Bilateral abducens palsy in closed head injury: A comprehensive review of literature based on a case report

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ABSTRACT

Isolated bilateral sixth nerve palsies are rare, particularly in the setting of trauma. Most post-head injury cases with bilateral abducens palsy involve either basal skull fractures, particularly clival fractures. We present a case of bilateral abducens palsy after closed head injury in a young male who presented to the emergency department and a comprehensive literature review based on our clinical case. A Medline search for bilateral abducens palsy in closed head injury showed 89 results. Articles were excluded if crush head injury, non-traumatic bilateral abducens nerve palsy, associated vascular malformations were reported. After thorough search and filtering of those articles, fifty-one publications were found which reported and discussed about traumatic bilateral abducens palsy with closed head injury. In these 51 articles, a total of 139 cases were recorded. Several theories have been postulated to explain mechanisms of abducens nerve injury in trauma both in immediate and delayed settings. In our case, patient presented with immediate onset of bilateral abducens palsy. On imaging, clival fracture was seen in CT brain, which can be attributed for the nerve injury. Cases with retroclival extradural haematoma had higher chances of multiple cranial nerve injuries. Cases with multiple basal skull fracture involving petrous temporal bone fracture had higher chances of facial nerve injury. Along with bilateral involvement, the poorer outcome for recovery can be related with the severity of the adduction deficit. Our case showed no improvement in bilateral abduction during follow-up at 6 months. Clinical presentation of traumatic bilateral abducens nerve palsy is rare following closed head trauma and is usually associated with other injuries which are incompatible with life. It can be associated with other nerve injuries depending on basal skull fractures.

Key words: Bilateral abducens palsy; Closed head injury; Clival fracture

INTRODUCTION

Unilateral abducens nerve palsy has been reported to occur in 1% to 2.7% of all head trauma.¹ The extended intracranial course of 6th nerve along with its anatomical relationship to the petrous apex, makes it more susceptible to traumatic injury.¹ Isolated bilateral sixth nerve palsies are rare, particularly in the setting of trauma. Most post-head injury cases with bilateral abducens palsy involve either basal skull fractures, particularly clival fractures or other intracranial pathologies with or without cervical spine injury.¹

We present a case of bilateral abducens palsy after head injury in a young male who presented to the emergency department of our institute and a comprehensive literature review based on our clinical case. To the best of our knowledge, no publication in the literature discusses the total number of cases along with the imaging findings and clinical course of those cases.

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MATERIALS AND METHODS

A Medline search for key words “bilateral abducens palsy” and “closed head injury” showed 89 results. Publications were limited to those published in English. Articles were excluded if crush head injury, non-traumatic bilateral abducens nerve palsy, associated vascular malformations were reported. After thorough search and filtering of those articles, fifty-one publications were found which reported and discussed about traumatic bilateral abducens palsy with closed head injury. In these 51 articles, a total of 139 cases were recorded.

RESULTS

The results are summarized in Table 1. The results include author, year of publication, associated cranial nerve injury, radiological findings, presentation and recovery wherever mentioned by the author in tabular form.

CLINICAL CASE

A 22-year-old male, pillion rider on a two-wheeler was involved in motor vehicle accident when they accidentally skid and fell. He sustained injury to the head. Patient had 2 episodes of vomiting and loss of consciousness post injury for 2 minutes with no history of seizures and nasal/ear bleed post injury. On arrival at the emergency department, he was haemodynamically stable. He was conscious, oriented and moving all four limbs. A secondary survey did not reveal any additional signs of injury or burns.

After the patient was stabilized, a detailed neurological examination revealed bilateral abducens nerve palsies along

| Sl. No. | Author            | Year | No. of cases | Associated cranial nerve | Radiology of the cranium | Presentation | Recovery |
|---------|-------------------|------|--------------|--------------------------|--------------------------|--------------|----------|
| 1       | Schneider et al   | 1971 | 2            | Nil                      | Normal                   | Immediate    | No       |
| 2       | Roberts et al     | 1972 | 1            | Nil                      | Normal                   | Delayed      | No       |
| 3       | Keane et al       | 1976 | 11           | Not known                | Not known                | Not known    | Not known |
| 4       | Takagi et al      | 1976 | 3            | Nil                      | Normal                   | Immediate    | 2 cases recovered |
| 5       | Goubran et al     | 1978 | 1            | Nil                      | Middle cranial fossa fracture through the sella turcica | Immediate    | Yes |
| 6       | Limnaios et al    | 1980 | 1            | Nil                      | Normal                   | Immediate    | Partial |
| 7       | Arias et al       | 1985 | 1            | Nil                      | Normal                   | Immediate    | No       |
| 8       | Dire et al        | 1987 | 1            | Nil                      | Not done                 | Immediate    | Not known |
| 9       | Ghorayeb et al    | 1987 | 3            | Not known                | B/L temporal bone fracture | Not known    | Not known |
| 10      | Marconi et al     | 1994 | 1            | Nil                      | Basal skull fracture     | Immediate    | Yes |
| 11      | Lazow et al       | 1995 | 1            | Nil                      | Normal                   | Immediate    | No       |
| 12      | Lepore et al      | 1995 | 4            | One patient U/L 3rd, 4th palsy | Normal | Not known | Not known |
| 13      | Celikoz et al     | 1996 | 1            | Nil                      | Fronto-nasal-ethmoidal fracture | Immediate    | No |
| 14      | Mutyala et al     | 1996 | 13           | Not known                | Not known                | Not known    | 12% patients |
| 15      | Lahbabi et al     | 1997 | 1            | Nil                      | Normal                   | Immediate    | No |
| 16      | Holmes et al      | 1998 | 8            | Not known                | Not known                | Not known    | 38% patients |
| 17      | Mizushima et al   | 1998 | 1            | Nil                      | Retro-clival extradural hematoma | Immediate    | Yes |
| 18      | Holmes et al      | 2002 | 22           | Not known                | Not known                | Not known    | Not known |
| 19      | Lee et al         | 2002 | 1            | Left 7th palsy           | Fracture line extending from one temporal bone crossing to the contralateral temporal bone including clivus | Immediate    | Yes |
| 20      | Gaul et al        | 2002 | 1            | Nil                      | Normal                   | Immediate    | No |
| 21      | Advani et al      | 2003 | 1            | Nil                      | Normal                   | Immediate    | No |
| 22      | Dobbs et al       | 2003 | 1            | Nil                      | Normal                   | Immediate    | No |
| 23      | Binder et al      | 2004 | 1            | B/L 4th palsy            | Midline parietal depressed fracture obliterating flow in the subjacent sursagittal sinus | Delayed      | Yes |
| 24      | Dwarakanath et al | 2006 | 1            | Nil                      | Pneumocephalus in the preopticine cistern. Right temporal and sphenoid sinus fracture extending into the petrous apex | Immediate    | Yes |
| 25      | Calisaneler et al | 2006 | 1            | Left 7th, 12th palsy    | Retro-clival extradural haemorrhage | Immediate    | Yes |

(Contd...)
with Grade 4 right facial nerve palsy according to House-Brackman grading. Rest of the neurological examination was normal. His ophthalmological examination revealed his uncorrected vision on bedside in the both eyes was finger counting at >3 meters, colour vision was normal in both eyes. Both anterior and posterior segment were normal with no evidence of disc oedema. Abduction testing revealed inability to abduct past the midline bilaterally compatible with -4 abduction deficits. He complained of diplopia on both left and right horizontal gaze.

The CT (Computed tomography) Brain showed an extensive pneumocephalus with pneumoventricles with a linear undisplaced fracture noted in squamous part of left temporal bone extending into the petrous part of ipsilateral temporal bone along with linear undisplaced fracture in left occipital bone extending into right occipital bone. There was also extensive pneumocephalus extending into both parietal bones.

### Table 1: (Continued)

| Sl. No. | Author                      | Year | No. of cases | Associated cranial nerve | Radiology of the cranium                                                                 | Presentation | Recovery |
|---------|-----------------------------|------|--------------|-------------------------|----------------------------------------------------------------------------------------|--------------|----------|
| 26      | Durkin et al                | 2006 | 29           | Not known               | Not known                                                                               | Not known    | Not known|
| 27      | Ruiz-de-Rio et al           | 2006 | 1            | Left 3rd palsy          | Diffuse axonal injury                                                                    | Immediate    | No       |
| 28      | Ratilal et al               | 2006 | 1            | Bl/L 5th, left 12th palsy| Bilateral petrous bones and clivus fracture extending to the posterior clinoid process | Immediate    | No       |
| 29      | Katsumo et al               | 2007 | 1            | Nil                     | Retro-clival extradural haemorrhage                                                      | Immediate    | No       |
| 30      | Schneck et al               | 2008 | 1            | Nil                     | Pre- pontine extra-axial hematoma                                                        | Immediate    | Yes      |
| 31      | Kwon et al                  | 2009 | 1            | Right 9th, 12th palsy   | Retro-clival extradural haemorrhage                                                      | Immediate    | Yes      |
| 32      | Taskin et al                | 2010 | 1            | Nil                     | Normal                                                                                  | Immediate    | Yes      |
| 33      | Nayil et al                 | 2010 | 1            | Nil                     | Extrudal haemattoma in vertex with parietal bone fracture                                | Delated      | Yes      |
| 34      | Pancko et al                | 2010 | 1            | Left 7th palsy          | Skull base fracture extending transversely across the petrous bone and right occipital bone, transverse fracture across the sphenoid sinus with extensive pneumocephalus | Immediate    | No       |
| 35      | Tubbs et al                 | 2010 | 1            | Nil                     | Retro-clival extradural haemorrhage                                                      | Immediate    | Yes      |
| 36      | Palmowski-Wolfe et al       | 2010 | 1            | Nil                     | Small bleedings in the brainstem and in the left hemisphere                              | Immediate    | No       |
| 37      | Czyz et al                  | 2011 | 1            | Nil                     | Normal                                                                                  | Immediate    | No       |
| 38      | Yilmaz et al                | 2011 | 1            | Right 7th, 9th, 12th palsy| Retro-clival extradural haemorrhage                                                      | Immediate    | Yes      |
| 39      | Lopes et al                 | 2011 | 1            | Nil                     | Avulsion of 6th nerve                                                                    | Immediate    | No       |
| 40      | Salunke et al               | 2012 | 2            | Nil                     | Case 1. Right convexity chronic                                                          | Delayed      | Yes      |
| 41      | Yanamadala et al            | 2012 | 1            | Nil                     | Subdural hematoma                                                                        | Delayed      | No       |
| 42      | Nicot et al                 | 2012 | 1            | Nil                     | Case 2. Normal                                                                          | Immediate    | Yes      |
| 43      | Selcuk et al                | 2013 | 1            | U/L 12th palsy          | Occipital, sellar and clival fractures with pneumatocephalus in interpeduncular cistern, intraventricular hemorrhage | Immediate    | Yes      |
| 44      | Fam et al                   | 2015 | 1            | Nil                     | Normal                                                                                  | Immediate    | Yes      |
| 45      | Orajiaka et al              | 2015 | 1            | Nil                     | Bilateral temporal bone fractures                                                         | Immediate    | No       |
| 46      | Salunke et al               | 2016 | 1            | B/L 7th palsy           | Oblique fracture of the left petrous and right longitudinal petrous fracture extending into the temporal squama with pneumocephalus | Immediate    | Yes      |
| 47      | Paiva et al                 | 2016 | 1            | Right 7th palsy         | Retroclival and parenchyma pneumocephalus, right temporal bone fracture                   | Immediate    | No       |
| 48      | Nguyen et al                | 2016 | 1            | Nil                     | Retroclival hematoma in both the subdural and epidural space                            | Immediate    | Yes      |
| 49      | Ravindran et al             | 2017 | 2            | Nil                     | Case1. Normal                                                                           | Delayed      | No       |
| 50      | Serio et al                 | 2019 | 1            | Nil                     | Case 2. Avulsion of 6th nerve                                                            | Immediate    | No       |
| 51      | Sahlu et al                 | 2020 | 1            | Nil                     | Subacute retroclival subdural hemorrhage with left cerebellar and upper cervical spine extension | Immediate    | No       |
fractures involving the body of sphenoid bone and linear undisplaced fracture noted in mastoid part of right temporal bone. Linear undisplaced fracture was also noted in the clivus [Figure 1]. Cervical spine CT screening was normal.

Patient was admitted in the ICU and treated with oxygen inhalation, head end elevation, antiepileptic and steroids. The serial CT scans of brain showed reduction in pneumocephalus and pneumoventricle. The MRI brain showed ventriculomegaly with pneumoventricle with no evidence of abducens nerve avulsion [Figure 2]. Patient was discharged and is on follow up. Eye signs have not improved on follow-up at 6 months, but facial palsy has improved to grade 2 according to House-Brackman grading.

**DISCUSSION**

**Anatomy of abducens nerve**

Abducens nerve vulnerability in traumatic brain injury is due to its tortuous and lengthy intracranial course. Anatomically it is divided into 5 segments: brain stem, subarachnoid space, petrous apex, cavernous sinus and orbit. Arising from the abducens nucleus in the floor of the fourth ventricle deep to the facial colliculus, nerve exits the brainstem at the pontomedullary junction, traversing anteriorly before ascending in the subarachnoid space posterior to the clivus. After approximately 1.5 cm, nerve ascends over the ridge of the petrous bone and later passes under the petroclinoid (Gruber's) ligament. This triangular space demarcated by Gruber's ligament, the posterior clinoid process and the petrous apex is known as Dorello's canal. After passing through the canal, the nerve enters the cavernous sinus and then passes through superior orbital fissure to supply the lateral rectus muscle. Occasionally, the nerve bifurcates as it traverses Dorello's canal with one trunk passing superior to Gruber's ligament and the other passing inferior to it. Bilateral abducens palsy following head injury is a rare but a well-described entity particularly when associated with skull base fractures. Several theories have been postulated to explain mechanisms of abducens nerve injury in trauma.

In 1971, Schneider et al., postulated that upward movement of the brain could result in compression of the abducens nerve against the rigid Gruber's ligament leading to avulsion of nerve. However, a 1976 case series which included 3 cases by Takagi et al., disputed this hypothesis, arguing that the injury of the abducens nerve below Gruber's ligament by the dura and the petrous apex prevented the injury to the abducens nerve by upward cranial displacement. Rather, they hypothesized that the force directed in the mid-frontal bone resulted in stretching of both the abducens nerves with the apex of the petrous bone acting as a fulcrum for compression of the nerves.
Indeed, in the absence of skull fractures, the mechanism proposed by Takagi et al., would appear most appropriate. Following head injury with associated fracture of the skull base involving the clivus, clival epidural haematoma may occur. Epidural haematoma compresses the bilateral abducens nerve resulting in injury. In 1985, Arias et al concluded that the points of entry of the nerve into both the extradural space and the petrous ridge are the most probable locations for the avulsion of abducens nerve. Moreover, post-mortem analysis of ten post-traumatic bilateral abducens palsy cases at autopsy found injury to the nerve to be most evident at the sites of the dural entry point and petrous apex. Keane et al., in 1976 suggested that the incidence of traumatic bilateral abducens palsy is similar to that of unilateral palsy. It has been postulated that the apparent paucity of reported bilateral cases is due to patients not surviving the initial trauma due to severity of injury. A review by Arias et al., in 1985 identified 10 cases of traumatic bilateral abducens palsy, of which 3 had an associated cervical spine fracture without skull fracture. Lazow et al., reported an additional three cases in 1995.

Delayed presentation of post-traumatic bilateral abducens palsy is very rare with only six cases reported in the literature. The mechanism for a delayed presentation of bilateral abducens palsy is unclear. Many mechanisms have been proposed which includes vascular causes like vasospasm and ischemia. It is related to disruption of blood supply from branches of the meningodorsal artery and also tissue edema, similar to the mechanism of delayed onset traumatic 7th nerve palsy.

Increase in size of post traumatic retroclival epidural haematoma, causes posterior displacement of brainstem leading to abnormal stretching of the bilateral abducens nerve anywhere along its course. Progressive edema may impinge on the sheath of the nerve, leading to axonal damage of the nerve. Additionally, delayed intracranial haemorrhage has been postulated to be other mechanism, with asymptomatic time of up to 1 month reported in cases of delayed intra cranial haemorrhage. Devin K. Binder et al., had reported a case with depressed skull fracture compressing superior sagittal sinus causing raised Intracranial pressure and bilateral abducens palsy on 4th day. Post operatively after removing the depressed fragments, the nerve palsy improved. Nayil K et al., reported had reported a case with head injury with CT brain suggestive of vertex Extrudal haemorrhage with delayed signs of raised intracranial pressure symptoms along with bilateral abducens nerve palsy. Post operatively abducens nerve palsy improved. Elevated intracranial pressure is known to cause bilateral abducens palsy. This may be one of the mechanisms of delayed-onset bilateral abducens paresis following head injury. Thus, there may be other reasons of delayed-onset bilateral abducens nerve palsy apart from direct trauma to the nerve. Ravindran et al postulated that partial avulsion of the abducens nerve, sustained at the time of initial trauma, followed by stretching or compression of the nerve by a combination of the mechanisms could result in delayed complete avulsion of the nerve.

Out of 51 publications which include 139 cases, forty-one cases presented with immediate bilateral palsy, six cases were of delayed presentation while in the rest of the cases the time of presentation was not mentioned. In our case, patient presented with immediate onset of bilateral abducens palsy. On imaging clival fracture was seen in CT brain, which can be attributed for the nerve injury. The most common associated nerves involved along with bilateral abducens nerve injury are facial and hypoglossal nerves.

Other nerves involved according to literature review were oculomotor, trochlear, trigeminal nerves. Cases with retroclival extradural haematoma had higher chances of multiple cranial nerve injuries. Cases with multiple basal skull fracture involving petrous temporal bone fracture had higher chances of facial nerve injury. Our case presented with associated right facial nerve involvement which can be attributed to linear un-displaced fracture in mastoid part of right temporal bone.

We cannot comment on the rate of recovery in our review as different publications have chosen different time period for recovery. Few publications mention partial recovery at their follow-up. In our review, twenty-three patients show recovery while 29 patients did not recover irrespective of the follow up period mentioned by the authors. In rest of the cases, the recovery was not mentioned. Holmes et al., reported spontaneous recovery in 38% of bilateral traumatic abducens palsy at 3 months of follow-up. Mutyala et al., reported a recovery rate of 12% in the same. However, they did not mention the time period of follow-up. Unilateral 6th nerve palsy has been reported to recover spontaneously in 12 -73%, 32, 33.

Our case showed no improvement in bilateral abduction during follow-up at 6 months, however facial nerve palsy improved to grade 2. Along with bilateral involvement, the poorer outcome can be related with the severity of the abduction deficit, with complete deficits having lower rates of spontaneous recovery. Majority of the publications on recovery are limited by the small number of sample size. Cases of bilateral abducens nerve palsy following trauma are probably rare as the force required is usually not compatible with life. For the same reason, traumatic bilateral abducens nerve palsies are frequently accompanied with life-threatening injuries like skull base fracture.
CONCLUSION

To summarize, clinical presentation of traumatic bilateral abducens nerve palsy is rare following closed head trauma and is usually associated with other injuries which are incompatible with life. Due to its long intracranial course, abducens nerve is vulnerable for injury and various mechanisms have been described separately for immediate and delayed presentation. It can be associated with other nerve injuries depending on basal skull fractures. Severity of abduction deficits and bilateral nerve injury are independent risk factors for poor outcome.

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SBV-Concept and design of the study; prepared first draft of manuscript, Interpreted the results; reviewed the literature and manuscript preparation.
RKR-Concept and design of the study; prepared first draft of manuscript reviewed the Literature and manuscript preparation; Concept coordination, revision of the manuscript.
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