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Combat radiology: Challenges and opportunities

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ABSTRACT

Radiology services in a combat situation are essentially centred on assisting the battle field physicians/surgeons to save/salvage life and limb. Timely and accurate detection of type and mapping of extent of injury can aid in making imaging based triage which can be of immense help to the treating physicians/trauma surgeons. With the availability of rapid assessment (clinical as well as imaging based) and quick transport facility, the focus has gradually been shifting from merely limb-saving to life-saving strategies. Providing the right imaging modality at the right time for the right patient at the right place is the need of the hour and will dictate the success of combat casualty care. Although there are limitations in terms of terrain and hostility in a combat scenario, newer developments in the field of Radiodiagnosis and imaging can be optimally utilized for better casualty care services. Point of care Digital/Computed Radiography and basic Ultrasonography for trauma complemented by usage of multidetector computed tomography will go a long way in helping timely and accurate management of victims of blast and ballistic injury in a combat scenario. Following a rigid, easy to understand yet comprehensive protocol and radiology reporting system will be invaluable in the combat scenario despite various limitations.

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Introduction

Combat radiology is considered as old as radiology itself and possibly dates back to 1897.[1] Although technically, combat radiology may not be very different from peace time radiology, there are many environmental (climate/terrain related), situational, administrative, logistic and operational differences between the two which make combat radiology very unique and highly demanding. Keeping pace with the unparalleled advancement of radiologic technology and changing combat dynamics, combat radiology has assumed even greater role in the assessment, triage and management of combat casualties. Modification, innovation and creativity

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in a hostile environment with limited resources remain the cornerstone of successful casualty management in a combat scenario. Speed, clarity, adequacy and accuracy coupled with immediate remote transmission of data/results are the essence of present day combat radiology.

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The requirement

1) Basic radiology facility (Radiography) is required at the Forward Surgical Centre (FSC) where surgical and critical care specialists are available and initial life and limb saving treatment is done. Facility for computed radiography at a peripheral point of care location would be ideal. Ultrasonography (USG) facility should be available at the FSC level. A Computed Tomography (CT) scan machine should preferably be available with trained technologists and radiologist at the nearest border static hospital.
2) All components of combat radiology setup are required to be functional 24 × 7 with trained technical manpower like any other emergency radiology department.
3) Facility for image transfer and cross consultation among radiologists and other concerned specialists at a remote location must be available, possibly on the same information networks that serve the combat personnel as this will ensure a robust information-sharing platform that is secure and reliable.

Challenges

1) Setting up the radiology facility in the combat zone in temporary shelters amidst hostility and adverse terrain/climatic conditions is always a challenge. Non-availability of adequate space for proper functioning of X-ray machines is always a major constraint. X-ray equipment require relatively high voltage electricity supply for smooth functioning. In the absence of a dedicated source of constant electricity supply with stable voltage, optimum functioning of the radiographic equipment cannot be guaranteed. Voltage fluctuations in the electrical supply are a major risk factor for breakdown of radiological equipment including ultrasonography machines. Temperature and dust control is another daunting task.
2) Construction of light proof, dark room facility for handling of radiographic films is often difficult. Non-availability of automatic film processors may be another constraint. Manual processing of films is not often practically feasible in extremes of temperature in field conditions. Similarly, storage of radiographic films in optimum temperature becomes increasingly difficult in such situations.
3) Transportation of sophisticated electro-medical equipment (like X-ray machines) to field/combat location may be difficult because of unfavourable terrain and climate. Radiography for deep seated structures like abdomen, lumbo-sacral spine etc. is often suboptimal with the low mA portable machines commonly transported in field locations. Most of the radiology equipment being sophisticated, field repairs for minor breakdown can be difficult in the absence of technical expertise in combat location.
4) Ensuring radiation protection measures is often difficult in field conditions.
5) Availability of functioning USG machines with requisite probes and trained manpower for operating such machines optimally often remains a challenge. Availability of multi-detector CT scan machine at the nearest static hospital, though ideal, may not always be possible.

Discussion

Success of combat casualty care, to a large extent, will depend on the success of combat radiology services, which in turn will depend mainly on three factors: (a) *speed*: rapidity of diagnosis, (b) *accuracy*, and (c) *reach*: how forward the diagnostic facility can be advanced. Most injuries in combat scenario are likely to be ballistic and/or blast injuries often resulting in poly-trauma. Familiarity of imaging appearances of poly-trauma due to ballistic/blast injuries is of paramount importance for timely and appropriate management of such cases. Familiarity with wound ballistics and wound cavity and even number guide can prove very useful.[2–4]

Staffing

In an ideal situation, a radiology technologist needs to be placed at the FSC where the surgical team consisting of surgeons and anaesthetists would be available round the clock. A portable USG machine is ideally located at the FSC level. The surgeon as well as anaesthetist should be familiar with carrying out Focussed Assessment with Sonography for Trauma (FAST) and preferably Extended Focussed Assessment with Sonography in Trauma (EFAST). High end radiology equipment like MDCT should ideally be available at the nearest static hospital where facility for definitive treatment will be available. A radiologist is preferably stationed at the CT scan centre for augmenting the radiology services.

Radiography

Radiography plays an important role in the initial screening and evaluation of combat casualty particularly for the skeletal injuries. Portable, low mA machines are often limited by technically suboptimal radiography particularly for abdomen and thicker body parts. Also, the issue of conventional

film processing becomes very cumbersome and challenging in the combat scenario. In such a situation, ideal is to have battery operated remote controlled direct digital radiography. However, in the absence of a portable digital radiography system, a compact, portable, lightweight all weather computed radiography system mounted on a wheeled cart or table top with high quality image management software, is a viable alternative which can make use of the existing radiography machines in field situations. This will also enable clearer images ready to be shared through available tele-media.

Role of ultrasonography

Ultrasonography (USG) has a versatile capability in the setting of polytrauma. Availability of high resolution, light weight, portable USG machines with inbuilt Colour Doppler facility enables timely detection and quantification of most of the visceral and vascular injuries. Early detection and quantification of hemoperitoneum and haemothorax makes USG the frontline imaging modality in polytrauma in trained hands. Rapid assessment of intrabdominal injuries by means of four quadrants USG by the 1st level physician, also known as FAST has been found to be of proven benefit. Recently evolved EFAST has added the role of USG in the detection of pneumothorax in addition to intraabdominal injuries. Point Of Care (POC) USG by a trained physician/technologist may soon become a reality in the setting of combat casualty care. Development of battery operated pocket sized ultraportable yet high resolution USG machine with inbuilt Wi-Fi and DICOM capabilities by various manufacturers is surely going to change the dynamics of point of care imaging in a combat scenario.

CT scan – a major break through in diagnostic traumatology

The concept of whole body CT or Pan CT in cases of severe poly trauma is rapidly gaining popularity. The same is also true for combat casualty due to ballistic and or blast injuries. Multi-Detector CT (MDCT) is a boon for any trauma centre. MDCT has several advantages in the setting of poly-trauma. Because of increased scanning speed, the whole body can be scanned in a matter of 20–30 s depending on the technique. Accurate contrast bolus synchronization can be achieved with exquisite display of vascular anatomy which is very helpful in cases of suspected vascular injury. Patient can be scanned in supine position or the position of comfort without losing any significant information. 3D data acquisition with thin collimation helps creation of excellent multi-planar reconstructions (MPR) both in orthogonal as well as non-orthogonal planes in near isotropic voxels. This helps in quick assessment of organ damage. Curved MPR can be of immense value in delineating the trajectory path of a missile. MDCT also enables exact anatomic localization of retained ballistic and blast fragments within the body. With the regular use of MDCT, accurate anatomic positioning and trajectory mapping can be done without any complex construction analysis model (like coordinate system) and a three dimensional in vivo orientation and information about the ballistic/blast fragments can be provided very quickly. Prior knowledge of clinical details of patient including number and site of entry wound/s further facilitates tracking the missile fragments and their pathway. Knowledge of ricochet trajectories especially when there is a bone in the path of a missile is essential to detect presence of missile fragments at unusual places. 3D volume rendered images provide exquisite details of bony anatomy and vascular anatomy (in angiographic studies) rendering it easy to understand by the treating surgeons. MDCT can help in excluding life threatening injuries that need immediate attention and also help in triage by diagnosing clinically non-obvious injuries as well as minor injuries not requiring immediate attention. In the absence of a good quality radiograph, a CT scanogram/scout can be a reasonable substitute in the emergency setting.

Radiological triage

Widespread use of USG and MDCT has revolutionized the management of poly trauma under any setting. It is well established that radiological assessment of the severity and extent of injury often dictates the management and parallels the outcome. This is especially true in cases of head injury because of availability of rapid evacuation facility to a definitive neurosurgical centre. The concept of Radiological triage has already gained widespread acceptance in the field of traumatology.

Standardized reporting

A unique feature of combat casualty care is the arrival of often unexpected high casualty load at a short time interval putting further strain in already burdened system at every level of health care. In this scenario, it is often helpful to communicate the radiology report in a prescribed format covering all aspects (as deemed appropriate by the team) preferably in a binary format (like Yes/No) rather than elaborate reporting system.[2] This helps the treating surgical team to understand and interpret the report quickly rather than trying to read and interpret an elaborate report. Hand written report should preferably be avoided. All these measures also help in data archiving for record purposes which is an essential component of combat casualty care.

Magnetic resonance imaging (MRI)

The role of Magnetic resonance imaging (MRI) in acute injuries in the combat scenario is limited. Besides, there is always a potential for migration of unsuspected ferromagnetic fragments within the body under the strong magnetic field with potential disastrous consequences. MRI is best reserved for cold cases who have undergone thorough imaging prior and have ruled out any contraindications to MRI. MRI, however, has a definite role in the evaluation of severe traumatic Brain Injuries like Diffuse Axonal Injury and also for follow up of head injury cases.

Interventional radiology

As of now, interventional radiology facilities are best located at a zonal or tertiary care level hospitals and do not have any specific advantage in the combat area.

Combat teleradiology

Importance of image archiving, communication and transmission for consultation with the surgical team/radiologists at higher echelon health care stations cannot be over emphasized as in peace time emergency radiology services. Provided, civil communication and internet system is functional, images can be transferred even with the help of a smart phone. In the event of absence or breakdown of civil communication system, alternative feasibility of a secured yet dedicated defence communication system can be explored for transmission of the images to higher centres without jeopardizing the security which is vital for any country.

Conclusion

Present day radiology has essentially revolutionized the management of multiple disciplines of health care. The advent of computed radiography, digital radiography and MDCT has given a major boost in the timely and definitive management for the severely injured in any setting. Using modern technology, making the right equipment available at the right place with the right person handling the same will definitely bring the anticipated change in the combat casualty care. Following a rigid, easy to understand yet comprehensive protocol and radiology reporting system will be invaluable in the combat scenario despite various limitations.

Conflicts of interest

The authors have none to declare.

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REFERENCES

1. Ramoutsaki IA, Giannacos EN, Livadas GN. Birth of battlefield radiology: Greco-Turkish War of 1897. *Radiographics*. 2001;21:263–266.
2. Folio LR. *Combat Radiology in Diagnostic Imaging in Blast and Ballistic Injuries*. Springer; 2010.
3. Folio LR, Fischer TV, Shogan PJ, et al. CT-based ballistic wound path identification and trajectory analysis in anatomic ballistic phantoms. *Radiology*. 2011;258(3):923–929.
4. Folio LR, Fischer T, Shogan P, Frew M, Dwyer A, Provenzale JM. Blast and ballistic trajectories in combat casualties: a preliminary analysis using a cartesian positioning system with MDCT. *Am J Roentgenol*. 2011;197(2):W233–W240.
5. Long J. Combat radiology: a unique opportunity for patient-centered radiology. *J Am Coll Radiol*. 2010;7(12):915–917.
6. Graham RN. Battlefield radiology. *Br J Radiol*. 2012;85 (1020):1556–1565.