DELAYED RECURRENT POST-TRAUMATIC BACTERIAL MENINGITIS: STUDY WITH A HIGHLIGHT ON SOME FORENSIC ASPECTS

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Abstract

Introduction: Recurrent post-traumatic bacterial meningitis is a formidable delayed complication of head injury, which is indeed related to very high morbidity and mortality. Its recurrent nature can inflict a huge impact on the patient's life. Forensic investigation of this condition serves both; legal and medical interests.

The current study aimed to study the demographic, clinical, laboratory characteristics and outcomes of patients with delayed recurrent post-traumatic bacterial meningitis, and to shed light on some forensic aspects related to this condition.

Methodology: This retrospective study was done on cases of delayed recurrent post-traumatic bacterial meningitis admitted to Shebin El-kom Fever Hospital in Menoufia Governorate from January 2008 to December 2022.

Result: This study was conducted on 23 patients with delayed recurrent post-traumatic bacterial meningitis. The most common causes of trauma were road traffic accidents (RTA), followed by falls then assaults. Most patients had severe head injury (HI) and were hospitalized for an average duration of 10.5 days. Nineteen patients had cerebrospinal fluid (CSF) leaks, with a delayed time of its appearance in nine cases, with an average time of 11.9 months after HI. Most patients experienced their first meningitis attack within 2-12 months after the injury and the fatality rate of this condition was 17.4%.

Conclusion: Post traumatic recurrent bacterial meningitis has a heavy impact on the patient's life and their families. Meningitis developing as a late complication of HI can have significant forensic importance as accurate diagnosis and proving causality can impact criminal responsibility, insurance claims, and compensation. Long-term follow-up for the potential occurrence of delayed leaks and meningitis after head injuries is important.

Key words
Meningitis, posttraumatic, delayed, recurrent.

INTRODUCTION

Traumatic brain injury (TBI) is a global public health problem, and a leading cause of mortality, morbidity, and disability. There were 27,16 million new cases and 48,99 million prevalent cases of TBI worldwide in 2019 with an incidence rate of 369 per 100,000 world population **(Guan et al., 2023).**

Among TBI, skull base fractures (SBF) are often encountered in the setting of severe head injury (HI). It has been reported to occur in 3.5-24% of all head injury patients **(Wani et al., 2013)**.

SBF may be associated with dural tears and, consequently, with cerebrospinal fluid (CSF) leak. Traumatic CSF leak is a complication in around 2% of all head injuries and 12–30% of all cases of SBF **(Sivanandapanicker et al., 2018).**

A CSF leak usually starts immediately after the injury or within subsequent days. Most CSF leaks resolve spontaneously within 3-5 days, and a small percentage of patients continue with leaks necessitating surgical repair of the defect. In the literature, there are many reports of CSF leaks that could occur months, years, or decades after trauma **(Guyer and Turner, 2015).**

Persistent or delayed-onset CSF leak is a risk factor for bacterial meningitis, and patients usually go through recurrent episodes of meningitis **(Sonig et al., 2012).**

Regardless of the proximity to the event, post-traumatic bacterial meningitis is a serious disease with high morbidity and mortality, and the recurrent nature of this condition can have a significant burden on the patient's life (**Raffaele et al., 2020).**

As a complication of head trauma, the delayed onset, and the recurrent nature of bacterial meningitis represent a critical challenge from a forensic perspective, particularly to prove the relationship between head trauma and the subsequent medical complications (**La Russa et al, 2020**).

OBJECTIVES

The aim of the current study was to present the demographic, clinical, laboratory characteristics and outcome of patients with delayed recurrent post-traumatic bacterial meningitis., and to shed light on some forensic aspects related to this condition

METHODOLOGY

Study design:

This retrospective case series study was done on cases of delayed recurrent post-traumatic bacterial meningitis admitted during the period from January 2008 to December 2022 to Shebin El-kom Fever Hospital.

Inclusion criteria:

Only cases of delayed recurrent post-traumatic bacterial meningitis were included in this study.

- Bacterial meningitis was diagnosed by clinical findings and either CSF pleocytosis and positive CSF bacterial culture or typical CSF findings of acute bacterial meningitis i.e., a polymorphonuclear leukocytic pleocytosis with more than 1000 cells/ul, elevated total protein content >120 mg/dl, and a low CSF glucose concentration (<30 mg/dl and a ratio of CSF to blood glucose of <0.3) **(Pfister and Roos, 2003).**

- Post-traumatic meningitis (PTM) means infection of the leptomeninges when the infectious agent gains access to the intracranial compartment by traumatic means **(Matschke and Tsokos, 2002).**

- Delayed post-traumatic meningitis means meningitis occurring at least one month after the causative trauma.

- Recurrent meningitis means at least two attacks of bacterial meningitis with a period of complete clinical and laboratory normality in between **(Deveci et al., 2015).**

Exclusion criteria:

- Cases of non-bacterial meningitis.

- Cases of bacterial meningitis with no history of trauma; history of recent trauma (early-onset meningitis); post-surgery meningitis; patients with ventriculoperitoneal shunts; and immune-compromised patients.

- First attack of delayed post-traumatic meningitis.

Ethical Considerations:

Before beginning work on that study, ethical approval was obtained from the Faculty of Medicine, Menoufia University Research Ethics Committee. The IRB approval number for this study was (2\2024\FORE١٠). Before the study started, participants or their legal guardians gave their valid informed consent. All personal information was kept anonymous to protect the confidentiality of the records.

Data collection:

Demographic data and a detailed history of causative trauma including its cause and radiologic findings if available were recorded. An inquiry about the presence of CSF leak, its type, the leak or vaccination if attempted, and lastly, the outcome (morbidity and mortality) was recorded.

Statistical methods:

Results were collected, tabulated, statistically analyzed by IBM personal computer and statistical package SPSS version 22 (Armonk, NY: IBM Corp, 2013). Two types of statistics were done-

-Descriptive statistics: e.g. percentage (%), mean (x), standard deviation (SD) and range.

-Analytic statistics: e.g. -Fisher exact test was used to study association between two qualitative variables when expected values of more than 20% if cells were less than 5.

onset, and its course were obtained. Clinical features in our patients at hospital admission and the results of CSF analysis were recorded during the meningitis attacks. Results of surgical repair of

-A P-value of < 0.05 was considered statistically significant.

RESULTS

This study reported on 23 patients with delayed recurrent post-traumatic bacterial meningitis seen at Shebin El-kom Fever Hospital; the largest referral fever hospital in Menoufia Governorate. The hospital is the center for the management of central nervous system infections including meningitis during the period from January 2008 to December 2022. During these 15 years, patients were repeatedly admitted to the hospital for the same condition.

Table (1): Demographic data of delayed recurrent post-traumatic bacterial meningitis cases.

Demographic Data		(N=23)	%
Age at the time of trauma	Mean (±SD)	12.26±9.64	
	0-6	9	39.2
	7-18	7	30.4
	19-40	7	30.4
Sex	Male	18	78.3
	Female	5	21.7
Residence	Rural	17	73.9
	Urban	6	26.1

Demographic data for our subjects is shown in **Table (1).** Age at the time of injury was on average 12.3 years and ranged from three to thirty-seven years old. The youngest group (0-6 years) dominated accounting for nearly forty percent of the cases while ages (7-18 years) and (19-40 years) were exactly equated at 30.4% each. Males comprised almost four times as many as females did; (78.3%) males, versus (21.7%) females. On the other hand, it was discovered that seventy-three-point nine percent of these patients came from villages or rural areas of residence.

Table (2): Characteristics of trauma and hospital stay in delayed recurrent post-traumatic bacterial meningitis cases.

Variables		No= 23	%
Cause of trauma:	RTA (MBA)	10	(43.5)
	RTA (MVA)	3	(13.0)
	Fall	6	(26.1)
	Assault	4	(17.4)
Cranial injuries:	Available data No	20	(87.0)
	available data	3	(13.0)
Associated injuries:	Yes (arm, leg, spine)	6	(26.1)
	No	17	(73.9)
Hospital admission:	ICU	14	(60.9)
	Ward	4	(17.4)
	No	5	21.7
Duration of hospital stay (days)	**Mean ± SD**	10.50±9.69	--------
	Range	(3-35) d	

Table (2) demonstrates that RTA were the most common cause of trauma in our patients (56.5%) followed by falls (26.1%) while assault was present in four patients only (17.4%). Of note, most cases of RTA were due to motor bicycle accidents (MBA**)** (43.5%). All patient in this study had history of previous head injuries, and 87% of them had available radiological data about these injuries. Most patients did not have associated injuries beyond the cranial injuries, with only about a quarter (26.1%) experiencing additional injuries to the arm, leg, or spine. Most patients experienced severe trauma necessitating their admission to a hospital. Among the 23 patients, 18 (78.3%) were admitted to the hospital, and the majority of them were admitted to an intensive care unit (ICU), while the rest of the cases were managed in a hospital emergency and chose outpatient treatment after emergency stabilization in the hospital. The duration of hospital stays varied widely, with an average stay of approximately 10.5 days. The standard deviation of ±9.69 shows a high variability, with some patients requiring extended periods of hospitalization up to 35 days.

Table (3): Age to type of trauma in delayed recurrent post-traumatic bacterial meningitis cases.

Type of trauma	NO	Age in years	
		Mean ± SD	**Range (min-max)**
RTA	13	14.85±10.33	(3-37) y
- MBA	10	16.80±10.87	(3-37) y
- MVA	3	8.33±5.03	(3-13) y
Fall	6	5.67±1.97	(4-9) y
Assault	4	11.35±5.68	(6-25) y

Road traffic accidents **(RTA).** Motor bicycle accidents (**MBA)** Motor vehicle accidents (**MVA)**

Generally, MBA patients mostly affect adults and teenagers whose mean age is about 16.80 years with a very wide age range of 3 to 37 years. Those who are suffering from motor vehicle

accidents (MVA) mainly affect younger children whose mean age is about 8.33 years, with an age range of 3 to 13 years. At a limited range of 4 to 9 years, and a mean age of 5.67 years, falls are primarily a problem for younger children. The patients who experienced assault had a wide age range, from early childhood to young adulthood, with an average age of 11.35 years and a range of 6 to 25 years as shown in **Table (3).**

Table (4): Radiology finding among delayed recurrent post-traumatic bacterial meningitis cases.

	Radiology Finding	No	%
Available data (20)	Fractures ACF	19	95
	Fractures Mcf	1	5
	Associated cranial injuries	3	15
	Extracranial injuries	8	40
Unavailable data		3	13

ACF: anterior cranial fossa, **MCF:** middle cranial fossa

Table (4) listed the Radiologic studies [computed tomography (CT), magnetic resonance (MRI), or CT-cisternography] were not available with 3 patients. Of the available studies, 19 patients had evidence of anterior cranial fossa fractures (frontal bone, orbital plate of frontal bone, or cribriform plate of the ethmoid), and one patient with middle cranial fossa fracture (petrous bone). Three patients had associated cranial findings (subarachnoid hemorrhage, or pneumocephalus). Only 8 patients had an added extracranial injury (nasal bone, mandible, spine, or a limb fracture).

Table (5): CSF leakage criteria in delayed recurrent post-traumatic bacterial meningitis cases.

Variables		No (%)
CSF leakage:	Yes	20 (87.0)
	No	3 (13.0)
Type of CSF leakage:	Rhinorrhea	19 (82.6)
	Otorrhea	1 (4.3)
Onset of CSF leakage:	Early	12 (52.2)
	Late (6-24 Months)	8 (34.8)
Course of CSF leakage	Continuous	14 (60.9)
	Intermittent	6 (26.1)

CSF: cerebrospinal fluid

Concerning CSF leaks, as shown in **Table (5),** most patients reported the presence of CSF leak (87%), while in 3 patients (13%) no CSF leak was reported. CSF rhinorrhea (leakage of CSF through the nose) was present in 19 patients (82.6%), while CSF otorrhea (leakage of CSF through the ear) was present in one patient only (4.3%). CSF leak was present early since the time of trauma in 12 patients (52.2%), whereas in 8 patients (34.8%) its onset was delayed with a mean time from trauma to the appearance of CSF leak of 11.9 months (range from 6 to 24 months). CSF leak was continuous in 14 patients (60.9%) while its course was intermittent in 6 patients (26.1%).

Table (6): Summary of clinical manifestations and cytochemical analysis during the attacks in delayed recurrent post-traumatic bacterial meningitis c**ases.**

Variable	Category	Mean ± SD
Symptoms (% of attacks)	Fever	91.07 ± 10.72
	Headache	75.15 ± 22.68
	Neck rigidity	79.93 ± 15.73
	Altered consciousness	77.20 ± 15.13
	Convulsions	40.03 ± 23.44
Cytochemical analysis	WBCs/m3	7898.00±4097.58
	Glucose (mg %)	30.20±9.50
	Protein (mg %)	253.84±53.79

We reported a total number of 137 episodes of bacterial meningitis attack among the 23 patients (range: 2-13). The main clinical manifestations during the attacks in our cases i.e., fever, headache, neck rigidity, altered mental status and convulsions were present in 91.07, 75.15, 79.93, 77.2, and 40.03% of attacks respectively **Table (6).**

In addition, the results of the cytochemical analysis of CSF samples are also shown in **Table (6).** The mean total leukocytic count was 7898/m3 (range from 2925-16.750/m3), the mean glucose concentration was 30.20 mg% (range from 13-48 mg%), and the Protein concentration ranged from 196.7 to 425.0mg% with a mean value of 253.84 mg%.

Most patients (60.9%) experienced their first meningitis attack within 2-12 months after the injury. Only a few patients had a delayed onset, with 21.7% of cases developing their first attack within 13-24 months and 17.4% after 24 months. The average time from injury to the first attack is about 12.88 months, ranging from 2 to 36 months.

About 52.2% of the patients suffered 2-4 attacks, while in 26.1%, the frequency of attacks ranged from 5-10. In as high as 21.7%, the attacks were more than 10 in number, thus pointing toward recurrent and severe cases. The average number of attacks per patient was about 5.96, with a minimum and maximum of 2 and 13 attacks, respectively.

Table (7): Criteria of meningitis attacks in delayed recurrent post-traumatic bacterial meningitis cases.

Variable	Category		Cases (n=23)	Mean ± SD	Range
Duration from injury to first attack (months)	**2-12**		14 (60.9%)	12.88 ± 5.79	2-36 m
	13-24		5 (21.7%)		
	>24		4 (17.4%)		
Number of attacks	**2-4**		12 (52.2%)	5.96 ± 3.83	2-13
	5-10		6 (26.1%)		
	>10		5 (21.7%)		
Surgical interventions	**Yes**		10 (43.5%)	-	-
	No		13 (56.5%)	-	-
Vaccination	**Yes**		14 (60.9%)	-	-
	No		9 (39.1%)	-	-
Outcome	**Death**		4 (17.4%)	-	-
	Free after the last attack		14 (60.9%)	-	-
	Complication	-Convulsion	2 (8.7%)	-	-
		-Intellectual deficit	3 (13.0%)	-	-

Concerning the interventions done to prevent repetitions of meningitis as shown in **Table (7),** 43.5% of the patients underwent surgery, while 56.5% did not (the operation was successful in 6 patients with stoppage of CSF leak and cession of meningitis attacks, while in 4 patients the operation failed) . In terms of vaccination, 39.1% did not receive one, whereas 60.9% did (the response to vaccination varied; out of 14 patients who received the vaccine, 10 patients showed an excellent response with almost cession of meningitis attacks, while in 4 patients showed no response). As for the outcome, a high rate of 17.4% of patients died. Since the last event, 60.9% were symptom-free. Regarding complications, 21.7% experienced them, 8.7% of whom suffered convulsions, and 13.0% had an intellectual deficit.

Table (8): Relationship between the cause of trauma and the outcome of delayed recurrent post-traumatic bacterial meningitis cases.

Outcome	**Cause of trauma**				**Fisher exact test**	**p-value**
	Assault (n=4) No (%)	Fall (n=6) No (%)	MBA (n=10) No (%)	MVA (n=3) No (%)		
Free after the last attack	4 (100.0)	3 (50.0)	5 (50.0)	2 (66.7)	4.72	0.581
Complicated	0	2 (33.4)	3 (30.0)	0		
Death	0	1 (16.7)	2 (20.0)	1 (33.3)		

There was no significant relationship between the cause of trauma and the outcome of delayed recurrent post-traumatic bacterial meningitis cases. All cases caused by assault were free after the last attack. Death occurred in 20% of MBA, in 33.3% of MVA, and in 16.7% of cases caused by falls **Table (8).**

Table (9): Relationship between number of attacks and the outcome of delayed recurrent post-traumatic bacterial meningitis cases.

Outcome	Number of attacks			Fisher exact test	p-value
	2-4 (n=12) No (%)	5-10 (n=6) No (%)	>10 (n=5) No (%)		
Free after the last attack	11 (91.7)	2 (33.3)	1 (20.0)	11.61	0.021
Complicated	0 (0.0	3 (50.0)	2 (40.0)		
Death	1 (8.3)	1 (16.7)	2 (40.0)		

Table (9) showed that there was a significant association between bad outcomes (complication and death) with the increasing number of attacks in the studied cases (p=0.021). A significant majority, 91.7%, of patients who had 2–4 attacks were free of symptoms after the last attack. Again, a substantial proportion, 40.0%, of those with more than ten attacks died, highlighting the severe risk associated with a higher number of recurrent meningitis attacks.

Table (10): Relationship between duration from injury to the first attack and the outcome of delayed recurrent post-traumatic bacterial meningitis cases.

Outcome	Duration from injury to the first attack (months)			Fisher exact test	p-value
	2-12 m (n=14) No (%)	13-24 m (n=5) No (%)	>24 m (n=4) No (%)		
Free after the last attack	5 (35.7)	5 (100.0)	4 (100.0)	9.51	0.049
Complicated	5 (35.7)	0 (0.0)	0 (0.0)		
Death	4 (28.6)	0 (0.0)	0 (0.0)		

There was significant relationship between the duration from injury to the first attack and the outcome of delayed recurrent post-traumatic bacterial meningitis cases (p=0.049) **Table (10).**

DISCUSSION

Our study was done on twenty-three cases of delayed recurrent post-traumatic bacterial meningitis. To our knowledge, this study included the largest number of cases with this diagnosis. Most previous published studies on this topic were either a case report (**Crawford et al., 1994, Kendirli et al, 2006, Sharifi et al, 2019)** or included a smaller number of patients **(Maitra and Ghosh, 1989, Friedman et al., 2001, Deveci et al, 2015).** The small number of our cases could be due to that we had selected only delayed onset and recurrent post-traumatic meningitis, this condition complicates cases of severe head trauma with SBF and dural tear with CSF leak that does not heal spontaneously nor undergone operative repair. Also, no previous studies from Egypt explored this complication of HI.

The mean age at the time of trauma in our patients was 12.3 years (range:3-37 years). This was lower than that in other studies. **Malekpour-Afshar et al., (2009), and Deveci et al, (2015**), reported that the mean age for head trauma was 28

years. In the present study, the youngest group (0-6 years) dominated accounting for nearly forty percent of the sample while ages (7-18 years) and (19-40 years) were exactly equated at 30.4% each. This may refer to inexperience and the tendency to take risks contributes to the increased incidence of trauma in the younger age group. These results are in contrast with the study of **Ahmed, (2023),** who stated that the peak incidence of head trauma was in the fourth decade of life (30-<40 years). However, **Matney et al., (2022),** reported that the incidence of TBI is highest among the youngest and oldest age groups.

Males were more commonly affected than females in our study with a male-to-female ratio of 3.6:1. This agreed with most other studies **(Yadav et al., 2008, Malekpour-Afshar et al., 2009, Sivanandapanicker et al., 2018, Mokolane et al., 2019, Ha et al., 2023, Ahmed, 2023).** Males are more commonly involved in outdoor activities, rendering them more prone to trauma than females. Also, they are more likely to engage in fights, high-risk sports and to be employed in risky occupations **(Refaat et al., 2019).** Most cases in this study came from a rural community due to the nature of our locality- the rural-to-urban ratio was 2.8:1.

RTA were the most common cause of trauma (56.5%) followed by falls (26.1%) while assault occurred in four patient (17.4%). Many studies reported that RTA were the commonest cause of HI **(Kluba-Wojewoda et al., 2000, Hasheminia et al., 2015, Sivanandapanicker et al., 2018, Ha et al., 2023).**

Others reported that falls were more common **(Deveci et al, 2015, Leibu et al., 2017, Guan et al., 2023).** In the present study, falls were more common at younger ages (mean age: 5.7 years) than RTA which were common among early adulthood group (mean age: 14.9 years).

MBA was the main cause of trauma (76.9% of the RTA cases). In the rural community from which patients came, motor-bicycle riding emerged as the main means of transmission in recent years. Usually, young children were left to ride out of the inspection of the traffic authorities and without wearing helmets and their tendency to take risks put them at a major risk for severe trauma. This explains why most patients in MBA were young adults (mean age: 16.8 years).

It was difficult to assess the severity of trauma in patients accurately because trauma had occurred a long time before their presentation to fever hospital suffering from meningitis. Also, their trauma was managed at another hospital and their registries are not available for us. However, a good idea about the trauma severity can be drawn from the periods of hospital admission and the available radiologic studies with the patients.

Most patients had experienced severe trauma as reflected due to their need for hospital admission (78.3%); where (60.9%) needed ICU and 17.4 needed ward admission, with a mean length of hospital stay of 10.5 days. **Ahmed, (2023,** reported that in non-fatal cases of head trauma, 61.5% of cases were hospitalized for 2-7 days, 18.3% for more than 7 days, and 20.2% for less than 2 days. The length of hospital stay was 21±15.5 days in the study of **Plaisier et al., 2005** and 25.7±15.8 days in the study of **Malekpour-Afshar et al., 2009.**

In the current study, five patients were treated on an outpatient basis and the underlying skull base fracture (SBF) with its important complications was missed at the time of trauma. Patients with SBF may lack the classic clinical features e.g., Racoon eyes, Battle sign, and CSF leak, and a skull fracture may go unnoticed due to suboptimal CT scanning leading to missed diagnosis **(Sivanandapanicker et al., 2018).** Agreement with **Servais et al, (2005),** reported that two children had bacterial meningitis following a trivial skating injury, both of them had, anterior SBF as was diagnosed retrospectively.

Available radiologic studies showed that most of the patients suffered from anterior cranial fossa fractures (95%), while fractures affecting the middle cranial fossa were seen in one patient only. Various studies have reported that anterior cranial fossa fractures were the most common site in SBF **(Kluba-Wojewoda et al., 2000, Wani et al., 2013, Sivanandapanicker et al., 2018).** Other studies have reported that middle cranial fossa fracture was more common **(Abiodun et al., 2012, Yellinek et al., 2016).** The tendency of victims of

RTA to fall forward and those falling from a height to fall on their faces explains why most patients had anterior cranial fossa fractures.

Eight patients had associated injuries in other sites in their bodies (40%). This is lower than that reported by **Ha et al., (2023),** who found that multiple trauma (86.4%) was higher than that of isolated TBI". Also, "**Ahmed, (2023)** reported that only 20% of non-fatal cases had head trauma only.

As we were studying cases of recurrent post-traumatic meningitis, patients should have SBF and CSF leak which serves as a portal for infection. However, no CSF leak was reported in three patients (13%). Occult CSF leak can be the underlying cause. Also, dural healing may be absent and the fracture may be covered with only a small amount of fibrous tissue or brain parenchyma, which cannot work as an infection barrier **(Friedman et al., 2001)**. Post-traumatic meningitis (PTM) has also been reported with fractures across infected paranasal sinuses, middle ear structures, and mastoid air cells even without a dural tear **(Hosoglu et al., 1997).** "**Baktas et al., (2007),** presented a case of recurrent meningitis in a 34-years female patient with an occult skull base defect and without rhinorrhea (she did not have any rhinorrhea complaint, and nasal endoscopy and CT with metrizamide failed to demonstrate any subclinical rhinorrhea), however, a bony defect in the cribriform plate and a submucosal nasoseptal collection of CSF behind an intact septal nasal mucosa were detected in CT and MRI imaging studies. Also, **Chen and Jiang (2011),** presented a case of recurrent bacterial meningitis in a 9-year-old boy caused by an occult ethmoid bone fracture in the absence of CSF rhinorrhea".

In the present study, most of the patients had CSF leak in the form of CSF rhinorrhea (19/20), while CSF otorrhea occurred in one patient only. This can be explained by the dominance of anterior cranial fossa affection **(Manolo et al., 2012)**. In addition to the thin nature of the cribriform plate which separates the nasal cavity from cranial cavities making it susceptible to leaks **(Hiremath et al., 2019)**. **Sivanandapanicker et al., (2018),** found that in 43 patients with CSF leak, 34 (79.1%) had CSF rhinorrhea. Also, **Plaisier et al., (2005),** reported CSF rhinorrhea in 61.5% of patients", while "**Varshneya et al., (2019),** found that CSF otorrhea was the most common form of CSF leak (58.4%) in the pediatric population.

CSF leak usually occurs in the first 48 hours following trauma **(Guyer and Turner, 2015).** Most CSF leaks heal spontaneously within 3-5 days after trauma and a small percentage of patients continue with the leak necessitating surgical closure of the defect. However, reports of CSF leaks that occurred as a late complication of SBF have also been reported. **Kastner et al., (2001),** reported a delayed onset of rhinorrhea 2-25 years after trauma in 7 patients. **Sharifi et al., (2019),** reported a case of CSF rhinorrhea starting 5 years after trauma. **Guyer and Turner (2015),** presented a case of sphenoid sinus CSF leak 12 years after a closed head injury. **Leung et al., (2011),** reported a 37-year-old patient with delayed CSF rhinorrhea which started 9 years after blunt brain trauma. **Chrysouli et. al., (2020),** presented a case of CSF rhinorrhea in a 33-year-old man with a distant history of brain injury after a traffic accident 12 years ago . A prolonged delay of up to 44 years has been reported **(Schneider and Thompson, 1957).** In the current study, 12 patients reported a CSF leak that started at the time of trauma and persisted thereafter, while in ٨ patients, a CSF leak started late after trauma (range from ٦ to 24 months) from trauma to the onset of CSF leak.

Delayed onset or recurrence of CSF leak may occur due to absorption of a blood clot or separation of dura and arachnoid caused by subsiding cerebral edema **(McCormack et al., 1990).** Also, localized inflammation often helps to seal small dural tears, but atrophy of the resulting scar and changes to surrounding bone can potentially occur over many years thus weakening the site and increasing the risk for delayed leaks **(Leung et al., 2011).** Some patients with previous SBFs may also be at increased risk for developing CSF rhinorrhea due to predisposing factors such as obesity or intracranial hypertension. This is highlighted by examples of delayed CSF rhinorrhea that have occurred after acute events that elevate intracranial pressure including sneezing, coughing, and straining **(Gendeh et al., 2002).** Also, a very late onset of CSF leak may occur as brain shrinkage caused by aging may

cause the CSF leaking site to reopen **(Oh et al., 2017).**

CSF leak was continuous in 14 patients of our study while its course was intermittent in ٦ patients. Intermittent CSF leak was reported in other studies **(Kastner et al., 2001; Sharifi et al., 2019; Chrysouli et al., 2020).** Intermittent flow can sometimes be reproduced or increased with provocative maneuvers such as Valsalva. Some of our patients wrongly perceived intermittent CSF rhinorrhea as a cold or nasal allergy.

CSF leak is an independent risk factor for bacterial meningitis **(Sonig et al., 2012),** where bacteria gain access to the subarachnoid space through the fracture site. Patients with persistent CSF leaks usually go through recurrent attacks of meningitis with an annual risk of developing meningitis of approximately 10% **(Sharifi et al., 2019).** Closure of leaks if successful reduces the risk of meningitis **(Daudia et al., 2007).**

The chronic and recurrent nature of this condition has a hard negative health and social sequelae on the patient`s life. As a mirror of this, we report 137 episodes of meningitis with a mean of 6 attacks per patient. **Hosoglu et al., (1997),** reported 45 episodes of bacterial meningitis in ten adult patients. Also, the mean number of meningitis episodes was 2.6 ± 0.8 (range: 2-5 episodes) in the study of **Deveci et al., 2015.** In published articles, most patients with persistent CSF leak usually undergo a corrective surgery with secession of meningitis attacks, so, it was rare to report a recurrence rate like that reported in our series. Neither the number of episodes nor the interval between attacks in our series was uniform. Some patients experienced a rapid succession of multiple attacks (e.g., 13 attacks with only a few months in between), while others had only a few attacks with long periods in between. The size of the bone and dural defect seem to be an important prognostic factor of episodes of meningitis **(Yaldiz et al., 2015).**

As we selected only cases of delayed post-traumatic meningitis, excluding early onset cases, the mean duration elapsed between the time of trauma and the first attack of meningitis was ١٢.٩ months. **Plaisier et al., (2005),** reported a duration of 97.7 ± 320 days between trauma and meningitis. **Santos et al., (1986),** reported a median time of 1.1 years between head trauma and meningitis. **Giunta and Piazza, (1991)** described a case of recurrent bacterial meningitis 5 years after a closed head injury. Eight patients in the study of **Friedman et al., 2001,** presented with recurrent meningitis at an average of 6.5 years post-trauma. The range of interval between original trauma and the beginning of symptoms in the study of **Matschke and Tsokos, 2002,** was 2 days up to 8 years.

The clinical manifestations of meningitis in our cases; fever, headache, neck rigidity, altered mental status and convulsions were reported in 91.07, 75.15, 79.93, 77.2, and 40.03% respectively. Comparable rates were reported by **Gad, 2012.** In the study of **Plaisier et al., (2005),** fever was seen in all patients and 85% of them had a deterioration in consciousness . In a study on 10 patients with recurrent post-traumatic meningitis, "**Hosoglu et al., (1997),** found that the triad of fever, neck rigidity, and a decrease in mental status occurred in all patients". Due to the recurrent nature of the condition, our patients learned the clinical data of the disease, and they usually present with the earliest manifestation of the disease. However, some patients showed a rapidly progressive course with coma and convulsions occurring a few hours after the onset of the attack.

In bacterial meningitis, there is typically a polymorphonuclear leukocytic pleocytosis with more than 1000 cells/ul, elevated total protein content >120 mg/dl, and a low CSF glucose concentration (<30 mg/dl, and a ratio of CSF to blood glucose of <0.3) in most patients **(Pfister and Roos, 2003).** Following this, the mean CSF leukocytic count, protein content, and glucose levels were 7898 cells/ul, 253.8 mg/dl, and 30.2 mg/dl respectively in our study. **Plaisier et al., (2005),** reported levels of 4666, 383, and 63.7 for CSF leukocytic count, protein, and glucose levels respectively. Also, **Gad, (2012),** reported that the mean CSF leukocytic count, protein, and glucose levels in patients with bacterial meningitis were 3484.6 cells/ul, 135.9, and 48.3 respectively.

In patients with SBF and CSF leak, reconstructive surgery is recommended to prevent episodes of recurrent meningitis **(Kastner et al.,**

2001). In our study, 10 patients were referred for a corrective operation. The outcome of the surgery was variable; the operation was successful in 6 patients with stoppage of CSF leak and cession of meningitis attacks, while in 4 patients the operation failed. Also, pneumococcal vaccine is recommended to lower the risk of post-traumatic meningitis **(Hedberg et al., 2017).** However, in our patients the response to vaccination also varied; out of 14 patients who received the vaccine, 10 patients showed an excellent response with almost cession of meningitis attacks, while in 4 patients no response to the vaccine was reported.

Regarding the outcome of our cases, 4 patients died (17.4%), 2 cases died during episode of meningitis, 1 case died from cerebral hemorrhage due to rupture of cerebral aneurysm and the last case died due to post operative meningitis after surgical trial of dural repair.

As with other aspects of this disease, the outcome is widely variable. Mortality rates range from 0-65% **(Pliasier et al., 2005)**. No patients with recurrent bacterial meningitis died during the episodes in the study of **Deveci et al., 2015.** The fatality rate was 24.4% in the study of **Malekpour-Afshar et al., 2009,** 14.8% in the study of **Pliasier et al., 2005,** and 20.6% as reported by **Gad, 2012.**

Fourteen patients were normal after the last attack; Five patients in the current study were left with some sort of neurologic deficits e.g., intellectual problems or seizures. **Grimwood et al., (1995)** reported that children with meningitis are at risk for abnormal functioning, including fine motor deficits, lower intelligence quotient (IQ) scores, and behavioral challenges . This variable outcome, including death or long-term complications, may be relevant in forensic investigations of trauma and subsequent neurological disorders.

There was a significant association between bad outcomes (complication and death) with the increasing number of attacks in the studied cases (p=0.021). A significant majority, 91.7%, of patients who had 2–4 attacks were free of symptoms after the last attack. 40.0%, of those with more than ten attacks died. This highlights that an increased number of attacks is considered a risk factor for bad outcomes in these cases. This is in agreement with the study by **Englander et al., 2009.**

There was a significant relationship between the duration from injury to the first attack and the outcome of delayed recurrent post-traumatic bacterial meningitis cases as the time increased from injury to the first attack, the bad outcome will be expected. Attacks that occur early after trauma have more chances to be managed properly and get better outcomes. **La Russa et al., (2020)** stated that early recognition and early initiation of appropriate management and supportive care can improve the outcome significantly.

CONCLUSION

Delayed recurrent post-traumatic bacterial meningitis highlights several key aspects of this serious complication. Key findings indicate that RTA, particularly motor bicycle accidents, are a predominant cause of HI. The presence of SBF and cerebrospinal fluid (CSF) leaks, especially CSF rhinorrhea, are significant risk factors, these leaks can manifest immediately after the injury or even years later. The increasing repeated attacks of meningitis also strongly correlates with poorer outcomes, highlighting the severe impact of frequent episodes. the condition had a high mortality rate of 17.4%, and 21.7% of patients suffered severe complications such as convulsions and intellectual deficits. Meningitis developing as a late complication of head trauma can have significant forensic importance as victims can complain back for compensation and if death occurs it is considered unnatural death.

RECOMMENDATIONS

- Clinicians should be alert for SBF in HI cases, with high-resolution CT scans being the gold standard. Long-term follow-up can play a crucial role in identifying complications.
- Reconstructive surgery and pneumococcal vaccines are recommended for those suffering from post-traumatic recurrent meningitis.
- When a deceased person has a delayed post-traumatic meningitis history, forensic pathologists should take into account the likelihood that prior head trauma was a contributing factor in the death.

- It is, therefore, very important to establish a causal relationship between post-traumatic meningitis and prior trauma. Forensic experts should work in conjunction with neurosurgeons, infectious disease specialists, and radiologists in the assessment of the SBF in its potential role in PTM development.
- Proper documentation and reporting are important for legal processes in that they provide a timeline and set a clear cause-and-effect between the inflicted trauma and recurrent meningitis.
- further research studies should be done involving larger patient populations from various hospitals for more comprehensive and generalizable information.

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List of abbreviation:

Road traffic accident (RTA)

Head injury (HI)

Cerebral spinal fluid (CSF)

Skull base fracture (SBF)

Traumatic brain injury (TBI)

Computed tomography (CT)

intelligence quotient (IQ)

الملخص العربي

الالتهاب السحائي البكتيري المتكرر المتاخر الناتج من إصابات الرأس: دراسه مع تسليط الضوء على بعض جوانب الطب الشرعي

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مقدمة: يعد التهاب السحايا الجرثومي المتكرر هو أحد المضاعفات المتأخرة لإصابات الرأس، والذي يرتبط بالفعل بارتفاع معدلات الوفيات. طبيعتها المتكررة يمكن أن يكون لها تأثير كبير على حياة المريض. و دراسة هذه الحالات يخدم كلا الأمرين؛ المصالح القانونية والطبية.

الهدف من البحث: هدفت الدراسة الحالية إلى دراسة الخصائص والنتائج الديموغرافية والسريرية والمخبرية للمرضى المصابين بالتهاب السحايا البكتيري المتأخر والمتكرر الذي ينتج عن اصابات الراس، وإلقاء الضوء على بعض الجوانب الجنائية المتعلقة بهذه الحالات.

المرضى وطرق البحث: أجريت هذه الدراسة بأثر رجعي على حالات التهاب السحايا الجرثومي المتأخر والمتكرر الذي ينتج عن اصابات الراس . و قد تم إدخال هذه الحلات إلى مستشفى حميات شبين الكوم بمحافظة المنوفية في الفترة من يناير ٢٠٠٨ إلى ديسمبر ٢٠٢٢.

النتائج: أجريت هذه الدراسة على ٢٣ مريضاً يعانون من التهاب السحايا البكتيري المتأخر المتكرر الذي ينتج عن اصابات الراس. وكانت الأسباب الأكثر شيوعا للصدمات هي حوادث المرور، يليها السقوط من علو ثم الاعتداءات. كان معظم المرضى يعانون من إصابات شديدة في الرأس وتم إدخالهم إلى المستشفى لمدة متوسطها ١٠,٥ يومًا. كان تسعة عشر مريضاً يعانون من تسرب السائل النخاعي (CSF)، مع تأخر ظهوره في تسع حالات، بمتوسط وقت ١١,٩ شهرًا بعد الإصابة بالمرض. تعرض معظم المرضى لأول نوبة التهاب السحايا في غضون ٢-١٢ شهرًا بعد الإصابة وكان معدل الوفيات بسبب هذه الحالة ١٧,٤%.

الخلاصه: التهاب السحايا البكتيري المتأخرو المتكرر له تأثير كبير على حياة المريض وعائلته. و قد يحدث ذلك كمضاعفات متأخرة للاصابه في الراس. و دراسه مثل هذه الحلات له أهمية كبيرة في الطب الشرعي حيث أن التشخيص الدقيق وإثبات السببية يمكن أن يؤثر على المسؤولية الجنائية ومطالبات التأمين والتعويض. و قد اقضحت هذه الدراسه اهميه المتابعة طويلة المدى لمثل هذه الحالات لاحتمال حدوث التسربات المتأخرة والتهاب السحايا بعد إصابات الرأس.