Spontaneous Intracranial Bullet Migration: A Complication of Penetrating Cranial Gunshot Wound: Case Report and Review of the Literature

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Abstract
Spontaneous migration of retained bullets in the brain is a recognized rare complication of penetrating cranial gunshot wounds to the brain. The authors report one rare case in a 55-year old male patient who presented with a penetrating cranial gunshot wound and a retained bullet. He had a dense right hemiplegia and expressive aphasia on admission. Skull x-ray confirmed the retained intracranial bullet, which on CT scan was located at the left parieto-occipital region. He was managed conservatively. A repeat CT scan 17 days post injury showed spontaneous migration of the bullet to the left occipital pole adjacent to the superior sagittal sinus and near to the Torcula Herophili. He had a remarkable improvement of his right sided weakness but had severe receptive and expressive language deficits. This case highlights the need to watch out for the occurrence of spontaneous migration of intracranial bullets after a penetrating cranial gunshot wound and when detected management decisions should be individualized.

Keywords: Penetrating cranial gunshot wound, migrating bullet, superior sagittal sinus

INTRODUCTION
Cranial gunshot wounds (CGSWs) can result in a tangential, penetrating, or perforating wound. These wounds also have the possibility for intracranial rebound of projectiles and the possible swerving of projectiles inside the skull and around the brain(7). A penetrating wound results when the bullet's energy is depleted on penetrating the skull but still has sufficient amount of kinetic energy to enable partial penetration of the bullet through the brain substance(7). Bullets are
more likely to penetrate the skull when they strike more perpendicular than tangentially with resultant primary injuries and complications such as localized brain contusions, lacerations, haematomas, pseudoaneurysms or arteriovenous fistulae depending on the trajectory of the bullet\(^7\). However, on rare occasions, the bullet has been found to migrate spontaneously particularly when it is in close proximity to a ventricular system or the bullet remains non-fragmented\(^7,11,20\). This case report illustrates a spontaneous intracranial bullet migration after a penetrating CGSW and a review of the relevant literature. To the best of the authors' knowledge, this is one of the very few reports published in the literature concerning a spontaneous intracranial bullet migration and supports the rarity of this condition\(^14,28\).

**CASE PRESENTATION**

A 55-year-old man was admitted on March 8th, 2011, in our Department of Neurosurgery, Chris Han Baragwanath Academic Hospital (CHBAH), University of the Witwatersrand, Johannesburg, through the Trauma Emergency Department. The patient was brought to the Trauma Resuscitation room in the hospital's casualty by family members with a history of being found on the floor at a train station. There was no eye witness account of what lead to his condition. In the resuscitation room, he was found to be breathing spontaneously with an oxygen saturation of 98%. He had a blood pressure of 168/86 mmHg and a pulse rate of 63 beats/min. His Glasgow coma scale (GCS) was 11/15 (E4M6V1) and he had expressive aphasia as well as a dense right hemiplegia. An isolated gunshot wound was found in the frontal area on the left side of the top of the head. No exit wound was seen. A low dose whole body x-ray (LODOX) performed in the trauma resuscitation room showed a bullet in the head. This was confirmed on conventional skull x-ray (Fig. 1a and 1b). He was intubated in the resuscitation room by the trauma medical officers for neuroprotective ventilation. A Computed Tomography (CT) scan of the brain also confirmed the intracranial bullet (Fig. 2). In addition, the CT scan showed a left frontal lobe contusion and pneumocephalus with an overlying small frontal-parietal acute subdural haematoma. There was mass effect with a midline shift of \(\approx 5mm\) as well as a mild intracranial hypertension. A closer assessment of the CT scan revealed damage to the occipital horn of the left lateral ventricle indicating that the bullet grazed the ventricular system (Fig. 3). Though it was difficult to appreciate the exact location of the bullet due to metallic artefact in the CT scan films, it appeared to have lodged within the part of the occipital horn of the left lateral ventricle that was damaged by the bullet or in close proximity to it. Therefore, it can be deduced that the bullet traversed the brain parenchyma from the left frontal region and lodged at the parietal-occipital region.

Fig 1a: Lateral plain skull x-ray of patient on admission showing a retained intracranial bullet Fig. 1b Anterior posterior skull x-ray of patient on admission showing a non-fragmented bullet
The patient was thereafter admitted to our neurosurgery intensive care unit. He was started on prophylactic anticonvulsant therapy (phenytoin sodium) and given mannitol while in the trauma emergency department. The entrance wound on the scalp was dressed but not stitched and he was placed on neuro observations with the head of the bed elevated to 30 degrees. He was later extubated and demonstrated progressive improvement in his clinical and neurological state in our neurosurgery ward. He commenced rehabilitation and was attended to by both the physiotherapist and occupational therapist in the ward and later at the gymnasium. Speech therapy was also administered. His speech condition deteriorated about 2 weeks after injury with the occurrence of severe receptive and expressive language deficits, resulting in his inability both to imitate oral movements/sounds despite cuing and to follow simple commands. He was also unable to identify pictures/objects. Over time, he showed progressive improvement in his right sided weakness and was able to sit unsupported as well as safely feed himself and drink from a cup independently. In addition, he was able to make appropriate nodding and sound imitation with attempts to vocalize in response as well as smiling in recognition of the rehabilitation team. A follow up CT scan was done on day 17 post injury which

Fig 2: Axial non-contrast cranial CT scan of patient on admission showing pneumocephalus, acute subdural haematoma and a bullet (with metallic artefact) lodged in the left parietal-occipital region, close to the midline and adjacent to the occipital horn of the left lateral ventricle

Fig 3: Axial non-contrast cranial CT scan of patient on admission showing the damaged occipital horn of the left lateral ventricle (see arrow)
showed resolution of the frontal contusions, pneumocephalus and the acute subdural haematoma. However, a significant observation was the migration of the bullet from its initial position at the parietal-occipital region to the occipital pole adjacent to the superior sagittal sinus and close to the Torcula Herophili (Fig. 4 and 5). Surgical intervention was not attempted due to his clinical and neurological improvement. He was subsequently discharged home on day 26 post injury to the care of his relatives and for outpatient follow up in the neurosurgery clinic as well as with the rehabilitation team.

**Fig 4:** Cranial CT scout view on day 17 post CGSW showing the migration of the bullet in the occipital region

**Fig 5:** Axial non-contrast cranial CT scan at day 17 post CGSW showing the migration of the bullet (with metallic artefact) in the occipital region

**DISCUSSION**

Spontaneous migration of retained intracranial bullet is a rare complication of CGSW which was first documented in 1916 and several case reports have been reported in the literature thereafter.\(^{11,13,24,28}\). The reported incidence varies from 0-10\%\(^{8,11,17,25}\). Hagan\(^8\) had 0\% incidence in his series while Martin and Campbell\(^{17}\), Rapp et al\(^{21}\) and Wood\(^{25}\) had 1.1\%, 4.2\% and 10\% respectively in their series. Our case is the first of such report from our center so far and supports the rarity of this condition.

Spontaneous migration of retained intracranial bullet can be intracompartmental, transcompartmental, anterior or posterior migration. Intracompartmental migration can be in the supratentorial or infratentorial
compartment and this is the most common in occurrence\textsuperscript{(15)}. Transcompartmental migration from the supratentorial to the infratentorial compartment is rare\textsuperscript{(13,16,23,26)}. Most of the migrations from the supratentorial to the infratemporal compartment resulted in the bullet lodging around midline infratentorial structures\textsuperscript{(5,16,23)}. However, Kocak and Ozer\textsuperscript{(13)} reported migration from the supratentorial compartment to the contralateral infratentorial compartment in their case report. Anterior (antigravity) or posterior migration can also occur. Anterior movement has recently been reported by Alessi et al\textsuperscript{(1)} and Yadav et al\textsuperscript{(26)}, however, posterior relocation of retained intracranial bullet is the commonest pattern among cases reported in the literature\textsuperscript{(2,12,15,20,21,26)}. Further to the above patterns is the observation by Zafonte et al\textsuperscript{(28)} of “tumbling” or rotation of the retained bullet within the cerebellum. In our patient, the bullet resettlement corresponded to the commonest patterns. It was an intracompartamental posterior migration from the left parieto-occipital region to the left occipital pole close to the midline.

The time interval between the time of the CGSW and relocation of the retained bullet varies from a few hours to several years\textsuperscript{(11)}. Kamenski et al\textsuperscript{(1)} reported the shortest time interval of less than 12 hours in their case report. Zafonte et al\textsuperscript{(28)} observed the movement of the bullet from the left frontal region to the left temporal-parietal region after 24 hours while Rapp et al\textsuperscript{(21)} and, Kocak and Ozer\textsuperscript{(13)} noticed theirs 36 hours and 10 days respectively after injury. Kumar et al\textsuperscript{(14)} noted bullet migration from the left posterior frontal region to the left posterior occipital region on the 3rd day post CGSW, and further movement posteriorly on the 5th day when a CT scan was done due to worsening neurological status in their patient. In our patient, a repeat CT scan was done on the 17th day post injury and this revealed the bullet migration. The exact time interval can therefore not be definitely stated. Spontaneous bullet migration of retained intracranial bullet can continue for years as in the case of Liebeskind et al\textsuperscript{(16)} where the path of the bullet in the brain was monitored for 3 years with serial radiographic studies until the bullet lodged in a location within reach for surgical removal.

Various reasons have been adduced as possible mechanisms for the spontaneous migration of intracranial bullets. These include cerebral tissue softening resulting from surrounding edema, local cerebral tissue damage, the specific gravity of the bullet (which is higher than the specific gravity of cerebral tissue) and gravitational factors\textsuperscript{(10,13,19,22)}. Ventricular pulsations have also been considered to contribute to the migration of intracranial bullets as well as the sink function of the cerebral ventricles, which favors the movement of interstitial markers from the brain into cerebrospinal fluid\textsuperscript{(18,19)}. An example of ventricular sink action in clinical practice is demonstrated by the predisposition of brain abscesses and periventricular hemorrhages to rupture centripetally into the cerebral ventricles\textsuperscript{(19)}. While ventricular sink action may play a more significant role in spontaneous bullet migration if the retained intracranial bullet lies close to a cerebral ventricle, gravitational effects and the flow of cerebrospinal fluid (CSF) may contribute more significantly if the bullet is located in the ventricles or subarachnoid spaces\textsuperscript{(11,19)}. It has also been suggested that spontaneous intracranial bullet migration may result from an abscess or hematoma developing close to the bullet\textsuperscript{(11)}. After bullet migration, a streak of haemorrhagic contusion may be seen in a CT scan as an evidence of the track a bullet had taken to migrate through the brain parenchyma.

Factors that favour early spontaneous intracranial bullet migration include laceration or cavitation in the brain, bullet location near or within the ventricle or
subdural space as well as migration through a white matter tract by streamlined and intact bullet\(^{(3,4,22)}\). A factor that has been considered significant for late intracranial bullet migration is abscess formation, though the migratory distance tends to be small and rotatory in pattern\(^{(4,6)}\). In our patient, the metallic artefacts in the CT scan obscured the determination of the exact location of the bullet after the CGSW. However, careful assessment of the neuroimages showed that the bullet was non-fragmented and caused significant damage to the occipital horn of the left lateral ventricle and may have lodged in close proximity to it. Also a thin streak of haemorrhagic contusion suggestive of the track of migration as well as local edema could be seen along the position of the damaged occipital horn and adjoining brain parenchyma (Fig. 6). The spontaneous intracranial bullet migration could therefore have been aided by gravitational effects, local cerebral tissue damage and cerebral softening resulting from edema, and may have migrated earlier than when it was detected. The probability of an earlier bullet migration in our patient may be supported by the observation of deterioration in the patient's neurology at about 2 weeks post injury in keeping with reports of worsening neurology at the time of bullet migration\(^{(14)}\).

Complications of spontaneous intracranial bullet migration include deterioration in the patient's neurological status/image, brain abscess, intraventricular migration with or without hydrocephalus, and migration into the spinal cord\(^{(13,14,27,28)}\). Due to the above possible complications surgical management of spontaneous intracranial bullet migration has remained controversial\(^{(20,21)}\). However, documented management decisions vary from non-operative conservative management in patients with absence of complications to surgical removal of the migrating bullet if it causes complications\(^{(14,16,26)}\). Where surgical removal is considered, it is recommended that the migrating bullet be removed if it is reasonably accessible and if removal can be attempted without the risk of iatrogenic neurological damage\(^{(20,22)}\). Liebeskind et al\(^{(16)}\) monitored the path of a bullet in the brain for 3 years with serial radiographic studies until the bullet lodged in the floor of the fourth ventricle before it was surgically removed. However, Kumar et al\(^{(14)}\), in their recent

*Fig 6: Axial non-contrast cranial CT scan showing the track of haemorrhagic contusion (see arrow) suggestive of track of bullet migration*
case report, concluded that spontaneous intracranial bullet migration should be watched for and when detected should be considered an urgent indication for surgical removal. They based their conclusion on the damage to vital structures and the attendant neurological sequelae that could result from spontaneous intracranial bullet migration as was the case in their patient. Kocak and Ozer(13) also support urgent removal of migrating bullet if there is no contraindication. Rapp et al(21) recommend serial imaging studies to look for migrating bullet fragments and their subsequent surgical removal. Bullet localization prior to surgical removal is also recommended(11,15,21). Whereas Rapp et al(21) recommended intra-operative ultrasound to localize the fragment when possible; Kamenski et al(11) recommended any radiologic study to be performed as close as possible to the time of surgical operation to help localize the site of the bullet. Kumar et al(14) emphasized that intraoperative localization is essential. While surgical removal of migrating intracranial bullet is considered the goal standard, other methods of removal that have been documented include stereotactic removal of a small intracerebral pellet and ventriculoscopy for intraventricular location(4,6).

We decided to treat our patient conservatively because of the improvement in his neurological status. Follow up with serial radiologic studies in our outpatient clinic is justified.

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