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Otological manifestation due to blast injury

Hadi S. Hasan,[(1)] *

Muataz T. Abdul Kareem,[(2)]

Ali M. Khaleel,[(3)]

(1) Department of ENT
Al-Emam Ali hospital
Baghdad
Iraq

(2) Department of ENT
Al-Shaheed Dhari hospital
Baghdad
Iraq

(3) Department of ENT
Al-Kendy teaching hospital
Baghdad
Iraq

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ABSTRACT

Background: The ear is the most frequent organ affected during an explosion. Recognition of possible damage to it's auditory and vestibular components, and particularly the recovery time of the incurred damage, may help in planning the optimal treatment strategies for the otological manifestation of blast injury and preventing deleterious consequences.

Objective : to evaluate the otological manifestation of blast injury in relation to the distance of explosions, the site of the exposure, space of explosions and to the age of patients and to report the oto-vestibular initial symptoms and follow up .

Patients and Method : Forty two patients collected from AL amam Ali hospital in Baghdad and underwent complete physical, ENT examination ,balance study and pure tone audiomatry.

Result: Complaints deafness and aural fullness, blood stained discharge, and tinnitus resolved, whereas dizziness presists in some patients. By the end of three month follow up 25% of ear drum perforation (medium and small) had healed spontaneously. Hearing impairment was detected in 79 ears of the 84 ears. Recovery of hearing was complete in 9 ears and partial in 19 ears that followed up for one month. 6 patients were complained of vestibular balance abnormalities, 2 of them suffered from positional vertigo. Caloric test was not done because un-cooperation of patients and it was not valid all the time.

Conclusion: exposure to high powered explosion may result in sever auditory and vestibular damage. Various symptom and signs may resolve within a period of time. The distance from explosion, the side of explosion, the space of explosion and the age of the patient have relation to the presentation of the patient and subsequent treatment.

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**Corresponding author E mail :* Hadishammari6@gmail.com

Introduction

During the recent conflicts in Iraq and Afghanistan, explosions were the primary mechanism of injury (74% in one review)(1). Based on the mechanisms of blast injury, it is classified as primary,secondary, tertiary or quaternary. Detonation of high order explosives creates intense over-pressurisation impulse (blast wave), which produces anatomical and physiological injury due to direct impact is the primary kind. Primary blast injury affects the gas-filled structures,especially the lungs, gastrointestinal tract, and middle ear. Secondary injury refers to injury inflicted by flying debris or bomb component. Owing to the impact of the explosion, the victim sustains tertiary injury as the victim is thrown away. Any explosion-related injuries, other than the primary, secondary and tertiary types, are classified as quaternary injury(2). The ear is extremely susceptible to air pressure wave or blast caused explosion consequently the lesion of the eardrum and internal ear are the most frequent of all blast injury(3) in addition to eardrum lesion, the positive wave of air pressure causes dislocation or interruption of the chain of auditory ossicles or rupture of fenestrae although less frequently (4,5), this positive wave of pressure is followed by pronolged but less intensive negative wave affecting the ear to a considerably lesser extent (friedlander's curve)(6), the strength of the positive wave depaneds on the strength of explosion and on the strength of explosion and on the distance of the explosion site. Lesion are more severe if explosive occure indoors where the wave reflects from walls. Eardrum rupture may occure at a pressure of not more than 35 kpa, and pressure of 105 kpa causes rupture in 50% of eardrum in adults(6,7). Most TTMPs (about 80%) can heal spontaneously within 3 months post injury(8). The size of perforation due to blast injury classifed into three type large, medium and small (large subtotal perforation 85% of TM, medium half of TM 50% of TM and small one quedrant 15% of TM)(9)

Aim of the study

To evaluate the otological manifestation of blast injury in relation to the distance of explosion, site of the exposure, space of explosion and to the age of the patients and to report the oto-vestibular intial symptom and follow up .

Patients and method

Prospective study of the patients ,who subjected to plast injuries to the ear ,was performed between the period

from January to December 2012, 42 patients (84 ears) collected from otolarngology clinic in Al Emam Ali hospital suffering from otological symptoms were previosly didn't complain from any ear symptoms. Those patients who had major head injuries in addition to head injuries were not included in this study.

All the 42 patients (84 ears) underwent complete physical ,ENT,and neurological examination at time of presentation. Only 30 patients (60 ears) of them had been followed up for the next three months in otologlaryngology department .in addition to oto-neurological examination ,the patient underwent an auditory and balance assessment ,pure tone audiometry was performed with in first week in some patients and other after 2 week after explosion and 30 patients (60 ears) were followed weekly for three months including oto-neurological examination and auditory and balance assessment . their balance system was evaluated by clinical examination of nystagmus that result from changes in a subjects posotion ,Romberger's and Unterberger's test . the caloric test was not performed because the patients either invaled the test or uncooperation of patients . the distance from the explosion site to the patient was recored and classified into three group :less than 10 meters , from (10-20 meters) and more than 20 meters . the ears were facing the side of explosion or the ears were oppsite to the side of explosion wer recoreded . type of explosion was also recoreded either open or closed space explosion..

Results

This study include 42 cases (84ears) during the period from January to December 2012. There was a males predominance of victimes (35 case). The average age was
35 years (range of 15 to 55 years) who were subjected to blast injury and their oto-vestibular system was evaluated the finding at initial presentation are shown in table (1).

Table (1) finding at initial presentation in 42 patients(84 ears)

Clinical presentation and finding	No.	%
Aural fullness and deafness	**79 ears**	**94.04%**
T M perforation	**55 ears**	**65.47%**
Tinnitus	**52 ears**	**61.9%**
Otalgia	**12 ears**	**1.4.42%**
Unsteadince	**6patients**	**14.28%**
Blood stained discharge	**9 ears**	**10.7%**

The most common type of hearing loss among the studied patients was mixed deafness (56 ears 68.29%) pure sensorineural hearing loss (14 ears 17.07%) pure conductive hearing loss (9 ears 10.97%) and normal hearing loss (5 ears 5.95%) as shown in table (2)

Table (2) type of deafness at intial presentation of 79 ears (94.04%). MHL: mixed hearing loss SNHL: sensorineural hearing loss CHL: conductive hearing loss.

Type of deafness	Number	% total
M H L	56 ears	68.29%
S N H L	14 ears	17.07%
C H L	9 ears	10.97%

Fifty five ears (65.47%) had perforation of eardrum, and were large (subtotal) in 25 ears (45.45%), medium size (involving about half of tympanic membrane) in 18 ears (32.72%) and small (involving one quedrant of tympanic membrane) in 12 ears (21.18%) as shown in table (3).

Table (3) the No of ears in relation to the size of ear drum perforation.

size of perforation	Number	% total
Large (subtotal)	25 ears	45.45%
Medium	18 ears	32.72%
Small	12 ears	21.18%
Total	55 ears	65.47%

Among the ears that had tympanic membrane perforation (55 ears 65.47%) 38 ears (69.09%) had mixed hearing loss and 10 ears (18.18%) with sensorinural hearing loss , 7 ears (12.72%) with conductive hearing loss. Other 29 ears (34.52%) without eardrum perforation , 23 ears (79.31%) had mixed hearing loss , 4 ears (13.79%) had sensorinural hearing loss and 2(6.9%) ears with coductive hearing loss as shown in table (4).

Table(4) type of deafness in relation to TM perforation(55ears).

T M state	S N H L	C H L	M H L
Perforated TM 55ears(65.47%)	10ears(18.18%)	7ears(12.72%)	38ears(69.09%)
Intact T M 29ears(34.52%)	4ears(13.79%)	2ears(6.9%)	23ears(79.31%)

The ears facing the explosion were 22 ears (26.16%), 16 (72.72%) of them had ear drum perforation , the other 22 ears were opposite to the side of explosion, 5 ears (22.72%) had ear drum perforation.As shown in table (5).

Table (5) ear drum perforation in relation to the site of explosion.

Ear direction.	Ear drum perforation
Ears facing to explosion - 22 ears	16 ears (72.72%)
Ears opposite to explosion- 22 ears	5 ears (22.72%)

In those ears facing the explosion (22 ears), had conductive deafness in 8 ears (36.36%), sensorineural deafness in 4 ears (18.18%) and 10 ears (45.45%) had mixed hearing loss in addition the ears opposite to the site of explosion had conductive deafness in 5 ears (22.72%) ,sensorineural deafness in 5 ears (22.72%) and 12 ears (54.54%) had mixed hearing loss as shown in table (6).

Table (6)type of deafness in ears facing or opposite to the explosion

Ear direction	C H L	S N H L	M H L
Ear facing 22ears	8 ears (36.36%)	4 ears (18.18%)	10 ears (45.45%)
Ears opposite 22ears	5 ears (22.72%)	5 ears (22.72%)	12 ears (54.54%)

Six patients suffered from vestibular dysfunction , 4 of them (66.66%) complained of vertigo sensation not related to movement ,but no nystagmus was observed on physical examination . the other 2 patients (33.33%) suffered from positional vertigo , only in one patient a positional nystagmus was observed on Dix Hall pike test indicating paroxysmal positional vertigo and no nystagmus in the other patient as shown in table (7).

Table (7) vestibular dysfunction at intial presentation .

Vestibular dysfunction	No. and %
Unsteadiness (vertigo)	4 patients (66.66%)
Positional vertigo	2 patients (33.33%)

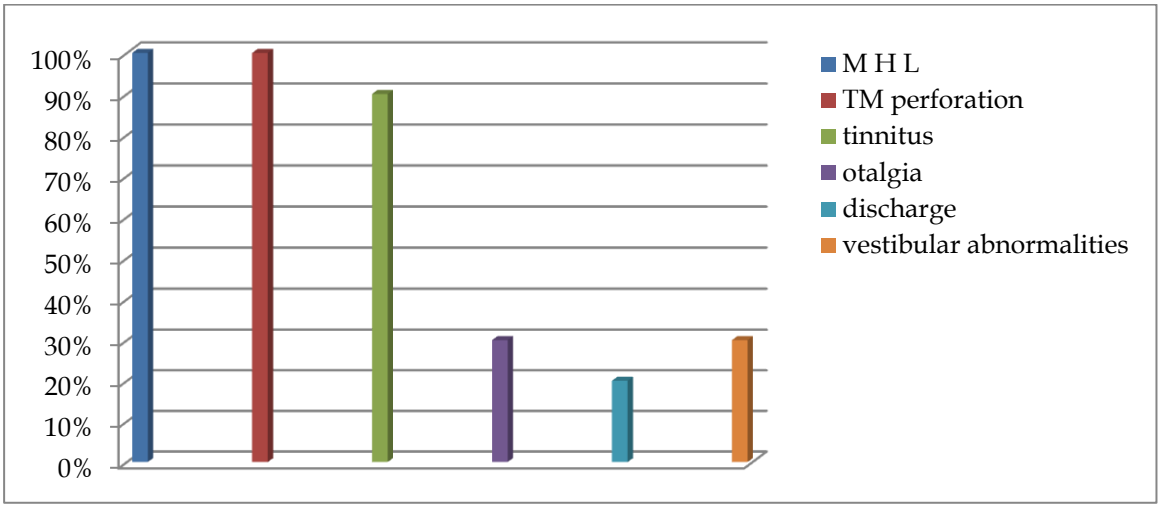
Patients were classified into 3 group according to distance between patient and site of explosion according to history from patients as follow :

1.10 patient (20 ears) in area less than 10 meters.

2.9 patients (18 ears) in the area 10-20 meters.

3.23 patients (46 ears) in the area more than 20 meters.

As shown in chart (1) ,in the first group ,deafness was found in all ears (100%). Total ears with mixed hearing loss were 20 ears. Tympanic membrane perforation was found in 20 ears (100%) ,tinnitus in 18 ears (90%), otalgia in 6 ears (30%) ,discharge in 4 ears (20%) , vestibular balance abnormalities in 3 patients (30%).



Chart(1) : symptoms and sign in 1st group of patients

In the seconed group (10-20m) 9 patients (18 ears) was involved. Deafness is main complaint, sensorineural hearing loss in 1 ear (5.55%), conductive hearing loss in 2 ears (11.11%) and mixed hearing loss in 15 ears (83.33%). TM perforation was found in 15 ears (83.33%), tinnitus in 17 ears (90%), otalgia in 5 ears (27.77%),discharge in 4 ears (22.22%), vestibular balance abnormalities in 3 patients (33.33%) as shown in chart (2).

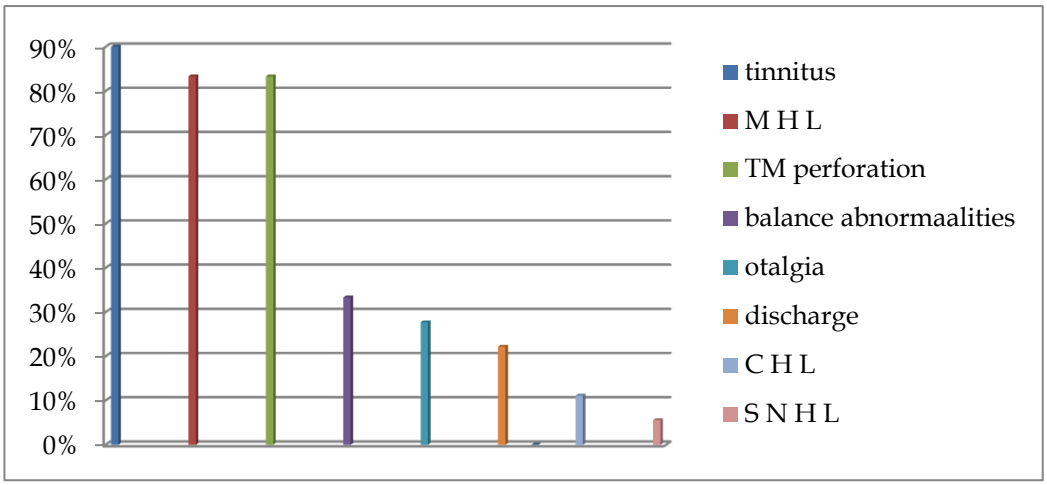


Chart (2) symptom and sign of the seconed group (10-20m)

In the third group (more than 20 m) 23 patients (46 ears) was involved. Deafness was found in 41 ears (89.13%), as sensorineural hearing loss in 11 ears (26.82%), conductive hearing loss in 9 ears (21.9%) and mixed hearing loss in 21 ears (51.21%). Tinnitus was found in 19 ears (41.30%), T.M.perforation in 20 ears (43.47%), otalgia and discharge in one ear (2.17%), vestibular balance abnormalities not found (0%) as shown in chart (3).

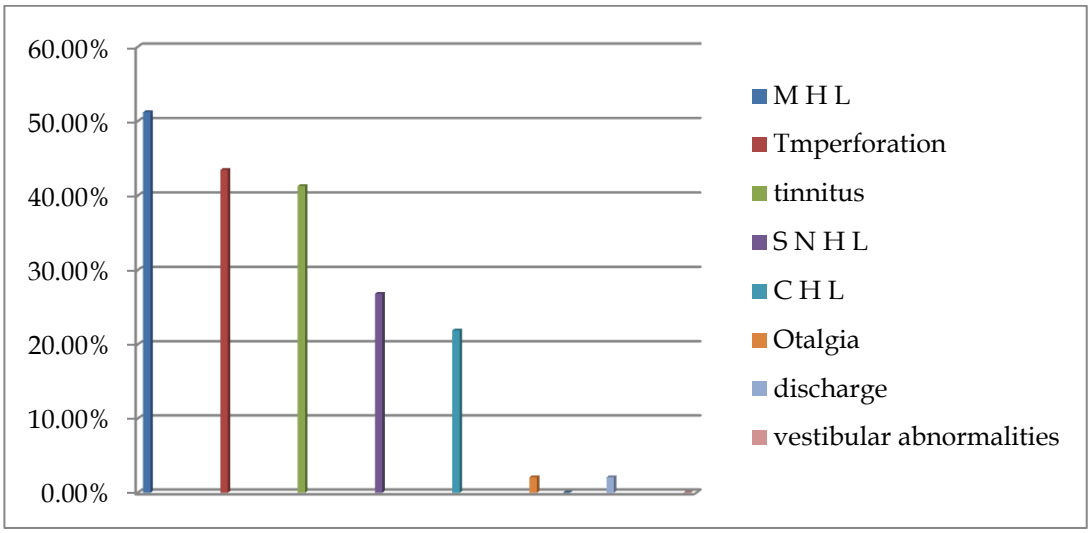


Chart (3) sign and symptom of third group (more than 20 m).

Ear drum perforation in relation to the distance of the patients from site of explosion, in the first group (less than 10 m)20 ears with perforation, 14 ears(70%) were large perforation (subtotal), 4 ears (20%) were medium, 2 ears (10%) were small. In the second group (10-20m), 15 ears with perforation, 7 ears (46.6%) were large, 5 ears (33.3%) were medium, 3 ears (20%) were small. In the third group (more than 20m), 20 ears with perforation, 8 ears (40%) were large, 7 ears (35%) were medium. 5 ears (25%) were small. As shown in chart (4).

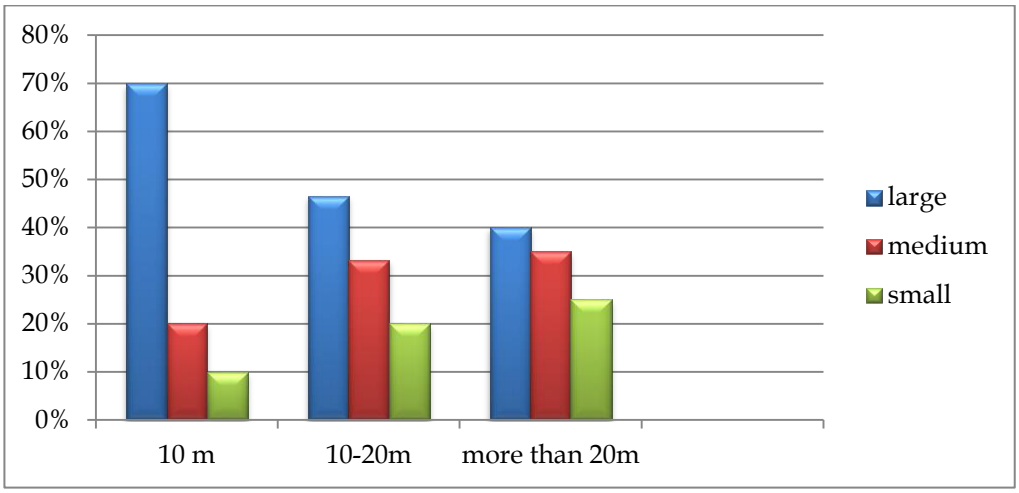


Chart (4) size of tympanic membrane in relation to the distance of the patient to explosion site.

According to age, the patients were classified into two group, the first group was less than 35 years old, and the second group was more than 35 years old. In the first group,deafness was found in 29 ears, 4 ears of them (13.79%) had conductive hearing loss, 4 ears (13.79%) had sensorineural hearing loss and 21 ears (72.4%) had mixed hearing loss.

In the second group, deafness was found in 50 ears, 10 ears (20%) had sensorineural hearing loss, 5 ears (10%) had conductive deafness and 35 ears (70%) had mixed hearing loss as shown in chart (5).

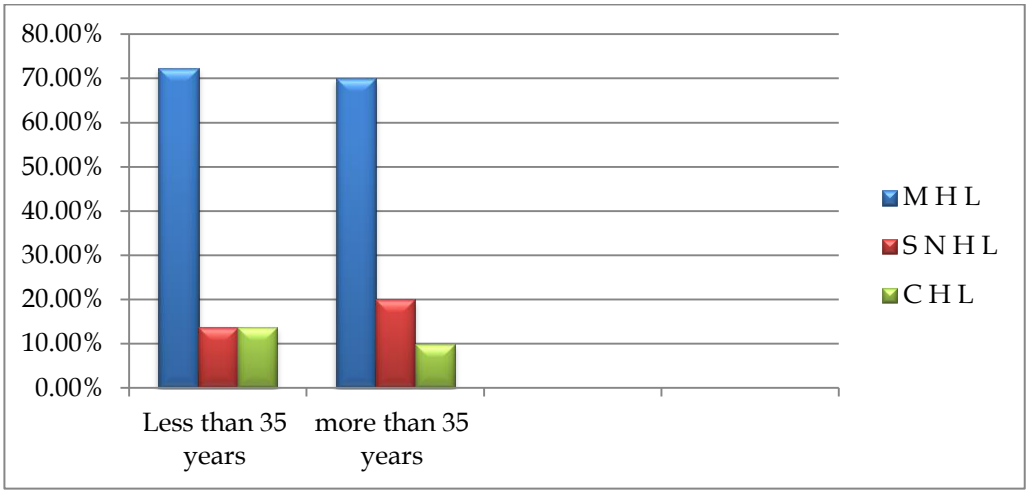


Chart (5) type of hearing loss in relation to the age of the patient.

In those patients were followed up weekly for three months (30 patients, 60 ears), 55 ears who complain of aural fullness and deafness were followed, 15 ears of them had sensorineural hearing loss, 13 ears had conductive hearing loss and 27 ears with mixed hearing loss. After three months followed up, 3 ears (20%) with SNHL were recovered and 7 ears (46.66%) had some improvement and no change in 5 ears (30%). 3 ears (23.07%) with CHL were recovered, 6 ears (48.15%) got some improvement and 4 ears (30.76%) showed no change. 27 ears withed mixed hearing loss, 9 ears (33.33%) were recovered, 14 ears (51.85%) were improved, and 3 ears (11.11%) no change as shown in table (8).

Table (8) type of hearing loss after 3 months follows up (60 ears)

Typ of hearing loss	recovered	improved	No change
S N H L	3 ears(20%)	7 ears(46.66%)	5 ears(30%)
C H L	3 ears(23.0%)	6 ears(48.15%)	4 ears(30.7%)
M H L	10ears(37.03%)	14ears(51.85%)	3ears(11.11%)

Tinnitus was followed in 36 ears , recovered in 22 ears (61.1%), improved in 6 ears (16.6%), and no change in 8 ears(22.22%).

Otalgia in 8 ears, disapeared in 4 ears (50%), improved in 2 ears (25%) and 2 ears (25%) still suffering after 3 months.

Unsteadiness was followed in 3 patients, improved in one patient, disapeared in one patient and one patient no changed.

The discharge disapeared in 3 ears (60%) and in other 2 ears(40%) changed to mucopurulent and improved by the end of 3 months follow. As shown in table (9) below.

Table (9) other symptoms after 3 months follow up.

Presented symptom	Improved	Recovered	No change
tinnitus	6 ears(16.6%)	22 ears(61.1%)	8 ears(22.22%)
Otalgia	2 ears (25%)	4 ears (50%)	2 ears (25%)
unsteadiness	One patient	One patient	One patient
blood stain disc	2 ears (40%)	3 ears (60%)	(0%)

Those ears with tympanic membrane peforation at time of initial presentation that followed up 3 months later (20 ears), 9 were large perforation, 5 were medium in size and 6 were small. No one healed from large perforation (0%), one perforation of medium size (20%) healed and 4 perforation (66.5%) of small size healed after 3 months as shown below in table (10).

Table (10) healed perforation after 3 months follow up in relation to size of perforation (20 ears).

Size of the perforation	Intial presentation	Healed after 3 months
Large	9 (45%)	0
Medium	5 (25%)	1 (20%)
small	6 (30%)	4 (66.5%)

According to type of explosion divided into tow type either open space or closed space. In the open space the tympanic membrane perforation was found in 45 ears, 15 ears (33.33%) were large, 18 ears (40%) were medium, and 12 ears (26.66%) were small. In closed space the tympanic perforation was found in 10 ears, 10 ears (100%) were large as show in table (11).

Table (11)type of TM perforation according to type of explosion

Size of perforation	Open space	Closed space
large	15 ears(33.33%)	10 ears(100%)
medium	18 ears (40%)	0%
small	12 ears (26.66%)	0%

Discussion:

Blast trauma is a complex type of physical trauma, which results from sudden and high-pressure changes during an explosion(10).the ear is the most common injured organ following an explosion. In contrast to other sites of blast-related injuries, such as lung and intestines, an injury to the ear has no devastating or life threatening effect on the victim. Eardrum perforation, hearing loss, and dizziness, may however interfere with dailly activities and have a telling effect upon the individual's quality of life(11). However, most of the studies advocates masterly inactivity as the prime mode of treatment since 90% and above of traumatic perforations heals spontaneously within three months of injury(12).

Middle ear and auditory damage due to blast injury are well documented(13,14). We reported the auditory and vestibular workup of patient who are were exposed to and survived a very high powered explosion.

The primary complaint of subjects exposed to blast injury of the ear includes, aural fullness and deafness, tinnitus, otalgia, dizziness and discharge(15,16,17,18). In this study showed mixed deafness is the commonest (65 ears 68.29%), some associated with tinnitus (52 ears 61.9%). Tympanic membrane perforation in this study is common (55 ears 65.4%). Otalgia and discharge were uncommon found respectively (12 ears 14.4 – 9 ears 10.7%). Vestibular balance abnormalities (unsteadiness) were also uncommon (6 patients 10.7%).

Rapture of tympanic membrane is due to the mechanical pressure of the positive phase of the blast wave(14). The incidince of eardrum perforation depends on the pressure parameters of the blast wave and reflections of of power wave from the wall if explosion occurs in confined spaces(14-19). This explains the relatively high percentage of eardrum perforation (65.4%) and most of the perforation was large perforation (45.45%).

It has been postulated(20) that damge to the middle ear may have a protective effect on the inner ear. However, the high incidence of sensorineural hearing loss (isolated or mixed) in association with blast injury dose not support this hypothesis(21).

This may explained by the slowness of the defensive capacity of the middle ear muscle compared to the velocity of blast wave, a characteristic that would prevent it from effectively protecting the inner ear(22). Indeed in this study 55 ears that had tympanic perforation, 38 ears (69.09%) had mixed hearing loss and those without

tympanic membrane perforation 29 ears, 23 ears (79.31%) had mixed hearing loss. In agreement with other study(22), isolated sensorineural hearing loss was found in (18.18%) of ears with tympanic membrane perforation in this study.

The ear facing the explosive noise and wind is more vulnerable to eardrum perforation than the ear which is in opposite direction(23). In this study 22 ears reported as in a position facing the explosion site, 16 ears (72.72%) had eardrum perforation, while the other 22 ears which in the opposite direction, only 5 ears (22.72%) had eardrum perforation.

The ears facing the explosions are more susceptable to have conductive deafness beside ears opposite to the explosion's pressure and winds where sesorineural deafness is more likely to occur, and the explanation for that probably because the eardrum perforation in the ear facing the explosion and the oval and round windows rupture in the ears opposite to the explosion(17,21,24). In this study 22 ears facing the explosion,had conductive deafness in (36.36%) and sensorineural deafness (18.18%), while 22 ears opposite to the explosion had conductive deafness in (22.72%) and sensorineural deafness in (22.72%).

Balance disorder as consequences of blast injury are considered uncommon(14,21). When present they were attributed to head injury(21). Rare cases of perilymphatic fistula(24) and paroxysmal positional vertigo were reported(14,21). In this study 6 patients (14.28%) complained of vestibular balance abnormalities.

Drag force of blast wind, are proportional to the velocieties and duration time of the winds, which in turn vary with distance from the point of detonations, yield of the weapon, and altitude of the burst(23). In this study the hearing loss in ears closer to the site of explosion were more severly affected, (100% had hearing loss, total mixed hearing loss%), than relatively ears where far from the site of explosion, (89.13% had deafness, 51.2% mixed. 26.82% SNHL, 12.9% CHL).

Tinnitus was more in the ears closer to the site of explosion (90%) than in ears far from the site of explosion (41.30%), and same for otalgia, was more in the ears closure to the explosion (30%) than in ears far from the site of explosion (2.17%).

Vestibular balance abnormalities reported in 3 patients (30%) from 10 patients where less than 10 meters from site of explosion, while (0%) no case reported in 23 patients where more than 20 meters from site of explosion, so the balance disorder are related to the distance from the victum to the site of explosion, the closer the

victum the more vestibule to be affected.

The size of the perforation of the of the eardrum was seen to be related to the distance from the explosion, in those ears closer to site of explosion, sub total perforation was high as 70%, medium size 20% and small size 10%, compared with those relatively far from the site of explosion (more than 20 M), large perforation in 40%, medium size 35% and small size 25%. So the more distance between the victum and explosive site the less in the size of perforation.

Regarding the age of the patients and type of hearing loss, we found that pure CHL were more in younger age group (3.79%). And pure SNHL loss were more in older age group than in the young age group by (6.2%), and mixed hearing loss less in the older age group than younger age group by (2.4%).

3 months follow up for 30 patients (60 ears), the aural fullness and deafness disappeared in only 15 ears (27.27%) and got some improvement in 27 ears (49.09%) but no change in 12 ears (21.81%), this is possible that the high spontaneous closure of eardrum perforation is responsible for recovery of pure conductive and for conductive component of mixed hearing loss. The sensorineural hearing loss is reversible immediately after blast and in other may resolve as late as month after injury (13). Temporary threshold shift of hearing was attributed to reversible changes in the permeablity of the lamina properia of the organ of Corti (13).

Looking at the over all picture, however, of 55 ears with deafness of all type and severity had been followed, only 15 ears (27.27%) had returen to normal at the end of 3 months.

The high percentage of tinnitus was reported to cease in 22 ears (61.1%) and improved in 6 ears (16.6%) and persist in 8 ears (22.22%) only after 3 months, and approximately same applied to otalgia, this probably due to resolusion of the acute insult after 3 months.

The discharge disappeared in most patients (60%) and improved in the rest (40%), with or without treatment.

So the discharge is self limiting providing that external meatus is clean.

It could be expected that as high as 75% of eardrum perforation did not heal completely by the end of 3 months follow up, since the spontaneous healing related to the size of perforation(24), and to the blast intensity(25). It could be expected that small size perforation of eardrum will heal spontaneously providing remained without infiction, and large perforation did not heal sponateously and might need myringoplasty(26).

All eardrum perforation that occur in closed space, were large (sub total).

At the end of three months follow up of 3 patients with vestibular balance abonrmalities, one patient contnued to suffer from balance abnormalities, this prpbably due to weak central compensation or due to CNS depressent e.g like cinnarazine or prochlorpromazine that they took.

Conclusion and recommendations

An explosion creating a sudden large pressure wave which may perforate the tympanic membrane or more commonly injury the inner ear, hearing loss and balance disorder may be unilateral or bilateral. Some recovery possible but profound hearing loss and benign positional vertigo can also result.

The finding of this study indicate that damage to the middle ear and inner ear in victim of a high powered explosion may involve a big number of patients and result in more sever damage to the tympanic membrane and high rate of hearing loss and balance disorder.

The various symptoms and sign may resolve within a period of time and may persist in some cases.

All tympanic membrane perforation in closed space were large (sub total perforation).

The distance of the victim from the site of explosions is an important factor to look after, because the way of presentation, severity of symptoms and sign and the possible recovery and out come may be different.

There is no stastical significant relation between the distance and the incidence of pure sensorineural hearing los, but there is relation with incidence and severity of conductive hearing loss (mixed hearing loss).

We found however, that the incidence and severity of sensorineural hearing loss were not related to the tympanic membrane perforation, on the other word, the tympanic membrane rupture was not a protective factor to the inner ear.

The side of the ear in relation to side of explosion is also an important factor to evaluate, so that the type of injury of the affected ear may be different.

The older age patients are more liable to have sensorineural type of deafness compared with young age patients, but there are no significant differences between two age group regarding conductive and mixed deafness.

After 3 months the prognosis of tinnitus, otalgia and discharge, is almost good, and that for vestibular balance abnormalities are favourable some may end with positional vertigo, other may need to be followed for several months.

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