (Prime Casualty Reception Facility) capability, HMAS Canberra Navy has an operational capability for X-ray and FAST ultrasound examinations on HMAS Choules. Operational radiology arrangements for the HMAS Canberra are under review at the time of writing and include X-ray and theatre image intensifier capability. CT capability has been discussed previously without positive implementation.⁴²

Currently, ADF operational service require physical transfer of the referral form and X-ray and ultrasound images acquired and recorded on optical disc or "thumb nail" drive to an Australian radiology practice site which is part of the group contracted to provide radiology services to the ADF for "untimely" reporting and incorporation into the medical record of the patient. Outside Australia, the delay is extended until the return to base of the deployed unit.

Teleradiology capability is under review so as to be able to supervise examinations and provide timely reporting of examinations as per the national guidelines for radiological services that apply to civilian services.⁴³⁻⁴⁵

ADF PACS: I-MED, Sonic and other contractors for the provision of radiology services to the ADF for its garrison members have commissioned the ADF PACS which is situated outside the IT (Information Technology) domain of the DRN (Defence Restricted Network) but is accessible both from within the DRN and from without at <https://adfdirect.com.au> and from without through the I-MED Intelrad / Comrad Network.⁴⁶

Next Steps

As the ADF commenced its wind down from more than a decade of deployment and war, amongst the many lessons learnt is the “Military Medical Revolution”¹ in respect to the trauma treatment system for ballistic and blast injuries. The arrival of patients at hospital requires Damage Control Resuscitation, Radiology and Surgery as best triaged by the trauma team leader.

Among the future projections on what military problems the ADF may next face are those put forward by Kilcullen,⁴⁷ suggesting possible terrorist, insurgency, revolution and / or criminal paramilitary activity in coastal mega-cities, usually with poor governance. Kilcullen has updated his projections in light of the current ISIS and more formal military action in Syria and Iraq.^{48,49} Favoured weapons are thought to include the usual high velocity ballistic types, relatively expensive RPGs and relatively inexpensive IEDs (Improvised Explosive Devices) and EFPs (Explosively Formed Projectiles). All of the above are causes of polytrauma with penetrating and blast injuries. Current civilian and military trauma management systems include CT and the radiologist as an essential component of the trauma team.

With the recent postponement of its deployable CT equipment order, the ADF is not capable of providing current military best practice standards of care to its members if it were to deploy without NATO or US forces. ADF radiographers and radiologists have undertaken the majority of preparation work to provide the manpower for deployed CT capability. ADF surgeons, anaesthetists and emergency physicians have deployed experience in working in the “Military Medical Revolution”. In planning for the immediate future, the ADF should include deployable CT capability by air, land and sea, and CT capability with the PCRf functions of the LHD naval vessels.⁴⁰ In civilian Australian practice, it should be noted that a Trauma Centre without a functioning CT scanner is usually closed for further admissions. Those admissions are usually due to accidents rather than the planned or expected injuries of operational military service.²⁹ This highlights the lack of CT capability in military

practice, when our members volunteer to take the risk of polytrauma in the service of our nation. At the same time, connection of current operational X-ray capability to the existing ADF PACS by teleradiology must proceed in order to get the standard of care up to community expectation.⁴¹

Conclusion

A Military Medical Revolution – the Military Trauma System – has been recognised to comprise developments during the MEAO wars over the last decade. A significant additional component to Damage Control Surgery and Resuscitation is Damage Control Radiology provided by onsite CT and radiologists. The ADF has benefited from the NATO supply of this service so as to provide the best standard of care to its members. As the ADF regroups and plans for a new era, including further operations in the Middle East, the recently postponed capability of having its own deployable CT requires implementation to provide current standards of care to members incurring ballistic and blast injuries on non-NATO or US supported deployments that may be required in Australia’s interests.

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Disclosures

The views expressed in this review are my personal views as a military radiologist and do not represent the policy of the ADF. I have neither financial interests nor incentives regarding the above.

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