*The Journal of Laryngology & Otology (2011)*, ***125***, *13–17*.

doi:10.1017/S0022215110002215

**MAIN ARTICLE**

# Ear injuries sustained by British service personnel subjected to blast trauma

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## Abstract

*Objectives*: To describe the pattern of ear injuries sustained by all British servicemen serving in Iraq and Afghanistan between 2006 and 2009; to identify all servicemen evacuated to the Royal Centre for Defence Medicine following blast injury; to ascertain how many underwent otological assessment; and to calculate the incidence of hearing loss.

*Design and setting*: A retrospective analysis of data obtained from the Joint Theatre Trauma Registry and the Defence Analytical and Statistics Agency, together with audiometry records from the University Hospitals Birmingham National Health Service Trust.

*Results*: Ear damage was present in 5 per cent of all British servicemen sustaining battle injuries. Tympanic membrane rupture occurred in 8 per cent of personnel evacuated with blast injuries. In 2006, 1 per cent of servicemen sustaining blast injury underwent audiography; this figure rose to 13 per cent in 2009. Fifty-three per cent of these audiograms were abnormal.

*Conclusion*: The incidence of tympanic membrane rupture was higher than that found in previous conflicts. Otological assessment prior to and following military deployment is required to determine the incidence of ear injury amongst British servicemen following blast trauma.

**Key words:** Blast; Ear; Tympanic Membrane; Audiogram; Military

## Introduction

The incidence of blast injuries has dramatically increased in the twenty-first century, and is now the main cause of head, face and neck injuries sustained by both US[3] and UK (J Breeze *et al.*, unpublished data) servicemen deployed on current operations. The auditory system is extremely sensitive to blast injuries due to its unique construction. Ear damage following blast injury has long been recognised[4] but is often difficult to quantify. Blast injuries should be suspected regardless of the distance between the patient and the blast centre, and the absence of injuries in other people who were near the patient.[5]

It is difficult to interpret the literature regarding otological damage in military populations, due to inconsistencies in the way injuries are classified. For example, many clinicians still consider impulse noise to be a form of noise-induced hearing loss (formerly termed report trauma). The most widely used classification is that described in the paper by Horrocks.[6]

There is little current data to support the current prevalence of permanent sensorineural hearing loss in military populations following blast injury. The historical prevalence of this condition in this population has been quoted as 30–55 per cent.[4,7–15] However, these figures are likely to include minor degrees of hearing loss, and do not reflect the current operational environment, where blast injury is the predominant form of injury. There are only two previous studies relating to blast injury of the ear which may have contemporary relevance. Roth *et al.*[10] retrospectively studied Israeli soldiers suffering blast-related perforated eardrums between 1967 and 1986, and found that 74 per cent developed sensorineural or mixed hearing loss and 60 per cent complained of tinnitus and/or vertigo. Lucic[11] studied 49 patients with explosive injury of the middle ear, finding ruptured tympanic membranes in 79 per cent.

Both UK and US authors[6,12] have recommended that all service personnel sustaining blast injuries should undergo compulsory audiometry, performed once evacuated. Seriously injured UK military casualties are usually returned to the UK within 36 hours of injury, and audiometry is not routinely undertaken prior to evacuation. Otoscopy is available at all points

Accepted for publication 10 June 2010 First published online 18 October 2010

along the medical evacuation chain, but is rarely performed. Currently, the majority of UK service personnel are evacuated to the Royal Centre for Defence Medicine, based at the University Hospitals Birmingham National Health Service (NHS) Trust. Guidance on the timing of audiography and on service personnel's fitness to deploy is given in the Director General Army Medical Services Policy Letter of September 2008[13] and the Surgeon General's Policy Letter of May 2009.[14] Audiograms are performed by the audiology department of the University Hospitals Birmingham NHS Trust, located in the same hospital complex in which military patients are accommodated. Audiography uptake was originally poor, with referrals made only when service personnel complained of hearing loss. However, following publication of the relevant policy letters, audiograms should now be performed annually for all service personnel, and also within six months before and after operational deployment, ensuring that individuals who have sustained hearing damage are protected as far as possible from further risk. In severe cases, this may render an individual no longer deployable. In other cases, service personnel may continue to deploy, following a documented medical risk assessment, taking into consideration the likely deployment conditions.

The primary aim of the present study was to be the first report to describe the pattern of ear injuries sustained by British servicemen in the twenty-first century. The secondary aims were (1) to identify all servicemen evacuated to the Royal Centre for Defence Medicine following blast injury, (2) to ascertain how many of these underwent formal otological assessment in accordance with the Director General Army Medical Services Policy Letter of 2008,[13] and (3) to calculate the incidence of ear damage.

## Methods

Data regarding battle injuries and the number of evacuations to the Royal Centre for Defence Medicine were supplied by the Defence Analytical and Statistics Agency, using the J97 Field Hospital Admissions For Those Wounded In Action register and comparing this to the Defence Patient Tracking System. The data included naval service personnel, army personnel (including those from the Gibraltar regiment), Royal Air Force personnel and reservists. Hospital admissions from the British Special Forces were not included.

The Joint Theatre Trauma Registry was used to identify and describe all types of ear injuries sustained by British servicemen on operations between 1 January 2006 and 31 December 2009. These figures were obtained by retrospective coding of hospital notes within the first four weeks of the serviceman's stay at the Royal Centre for Defence Medicine. Evidence of bony ossicular damage was ascertained from operative records in the hospital notes. Injuries identified from the Joint Theatre Trauma Registry were matched to the audiogram database held by University Hospitals Birmingham. Normal hearing was classified as a hearing threshold of 20 dBHL or better in both ears, while abnormal hearing was classified as a hearing threshold worse than 20 dBHL in either ear.

### *Ethical considerations*

In line with current Defence Medical Services policy, this study was approved by the Defence Medical Services research and ethics committee, and all patient data were anonymised. No external sources of funding were obtained.

## Results

Joint Theatre Trauma Registry entries between 1 January 2006 and 31 December 2009 were analysed for all causes of ear injury (Table I).

Ear damage was present in 5 per cent of all British servicemen sustaining battle injuries, whether evacuated to the UK or managed definitively in an operating theatre on site. External ear injuries accounted for 1 per cent of total battle injuries and 3 per cent of all evacuated blast injuries. Tympanic membrane rupture occurred in 4 per cent of total battle injuries and 8 per cent of evacuated blast injuries.

We studied the audiology records of patients who had sustained blast injury and been evacuated to the Royal Centre for Defence Medicine, to assess whether an audiogram had been performed and, if so, whether the result had been recorded (Table II). There were no cases of sensorineural hearing loss in the absence of tympanic membrane injury. The proportion of servicemen sustaining blast injury who underwent audiography once evacuated to the Royal Centre for Defence Medicine ranged from 1 per cent in 2006 to 13 per cent in 2009. Fifty-three per cent of these audiograms were abnormal. The time between injury and formal ear examination ranged from 3–52 days (mean 28.2 days) for those servicemen who had an intensive therapy unit admission to 3–26 days (mean 8.9 days) for those managed on general wards.

In addition, all blast injuries sustained in 2008 were studied in greater detail, including documentation of the location of the serviceman at the time of injury (Table III). For those patients described as being in a vehicle, the blast occurred outside the vehicle in 10 cases and inside the vehicle in two cases. Of those servicemen sustaining blast injuries in 2008 who had abnormal audiograms, 71 per cent were in vehicles at the time of the explosion. It was not possible to ascertain from the Joint Theatre Trauma Registry how close the serviceman was to the blast, whether in a vehicle or in the open.

## Discussion

This study found ear injuries to have occurred in 5 per cent of all British servicemen sustaining battle injuries, whether evacuated to the UK or managed definitively in an operating theatre on site. This figure is similar

https://doi.org/10.1017/S0022215110002215 Published online by Cambridge University Press

TABLE I
TOTAL BRITISH FORCES EAR AND OTHER INJURIES, 2006–2009*

| Year | Total battle injuries | Evac'd blast injury† | Ext ear injury | TM injury | Ossicular injury | Total ear injuries |
|---|---|---|---|---|---|---|
| 2006 | 178 | 69 | 0 | 2 | 0 | 2 |
| 2007 | 436 | 185 | 3 | 13 | 0 | 16 |
| 2008 | 255 | 131 | 3 | 10 | 2 | 15 |
| 2009 | 508 | 267 | 12 | 27 | 4 | 43 |
| Total | 1377 | 652 | 18 | 52 | 6 | 76 |

Data represent numbers of patients. *1 January 2006 to 31 December 2009. †To the Royal Centre for Defence Medicine. Evac'd = evacuated; ext = external; TM = tympanic membrane

to the 6 per cent reported for World War Two,[7] but higher than the 3 per cent described in a US review[1] of injuries sustained in Iraq and Afghanistan from 2001 to 2005. Wade *et al.*[2] found that the external ear was injured in 9 per cent of US servicemen serving in Afghanistan between March and September 2004. This figure is higher than that identified in the current study, which found that external ear injuries accounted for 1 per cent of total battle injuries and 3 per cent of all blast injuries. This is likely to reflect differences in the way that external ear injuries are coded in our Joint Theatre Trauma Registry – specifically, the fact that external ear lacerations can be coded as facial lacerations and not as ear trauma.

Tympanic membrane perforation is the most common significant combat-related ear injury,[6] compared with all forms of battlefield ear injury; even so, its incidence is likely to be under-reported.[12] The tympanic membrane is also the anatomical structure injured most frequently, and at the lowest pressure, by blasts.[5]

In this study, the incidence of tympanic membrane perforation in patients sustaining all types of injury (not just blast injury) was 4 per cent. This is similar to the figures of 2 per cent from World War Two,[7] 3 per cent from the US street battle in Mogadishu[15] and 7 per cent from Iraq.[16] However, when we assessed rates of tympanic membrane rupture in patients sustaining blast injury alone we found that the incidence had doubled; this correlated well with other reviews which found a similar incidence rise, to 12–50 per cent.[17–19] However, again, this figure is likely to be lower than the true incidence, as the time between injury and ear examination was between 3 and 52 days (few patients admitted to the intensive therapy unit were well enough to undergo pure tone audiometry), and some injuries may have healed by the time of audiography. Another limitation of this study was that servicemen who were not obviously injured following blast trauma may not have reported for medical assessment, allowing occult injury to be missed.

We found that 53 per cent of audiograms performed on evacuated servicemen who had sustained blast injury were abnormal. However, as only 13 per cent of evacuated UK servicemen underwent audiography while at the Royal Centre for Defence Medicine, the real figure will probably be even higher, with long-term consequences for the healthcare provision for our disabled veterans.

It was not possible to obtain pre-deployment hearing records. Therefore, it is possible that a small proportion of those servicemen with post-deployment hearing loss may have had abnormal audiograms prior to deployment.

Explosions occurring in confined spaces result in a higher incidence of primary blast injury, greater mortality and greater injury severity.[20] Leibovici *et al.*[21] compared 204 casualties from open-air bombings to 93 casualties from bus bombings. They found that explosions in a confined space caused more severe injuries and greater mortality. In our study, 71 per cent of the servicemen who sustained a 2008 blast injury and had an abnormal audiogram were in a vehicle at the time of the blast, and in the majority of these cases the blast occurred outside the vehicle. This may indicate that vehicles provide only limited

TABLE II
AUDIOGRAM RESULTS*

| Year | BI pts (*n*) | AGs done† | | AG result | |
|---|---|---|---|---|---|
| | | *n* | %‡ | Normal** | Abnormal§ |
| 2006 | 69 | 1 | 1 | 0 | 1 |
| 2007 | 185 | 6 | 3 | 1 | 5 |
| 2008 | 131 | 16 | 12 | 7 | 9 |
| 2009 | 267 | 34 | 13 | 19 | 15 |

*For patients evacuated to the Royal Centre for Defence Medicine (RCDM) having sustained a blast injury. †At RCDM. ‡Of all blast injury patients. **≤ 20 dBHL in both ears; §>20 dBHL in either ear. BI pts = blast injury patients; AG = audiogram

TABLE III
2008 BLAST INJURIES*: LOCATION AT TIME OF INJURY

| Location | Patients | |
|---|---|---|
| | Total (*n*) | Abnormal AG† (*n*) |
| In vehicle | 93 | 12 |
| In the open | 34 | 3 |
| Unknown | 4 | 1 |
| Total | 131 | 16 |

*131 servicemen. †>20 dBHL in either ear. AG = audiogram

https://doi.org/10.1017/S0022215110002215 Published online by Cambridge University Press

ear protection against the effects of the blast wave. Alternatively, the protection of a vehicle may enable personnel to survive a close proximity blast which would otherwise have been fatal.

- **The incidence of blast injuries has dramatically increased; they are now the main cause of head, face and neck injuries sustained by deployed British servicemen**
- **Ear damage was present in 5 per cent of all British servicemen sustaining battle injuries in Iraq and Afghanistan between 2006 and 2009**
- **External ear injuries constituted 1 per cent of total battle injuries and 3 per cent of all evacuated blast injuries**
- **Tympanic membrane rupture occurred in 4 per cent of total battle injuries and 8 per cent of evacuated blast injuries**
- **Of servicemen sustaining blast injuries and evacuated to the Royal Centre for Defence Medicine, only 1–13 per cent received an audiogram; 53 per cent of these tests were abnormal**

Current developments relating to hearing protection are likely to revolve around the Personal Interfaced Hearing Protection© project (Racal Acoustics, Harrow, UK). This communication system will also provide some blast protection. The system began to be introduced in late 2008 in order to address the limitations of conventional passive ear protection, which impairs situational awareness and communication, both of which are vital during military operations. None of the servicemen assessed during the study period were wearing the Personal Interfaced Hearing Protection communication system. It is expected that follow-up studies will analyse the incidence of ear injuries in soldiers wearing this system, to confirm its protective capabilities.

The increasing numbers of military ear injuries will necessitate increased follow-up provision. Xydakis *et al.*[3] found that unilateral or bilateral tympanic membrane perforations accounted for 58 per cent of patients seen by a military ENT service. Furthermore, Brennan[22] found that hearing loss was the most common reason for a post-deployment ENT outpatient appointment. Many service personnel may not present to the healthcare system until a period of time has elapsed after the causative event; thus, the establishment of immediate post-event hearing assessment is an important target, in order to identify and support these personnel. Hearing loss and tinnitus are currently the second most common reasons for disability claims to the American Veterans Association by former service members.[23]

In the twenty-first century, the increased frequency of blast injury amongst British service personnel will undoubtedly result in a greater incidence of long-term hearing loss, in addition to the increased incidence of tympanic membrane damage found in this study. This will undoubtedly increase the future burden on both our military healthcare system and the NHS.

## Conclusion

The incidence of tympanic membrane rupture amongst British servicemen was higher than that found in most previous conflicts, and is likely to reflect the increased number of blast injuries sustained by British service personnel in Iraq and Afghanistan. Over half of all British servicemen evacuated to the UK between 2006 and 2009 who had been exposed to blast injury had abnormal audiograms. However, as only 13 per cent of evacuated servicemen currently undergo audiography during their stay at the Royal Centre for Defence Medicine, this figure must be interpreted with caution; the true incidence of long-term hearing loss will probably be greater. Until the Director General Army Medical Services Policy Letter of September 2008 is fully implemented and all British service personnel undergo formal otological assessment prior to and following deployment, the true incidence of hearing loss amongst British service personnel following blast injury will remain unknown.

## Acknowledgements

The authors would like to thank Colonel T Hodgetts and Major S Robinson, Academic Department of Military Emergency Medicine, for their help in accessing data. We also thank Professor M Midwinter, Defence Professor of Surgery, and the Academic Department of Military Surgery and Trauma for their continuing support of our work. Finally, we thank both the ENT department and the audiology unit at University Hospitals Birmingham for their ongoing support in the management of our injured servicemen.

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Major J Breeze takes responsibility for the integrity of the content of the paper
Competing interests: None declared