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# Homage to a good man. Dr. Szabó Ioan † (1955-2023)

**Raluca Pașcalău**

Cluj County Emergence Hospital, Cluj, ROMANIA

*"Medicine is science and conscience warmed by love for human beings"*- this motto of Iuliu Hațieganu, the founding father of our Medical School in Cluj-Napoca, burns like the Olympic flame from one generation of alumni to another. Like any flame, it is still vulnerable to currents and winds such as political ambitions, professional competition, over-specialization or cultural ignorance.



Thus, to evoke the memory of someone like Dr. Szabó Ioan, who literally

enacted this principle as his way of living, is not just an occasion of kind remembrance for the ones who knew him, but a source of inspiration for the ones who did not, a way to keep the flame alive.

Dr. Szabó Ioan was a neurosurgeon who specialized in orbital and periorbital surgery and worked at the Neurosurgery Clinic of the Cluj

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**Keywords**  
Szabó Ioan

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County Emergence Hospital. He was not an academic, so he was never a celebrity, but his patients, residents and students admired him for his expertise, honesty, kindness and generosity. I got to know him after my first year of medical school when I did summer practice in the Neurosurgery Clinic and entered by chance in his operating room.

He immediately acknowledged my presence, asked me some anatomy questions and as I answered correctly, he told me to come closer to the wound and explained the procedure. From then on I followed him in the clinic as much as possible, we did some research together and had fascinating discussions about anatomy and philosophy. I regarded him as my mentor in medicine and life. Now at his too-early passing, I would like to sketch his portrait from three perspectives:

#### SCIENCE

Dr. Szabó was an erudite. No one could compete with his knowledge of anatomy, surgery, pathology and general culture. Firstly, was a hard-working student, graduating from the prestigious „Mihai Viteazul” high school in Turda and the University of Medicine and Pharmacy in Cluj-Napoca with maximal grades. Secondly, as a neurosurgeon he did his PhD in orbital surgery and developed this field which was unknown in our country, performing over 2000 orbital surgeries with innovative surgical approaches and orbit reconstruction techniques. In collaboration with his wife, anatomy teacher and neuro-ophthalmologist Dr. Bianca Szabó, he wrote several highly regarded monographs on the subject and published numerous research papers in international journals.

#### CONSCIENCE

The professional conduct of Dr. Szabó was irreproachable. The daily good deed was his constant goal. All his colleagues respected him for his fairness and generosity. For residents and students, he was like a parent, concerned for their progress, and always with a good advice at the right moment. Above all, Dr. Szabó cared for his patients sincerely

and deeply. He regarded them first as persons and then as surgical cases. I remember seeing him sometimes wiping his tears after describing the medical history of his patients. He always made time to explain to his patients where the pathology was and what was happening. He never left the clinic without making a last visit to the patient rooms.

#### LOVE FOR HUMAN BEINGS

Everybody who interacted with Dr. Szabó -from friends, patients and students, to doctors and nurses- remembers his way of speaking and listening which made the interlocutor feel like the most important person in the world. This quality came not just out of politeness, but from a deep love for human beings, rooted in his spiritual richness. Having a solid general knowledge and a genuine preoccupation with culture and civilization, Dr. Szabó traveled all around the world, not as a tourist but as an explorer. He liked to interact with locals from different cultures to understand their concerns and beliefs. From his long and thoroughly planned journeys, he collected numerous spiritual objects, mostly masks and representations of the human face. As an orbital surgeon concerned with facial reconstruction, he had a passion for the human face as a mirror of the spirit. Philosophically he had a profound understanding of the human being which was reflected in his medical conduct. His patients loved him. Many of them came at annual follow-ups for decades just to thank him and gladly let him know they felt well. As an ophthalmologist, I spend a lot of time looking at the patient's eyes but thinking of him I try to make time to also look in their eyes for a moment.

In Dr. Szabó, all three components of good medicine proposed by Iuliu Hațieganu blended harmoniously. He was an authentic and profound thinker and at the same time a joyful man. I will remember him with the mustache arched in a wise and kind smile. He was a wonderful doctor and a good man. May his example ignite the flame in many generations to come.



# Huge extradural multilevel lumbar abscess. Case report

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## ABSTRACT

Extensive spinal epidural abscesses (ESEAs), occupying three or more spinal regions, are rare forms of vertebral infection. Multilevel laminectomy in these cases is controversial because of the risk of vertebral instability. We report the case of a 47-year-old patient known with ureterohydronephrosis 2nd degree, admitted for severe vertebral pain (VAS 8/10) from 2 months, paraparesis (ASIA 1/5 left, 4/5 right, retention of urine and faeces) from three days. The analysis discovered Diabetes Mellitus type 2, and high levels of inflammatory tests. CT and MRI of the vertebral area with contrast revealed dorsal compression of the spinal cord and cauda equina by an epidural abscess extending from L1-L5, bilateral in the soft adjacent paravertebral tissues especially psoas muscles but sparing the intervertebral discs. Surgical treatment: alternate fenestrations L1-L5, more important on the left side. By this technique, we removed the fluid pus and also granulomatous pus from posterior epidural space L1-L5, bilateral medial foramina, interspinous and supraspinous space, and psoas muscles. The identified germ was *Staphylococcus aureus* +++. Postoperatively, we used a continuous drainage washing system with Vancomycine and diluted Betadine—a course of six-week Vancomycin 2 grams/day iv. The drainage system was blocked after 24 hours and we had to remove it and all the wires of the suture. We had to dress up every day for the surgical field and wash deep inside the field with diluted betadine for 3 weeks till the surgical field was completely cured. After 3 months postoperatively the patient was cured radiologically and clinically. Follow up 18 months. Conclusion: alternate fenestration has the advantages of removing liquid and granulomatous pus in the epidural posterior area and preserving the spine stability.

## INTRODUCTION

Spinal epidural abscess (SEAs) is defined as the accumulation of purulent contents in the epidural space of the spinal canal, causing spinal medullary and root ischemia via compression, resulting in persistent neurological disorders<sup>15</sup>. Spinal epidural abscess is a rare<sup>19</sup> 0.2–2 per 10,000 hospitalized patients<sup>1</sup>. Extensive spinal epidural abscesses (ESEAs) occupying three or more spinal regions are extremely rare and pose a therapeutic challenge as they have a higher mortality rate<sup>1,2</sup>. Patients with diabetes mellitus, acquired immunodeficiency syndrome, or who are under immunosuppressive

## Keywords

extensive extradural  
lumbar abscess,  
alternate laminotomy



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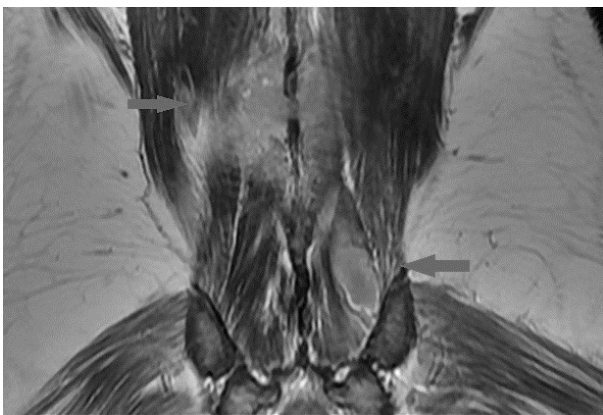


treatment after organ transplantation, drug addiction, alcoholism, cancer, and systemic inflammation or infection are more susceptible for contracting secondary epidural abscess<sup>4,5</sup>. The most common pathogen in both forms is *Staphylococcus aureus*, with methicillin resistant<sup>9,10</sup>. Most epidural abscesses are located at the thoracic or lumbar level<sup>14</sup>. Performing multilevel laminectomies is controversial in cases of extensive SEA considering the long surgical time and mechanical instability<sup>14</sup>.

#### CASE REPORT

We report the case of a 47-year old patient known with ureterohydronephrosis 2-nd degree, admitted for severe vertebral pain (VAS 8/10) from 2 months, paraparesis (ASIA 1/5 left, 4/5 right, retention of urine and feces) from three days. Local exam: right lumbar paramedian subcutaneous collection, depressible, erythematous, warm, slightly painful to palpation. Analysis discovered diabetes melitus type 2, evidence of chronic renal failure, high levels of inflammatory tests, leukocytosis with neutrophilia and lymphopenia. Pus was evaluated by diagnostic puncture from the subcutaneous collection. The identified germ was *Staphylococcus aureus* ++++.

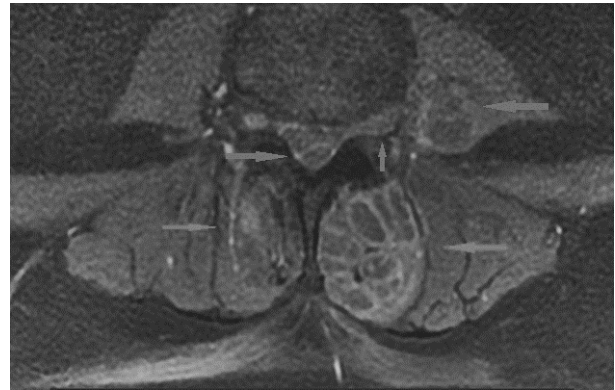
CT and MRI of the vertebral area with contrast revealed dorsal compression of the spinal cord and cauda equina by an epidural abscess extending from L1-L5, bilateral in the soft adjacent paravertebral tissues especially psoas muscles but sparing the intervertebral disc.



**Figure 1.** Lumbar vertebral with GD. Coronal view: pus in paravertebral and psoas muscle (Green arrows).

Combined surgical drainage and prolonged antibiotic therapy remain the ideal treatment. Surgical treatment and surgical target: Removal of

the pus. Technical dilemma: preserving of stability. For these reasons we choosed alternate fenestrations L1-L5, more important on the left side. By this technique we removed the ESEAs who consist in fluid pus and also granulomatous pus from posterior epidural space L1-L5, bilateral medial foramina, interspinous and supraspinous space, psoas muscles. And we preserved the stability.



**Figure 2.** Lumbar vertebral with GD. Axial view: pus in psoas muscle, extraforaminal, foraminal and posterior central area (Blue arrows). Pus in paravertebral muscles, dominantly on the left side (Red arrows).



**Figure 3.** Lumbar vertebral with GD. Lateral view: pus in subcutaneous space, posterior extradural space, interspinous space (Orange arrows).

The abscess in the left psoas muscle who was previously punctured and partially drained by diagnostic subcutaneous puncture, was not

operated by surgeons. The patient was abundantly washed intraoperatively with oxygenated water, diluted Betadine solution, Rifampicin and Physiological serum. Postoperatively, a lavage-drainage inn and out system with Vancomicyne and diluted Betadine consisting of 4 nasogastric intubation tubes connected to sterile drainage bags was installed. A course of six-week therapy with Vancomycin 2 grams/day iv and Ciprofloxacin 4 weeks was administered. The drainage system was blocked after 24 hours and we had to remove it and all the wires of the suture. We had to dress up every day the surgical field and wash deep inside the field with diluted betadine 3 weeks till the surgical field was completely cured. After 3 months postoperatively the patient was cured radiologically and clinically (the motor strength of both lower extremities improved (G5/G5), and she could walk without any assistance). Follow up at 18 months.



**Figure 4.** Postoperative vertebral Lumbar CT scan: alternate fenestrations L1-L5 (yellow arrows).

#### DISCUSSION

ESEAs is an uncommon but severe infectious condition that may lead to significant neurological disability and death<sup>11</sup>. It classically manifests as a triad of fever, back pain, and progressive

neurological deficits<sup>11</sup>. The route of infection is hematogenous spread of bacteria<sup>3</sup>. The incidence of ESEAs has increased, possibly because of the increase in the aging population; the prevalence of diabetes and the use of instrumentation, epidural catheters, and immunosuppressive therapy<sup>3</sup>. Prompt diagnosis and surgical drainage should be instituted because diagnostic delay is associated with poor outcomes and catastrophic consequences<sup>3,12</sup>.



**Figure 5.** Postoperative vertebral Lumbar MRI with GD - lateral view: healing of the abscess.

The standard treatment for patients with an extensive ESEAs remains controversial. A successful case of conservative antibacterial treatment of holospinal SEA has been reported<sup>8</sup>. In cases of extensive ESEAs involving multiple levels, spine surgeons hesitate to perform surgical decompression and drainage through multilevel laminectomies for patients with poor general conditions. These cases represent a treatment dilemma, especially for patients with medical comorbidities<sup>3</sup>.

Performing multilevel laminectomies may predispose patients to complications such as increased blood loss, increased postoperative pain and recovery time, and late kyphotic deformity and iatrogenic instability<sup>6,7</sup>. Ran et al<sup>13</sup> introduced the

concepts of aspiration and irrigation of multilevel SEA bypercutaneous CT-guided needle aspiration. However, in clinical practice, CT-guided percutaneous drainage of SEA is not commonly performed due to technical difficulties; it is only indicated for a dorsally located SEA with a confirmed purely liquid component<sup>3</sup>. Surgical drainage should be promptly considered for patients with neurological deficits because of the limited time window for irreversible damage<sup>3</sup>. Most authors prefer surgical decompression and abscess drainage because the progression of infection is unpredictable even if appropriate antibiotic therapy is established, and severe neurological compromise can follow vascular involvement of the spinal cord<sup>16</sup>. Some authors suggest that selective laminectomies at the rostral and caudal poles of the abscess with subsequent drainage<sup>16</sup>.

Others have performed the so-called apical laminectomy at the midcervical C3/5 level, the midthoracic T6/9 level, and the midlumbar L2/3 spinal segments<sup>16</sup>. Various epidural space drainage catheter types have been used. A Fogarty catheter, a 5-Fr 2 pediatric feeding tube, and soft silicone catheters for drainage have been used<sup>12,17</sup>. In the case of progressive neurological deficit, most authors agree on surgical treatment for SEA<sup>1,17</sup>. It is difficult to establish the exact criteria for drainage method selection in an extensive SEA due to greatly varied SEA locations and the presence of coexisting diseases. Appropriate antibiotic treatment for 4–12 weeks is essential<sup>1,17</sup>.

In our patient where the ESEAs without disc space involvement and without significant comorbidities we appreciate that the most efficient surgical technique consist in alternate laminectomies (partial removal of laminae, basis of spinous processes, medial parts of posterior foraminae bilaterally but specially on the most affected side).

The final objectives are:

- removal of most most important parts of the abscess (fluid by aspiration and granulomatous with the curettes)
- preserving of stability
- make possible healing by antibiotic treatment for residual pus

## CONCLUSION

Combined surgical drainage and prolonged antibiotic therapy remain the ideal treatment.

Alternate fenestration has the advantages of removal of liquid and granulomatous pus in epidural posterior area and preserve the spine stability. It is the the ideal solution for the stable patients with this kind of ESEAs

## Abbreviations:

CT = computed tomography;

MRI = magnetic resonance imaging;

MRSA = methicillin-resistant *Staphylococcus aureus*;

SEA = Spinal epidural abscess;

ESEAs = Extensive spinal epidural abscess; VAS = visual analog scale.

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# Improving bicycle and motorcycle helmet design to prevent traumatic brain injury. A review

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## ABSTRACT

Traumatic brain injury (TBI) from bicycle and motorcycle-related accidents continues to be a major medical and financial burden in the United States. The complex management and debilitating consequences of TBI demand greater attention to its prevention, of which much relies on helmet use and structure. Conventional helmets today rely on an expanded polystyrene (EPS)-liner, which works to mitigate the linear acceleration experienced by the brain during impact. However, recent evidence suggests that it is not the linear acceleration but the rotational acceleration of the impact that most contribute to TBI development. This has led to the development of novel helmet designs that aim to mitigate rotational kinematics in addition to linear kinematics. The objective of this study was to overview limitations in current helmet design and discuss two of the most well-studied novel prototypes: WaveCels and Multi-Directional Impact Protection Systems (MIPS). Though both ultimately reduce the rotational acceleration of injury, they differ in mechanism and efficacy. Given the importance of helmet structure in the prevention of TBI, we find that more work is needed directly comparing these and other new designs.

## INTRODUCTION

Bicycle and motorcycle injuries remain amongst the most common causes of traumatic brain injury (TBI) in the United States [20]. From 2009 to 2018, head injury from bicycle accidents accounted for almost 600,000 diagnoses of a concussion or a TBI in the emergency department [33]. Of all demographics, younger children are at greater risk of head injuries from biking accidents compared to adults [37]. Medical costs for pediatric bicycle-related TBIs reached 200 million in 2003, and have only increased since [34]. Helmets have long been championed as the ultimate protective mechanism against TBI. According to a Cochrane review, helmets can reduce the risk of head injury by up to 88% [37]. One study found that helmets lower the risk of severe TBI by 51% compared to non-helmeted bicycle riders [21]. Mortality and morbidity in TBI from bike-related accidents appear to be

## Keywords

traumatic brain injury,  
WaveCel,  
MIPS,  
protection,  
bicycle helmets,  
EPS



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negatively correlated with helmet use, though some suggest that those who wear helmets are simply fundamentally different from those who do not, and generally practice safer biking practices and less risk taking behavior [15, 29]. Despite the controversy, studies show the structural features of helmets can help prevent axonal shearing and linear components upon impact, thus reducing the severity of neurologic injury [13]. Helmets also reduce the incidence of skull fractures, meningeal bleeds, and parenchymal bleeds: common characteristics of more severe TBIs [14]. They decrease the likelihood of facial injuries, impaired consciousness, and the need for neurosurgical intervention as well.

Increased public awareness of the benefits of wearing a helmet have led to greater helmet use among cyclists [22]. Yet, despite this trend, traumatic brain injury (TBI) still remains the most common cause of death and admissions to hospitals from bike-related injuries, and has increased in prevalence over the past two decades [37]. Helmets are meant to manage all the energy transferred to the head during impacts. However, most of the helmets currently approved by the Consumer Product and Safety Commission (CPSC) have only been proven to reduce linear head acceleration, while angular acceleration is less tested [39]. In recent years, it is angular acceleration of the head that has shown to be a major source of axonal shear strain in TBI and concussions [3].

Novel helmet designs have now begun to target rotational head acceleration from oblique impact for greater protection against TBI. Among them are the Multi-Directional Impact Protection System (MIPS), which uses a slip liner mechanism, and WaveCels, composed of a collapsible cellular liner [4]. While both these prototypes have shown to greatly enhance impact mitigation performance, few studies exist directly compiling and comparing their benefits. Thus, in the following paper, we overview the management and biomechanics of TBI, the limitations of current helmets, and discuss these novel designs aimed at reducing TBI risk.

#### **ASSESSMENT AND TREATMENT OUTCOMES OF TBI**

Traumatic brain injuries (TBI) occur when a sudden trauma, such as from a bike collision or whiplash, causes deformation and destruction of brain tissue [31]. The severity of TBI can be evaluated by the Glasgow Coma Scale and is categorized into mild,

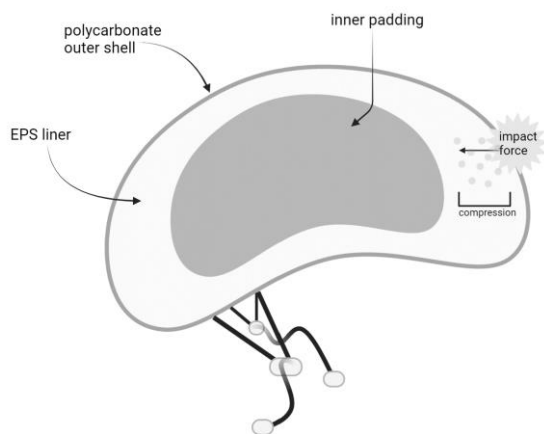
moderate, or severe [8]. Secondary injuries following TBIs can lead to impairment of cerebral oxygenation or autoregulation, which manifests as swelling and hematoma that compress brain structures and sagittally shift the brain [31]. An ideal neuromonitoring system for TBIs is continuous, noninvasive, appropriate for bedside and field environments, and affordable [30]. Thus, noninvasive monitoring, such as near-infrared spectroscopy (NIRS), is used to track the condition of the brain. Parameters used to assess brain conditions include cerebral perfusion pressure (CPP), an indicator for cerebral blood flow (CBF), mean arterial pressure (MAP), and intracranial pressure (ICP) [40]. An obstruction in CSFs generating a hydrocephalus and a blockage of arteries lead to reduced blood perfusion in the brain [31]. Initial management of patients with TBIs trauma is identical to typical trauma protocol — management of airway, breathing, and circulation with a rapid neurologic exam and prevention of hypothermia [11]. The neurologic exam involves examination of pupillary activity, assessment of lateralizing signs from increased ICP, and a GCS score calculation [31]. After resuscitation, patients undergo a non-contrast head CT, if possible, to better analyze the brain condition. As primary injuries of TBIs cannot be reversed, most subsequent management strategies prioritize preventing secondary injury through increasing MAP and/or decreasing ICP to prevent hypoxia and hypotension [12].

Given the serious and debilitating consequences of TBI, prevention is vital. Evidence indicates that many TBIs are caused primarily by acceleration loading during impact, as the brain suddenly decelerates while moving [32]. This acceleration can be either linear or rotational in nature. Linear acceleration is composed of the simple straight line forces the brain experiences in response to the deceleration, while rotational acceleration is more complex: the head moves differently relative to the neck and torso, causing the brain to “rotate” rapidly. Linear acceleration is more commonly associated with skull fractures, which can, in some cases, lead to more severe injury like epidural bleeding [26]. Although both linear and rotational acceleration ultimately contribute to TBI, one computational model estimated that 90% of total tissue strain was derived from rotational kinematics alone [42]. Given its complexities, the biomechanics of TBI should be

an important factor when considering the design of effective helmets.

#### CURRENT MOTORCYCLE / BICYCLE DESIGN

Conventional bicycle helmets are composed of 3 layers: a polycarbonate outer shell, an expanded polystyrene (EPS) liner, and an inner layer for padding [23]. The protective properties of the helmet depend on the cracking of the polycarbonate shell and compression of the liner [9]. When a force impacts the helmet, the cracking of the outer plastic shell and subsequent compression of the EPS liner help decrease the impact energy transferred to the head. The slow compression of the EPS liner specifically allows for increased duration of the impact, which results in both the depletion of the initial impact energy and decrease of the acceleration delivered to the head [23]. The process by which conventional bicycle helmets work to protect the brain from TBI is further illustrated in Figure 1.



**Figure 1.** Conventional helmet design and function. Conventional helmets adjust to force impacted first through the cracking and damage to the outer plastic shell, followed by the expanded polystyrene (EPS) liner compressing. Impact energy gets converted into heat, which is a by-product of plastic deformation and results in the cracking of the polycarbonate layer. Compression of EPS liner increases duration of the impact, which decreases the peak acceleration delivered to the head [9].

In the United States, bicycle helmets must endure testing by the US Consumer Product Safety Commission in order to demonstrate efficacy and safety. For example, helmets are required to

undergo impact attenuation testing, where helmets are dropped vertically onto a horizontal surface. The test establishes thresholds for peak linear acceleration, but fails to account for angular acceleration, as head surrogates during testing are constrained [39]. However, angular head acceleration from oblique impacts is known to cause TBI; in fact, most bike accidents involve oblique impacts with impact angles between 30 and 60 degrees, inducing radial and tangential forces to the head, and resulting in both linear and rotational head acceleration [27]. Studies have also shown that the typical angular acceleration experienced by a helmeted bicyclist exceeds the thresholds indicated for TBI despite linear acceleration levels remaining below such thresholds [23]. Because current standards do not include testing for angular acceleration and conventional helmets as a result do not account for angular acceleration, further research into novel helmet designs that reduce both linear and angular acceleration is being explored.

Angular, or rotational, acceleration to the head during oblique impacts results in shearing and strain to the corpus callosum and sulci of the brain [2]. The corpus callosum is the largest white matter tract connecting two hemispheres and is affected by diffuse axonal injury caused by impacts [35]. The sulci is involved in white matter injury from impacts and neurodegenerative disease [17]. A study recently found that axonal injury post-rotational TBI was specifically concentrated between white and gray matter tracts, which can be explained by the difference in tissue elasticity at these interfaces that allows one region to slide over the other, causing shear stress [25]. Another mechanism by which rotational acceleration to the head contributes to neurotrauma is by its effects on the neuronal cytoskeleton. Accumulation of heavy neurofilament subunits in the neuronal perikarya in several brain regions such as the cerebral cortex, hippocampus, cervical spinal cord, pyramidal tract, cranial nerves and cerebellum was found after induced rotational trauma in animal models [17]. Increased amyloid-beta expression and light neurofilament subunits were also observed in cortical white matter and granule cells of the hippocampus. These findings, observed a few days after rotational trauma was induced, are also consistent with those of several neurodegenerative diseases such as Alzheimer's and amyotrophic lateral sclerosis. Therefore, because

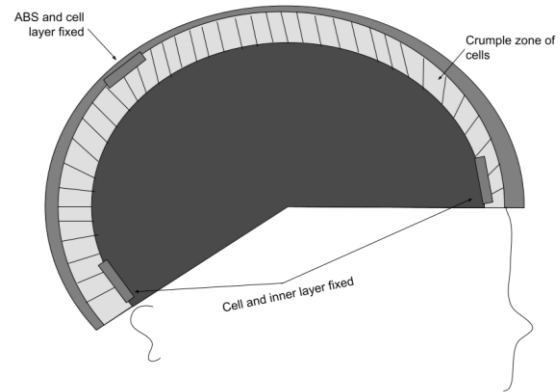
conventional bicycle helmet designs do not accommodate for angular acceleration, their utilization is more likely to result in the neurotrauma and TBI as previously described.

### IMPROVED DESIGNS

Limitations in current bicycle and motorcycle helmet design underscore the need for improved prototypes. In particular, given the role of oblique impacts in the development of neurotrauma from bicycle injury, a helmet design that incorporates anti-rotational protection may be of special benefit. Many such prototypes have been introduced in the literature, though a paucity of studies compiling and comparing these designs exist. We thus overview here two such widely-used concepts that have gained recognition in their capacity to enhance impact mitigation performance: WaveCel and Multi-Directional Impact Protection Systems (MIPS). Each attempts to reduce both linear and rotational acceleration, though they both utilize notably different mechanisms to achieve this aim.

### WAVECEL

Inspired by the Angular Impact Mitigation System developed by Hansen et.al, the WaveCel is a collapsible cellular structure that mimics, in part, a honeycomb [19]. Such “biomimetic” prototypes, which take inspiration from nature and progressed with the advent of new manufacturing technology, have gained popularity in recent years [23]. Indeed, the greater overall efficacy of bio-inspired designs in aspects such as energy absorption have sparked a global interest in their potential ability to prevent neurotrauma. Honeycomb structures, for example, have frequently been optimized in helmets, with their hexagonal shape allowing them to better withstand compression. In the case of WaveCels, “cells,” which are shaped like inverted “V’s,” are lined together in a honeycomb-like hierarchical arrangement [3]. They can flex against small, often frictional, forces, but if the WaveCel is met with a large enough impact, the cells collapse or crumple, elastically transmitting and redirecting the force. This process is better represented in Figure 2. The inherently collapsible nature of WaveCels give them a great advantage over traditional EPS liners by reducing helmet rigidity and therefore mitigating any potential shearing that could occur [23].



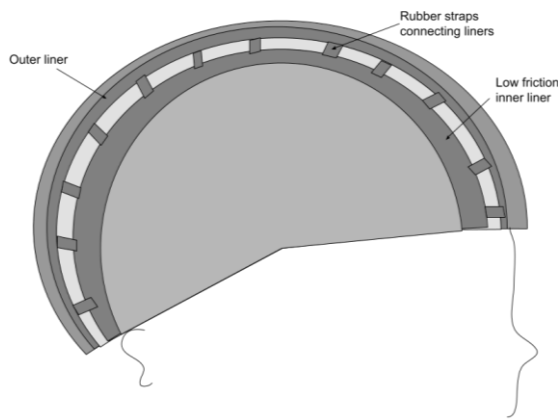
**Figure 2.** WaveCel design and function. Simple schematic of conventional WaveCel designs. A crumple zone of inverted “V” cells is suspended between an outer and inner layer, with key fixation points allowing for elasticity. Acrylonitrile butadiene styrene (ABS) is used most frequently in the outer shell of traditional helmets.

In one study, though the results were mixed for peak rotational acceleration, WaveCels were found to be superior to EPS helmets in lowering peak rotational velocity [4]. WaveCels were also noted as significantly reducing risk of head injury. This finding was corroborated by other work, which suggested that WaveCels performed better than conventional helmets in mitigating rotational kinematics as well as possible head injury [3]. Interestingly, the data available on WaveCels in regards to linear acceleration is not clear. One study suggested that WaveCels were no different than EPS in protecting against linear kinematics, while others have found that WaveCels performed significantly better than traditional helmets in mitigating linear acceleration [19]. The ambiguity surrounding WaveCels and their effects on linear kinematics warrants further study and exploration. However, what is ultimately clear from the literature is the notable anti-rotational properties of WaveCels, a characteristic that is demonstrably crucial to the etiology of neurotrauma [42].

### Multi-Directional Impact Protection Systems (MIPS)

MIPs, meanwhile, do not utilize a collapsible cellular structure, but rather are considered “slip layer” designs [4]. In this prototype, a low-friction thin “slip” liner is attached to an outer liner by rubber straps. An impact causes this slip liner to slide across the outer layer, dampening impact energy and allowing sliding between the head and the helmet, reducing

rotational acceleration. A schematic in Figure 3 depicts this more clearly.



**Figure 3.** MIPS design and function. Simple schematic of conventional MIPS designs. Rubber straps join the low friction inner liner with the outer liner, allowing it to slide past the layer.

MIPs are thought to be quite effective in protecting against oblique impacts, and in one study reduced rotational acceleration up to 56% [1]. Other work has similarly shown that although MIPS and control EPS-lined helmets performed the same in terms of linear acceleration, rotational kinematics were substantially mitigated with MIPS [41]. Compared to the EPS standard, MIPS also dramatically lowered neuronal strain from impact injury [2].

MIPS is perhaps more clear than WaveCels in regards to its effects on linear acceleration. In general, most work found that MIPS was no different than conventional helmets in terms of linear kinematics [6]. Interestingly, the effects of MIPs on even rotational kinematics are highly variable, with noted dissimilarities in the magnitudes of results across different MIPS studies. It has been suggested that this may be due to the impact mitigation performance of MIPS being contingent on certain factors, such as velocity of impact or headform type, but the reason for this ambiguity has yet to be made clear [7].

While much is available regarding the individual efficacies of WaveCel and MIPS helmets, little exists comparing their unique advantages and disadvantages directly. One study quantifying the efficacy of the two structural strategies showed that, under a certain narrow, controlled range of impact

conditions, rotational acceleration in WaveCel and MIPS helmets was significantly reduced, but was not more effective at reducing linear acceleration than EPS helmets [4]. They found that altogether, WaveCel helmets were predicted to be more effective in reducing brain injury risks from angular acceleration. Interestingly, another study found that although both WaveCel and MIPS helmets lowered strain on the corpus callosum and sulci compared to EPS, MIPS had a slightly higher effect with a lower overall strain [2]. The limited and variable results of these comparative analyses demand a deeper exploration into the differences between these different designs and mechanisms. Moreover, many of these studies were performed on anthropomorphic headforms with silicone scalp skins representing the mass and inertia of males, and so results do not perfectly emulate real-world bike crashes. These studies also often controlled for impact locations, suggesting the need for more data with variance in the locations of impact on the helmet. Currently, the only way to collect impact data from real-world head impacts is via CT scanning and collection of damage metrics to assess after the crash [18].

It is important to note as well that although MIPS and WaveCels are some of the most well-studied novel helmet designs, other such prototypes exist. The Hövding helmet, for example, mimics an airbag deployment system and releases an inflating plastic structure upon impact [38]. Several studies have found the Hövding helmet to be superior to other novel helmets in preventing both linear and rotational injury, but suggested that the duration of injury was much longer with Hövding [2]. Angular Impact Mitigation Systems (AIMS), which inspired the development of WaveCels, are also models of note, utilizing a hexagonal honeycomb structure to absorb energy of impact [23]. AIMS was found to be quite effective in mitigating linear and rotational acceleration, reducing these values by 14 and 34% respectively compared to the standard. However, little data is available comparing AIMS to other novel prototypes.

## CONCLUSION

Overall, traditional EPS lined helmets have shown to be demonstrably less effective at mitigating the rotational acceleration of impacts, which recent evidence suggests is a major factor in the development of TBI [42]. The novel helmet designs of

WaveCel and MIPS both work to significantly reduce rotational components of injury, though little is known about how the exact efficacies of these mechanisms compare to each other [4]. Therefore, continued research in helmet technology is needed, and should aim for a wider range of more realistic impacts to better understand the extent of a helmet design's ability to reduce linear and rotational acceleration of the head.

However, it is important to note that future studies examining novel helmet technology and helmet efficacy in human subjects are limited by ethical considerations. For example, comparisons between helmeted versus un-helmeted individuals with the knowledge that helmets prevent TBIs and death would be unethical to conduct. A blinded study would also be difficult as healthcare providers would have to know about helmet use for proper neurological assessment. Additionally, research with rodent models is limited by the lack of reproducible helmet designs at the rodent scale and the inability to directly compare neurological evaluations of rodents to those of human subjects [36].

Although the impacts of novel helmet designs in reducing the incidence of TBI have yet to be made clear, what is obvious is the importance of helmet use [37]. Legislation and public health messaging on a larger scale continues to be necessary in the promotion of helmet use, helping the general public to distinguish between new helmet models and to understand their ultimate protective capabilities.

### Abbreviations

**TBI:** Traumatic Brain Injury

**MIPS:** Multi-Directional Impact Protection System

**CPSC:** Consumer Product and Safety Commission

**EPS:** Expanded polystyrene

**ABS:** Acrylonitrile butadiene styrene

**NIIRS:** Near-infrared spectroscopy

**AIMS:** Angular Impact Mitigation Systems

**CPP:** Cerebral Perfusion Pressure

**CBF:** Cerebral Blood Flow

**MAP:** Mean Arterial Pressure

**ICP:** Intracranial pressure

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# Angiographic and preoperative assessment: number of perforating arteries in patients with anterior communicating artery segment aneurysms

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## ABSTRACT

**Background:** This study focuses on comparing and predicting the number of perforating arteries (PA) of the anterior communicating artery (AcoA) preoperatively by using cerebral angiographic studies and perioperative surgical observations.

**Materials and methods:** From April 2010 - March 2012, 13 patients with subarachnoidal haemorrhages undergoing surgery to repair an AcoA aneurysm were evaluated with digital subtraction angiography (DSA) and perioperative surgical observations available for the study. Each patient's number of PA arising from AcoA was investigated based on DSA imaging. DSA examinations were retrospectively evaluated by three neuroradiologists. The perioperative surgical observations were evaluated together by two neurosurgeons who performed surgical procedures.

**Results:** The number of PA of AcoA was classified into four groups. Group 1: No PA; Group 2: PA 1 to 3; Group 3: PA 4 to 6; Group 4: PA > 6. In our study, in 6 of 13 patients (46.1%) three radiological evaluations were in accordance with each other; in 8 (61.5%) cases the number of PA found in surgical observation was higher than the number obtained from at least two radiologic examinations. In all radiological examinations, PA numbers were most commonly (%61.5) classified as Group 2 (PA numbers between 1-3); in 76.9% of cases, the number of PA found in surgical observation was equal or more than those of radiological evaluations. Additionally, in 5 (38.4%) cases, the number of PA found in surgical observation was higher than the number of those radiologic examinations. **Conclusion:** We found that the number of perforating arteries of AcoA segment obtained from the surgical observation is slightly higher than the number obtained from the preoperative DSA assessment.

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## Keywords

angiographic,  
preoperative assessment,  
arteries,  
artery segment aneurysms

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## INTRODUCTION

Anterior Cerebral Artery (ACA) and the Perforating artery (PA) of the Anterior Communicating Artery (AcoA) segment carry significant importance in clinical and surgical interventions. Personality changes, decreased spontaneous activity, memory defects similar to Korsakoff's syndrome and mineral imbalance have been described due to impairment of the perforating arteries of the AcoA (1, 3, 11-14, 16). Preoperative diagnostic angiographic assessment is a notable tool for defining regional vascular pathologies, especially the saccular aneurysms and endovascular treatments. It is essential to identify perforating arteries during surgical and endovascular treatments of saccular aneurysms. Precise assessment of the perforating arteries and being aware of the possible vascular anomalies are key factors in preoperative evaluations specifically for AcoA aneurysms. High variety and small diameters of the perforating Arteries of the Anterior Communicating Artery (AcoA) segment cause difficulties in angiographic imaging (6, 13).

Different numbers and distributions of AcoA perforators can be seen during the surgeries. Literature review reveals insufficient information about cadaveric dissection studies on perforating arteries (5, 7, 8, 10, 12-14). We compared the perioperative observations and intraoperative microscope records with the cerebral digital subtraction angiography (DSA) of the AcoA perforators from AcoA aneurysm surgeries performed in our department.

In our knowledge, this is the first study comparing DSA evaluation of AcoA perforators with surgical observation. The purpose of our study is to determine the preoperative DSA imaging precision and reliability on numbers of perforating arteries of the Anterior Communicating Artery (AcoA) evaluated by Neuroradiologists, which could change the surgical approach and management of the case.

## MATERIALS AND METHODS

Our study was conducted on thirteen patients who were admitted to the neurosurgical clinic of the Dr. Lütfi Kırdar Kartal Teaching and Research Hospital between April 2010 – March 2012 with spontaneous subarachnoid hemorrhages (SAH), undergone a 4-way digital subtraction angiography (DSA) (both carotid and vertebral arteries) which revealed

anterior communicating artery aneurysms (AcoAA). Patients were preoperatively evaluated for SAH by using Fisher Grading and WFNS grading systems.

Only sufficiently valuable images, obtained intraoperatively through the ocular of the microscope of the AcoAA cases were included in the study. Cases not fitting this criteria were excluded.

The angiographic images, containing both carotid and vertebral arteries, were obtained using a 4-way digital subtraction angiography (DSA) in a different hospital. Perforating arteries of the anterior communicating artery segment were evaluated by DSA for every participating patient. Perioperative images were taken with Nikon Coolpix 4500 Japan photo camera.

Retrospective assessment of DSA imaging was conducted by skilled radiology operators and were evaluated by three Neuroradiologist. The intraoperatively collected recordings and perioperative observations were evaluated by two Neurosurgeons, who were experienced in vascular surgery.

The number of perforating arteries (PA) of AcoA was classified into four groups. Those are, Group 1: No PA; Group 2: PA 1 to 3; Group 3: PA 4 to 6; Group 4: PA > 6.

## RESULTS

For our study, we included 13 patients, ages varied from 28-70, 4 patients were female while the remaining 9 were male. 11 patients were classified as Fisher grade 2; 1 patient as Grade 3 and 1 patient as Grade 4. 8 patients were classified as WFNS grade 1, 4 patients as grade 2 and 1 patient as grade 3.

## Radiologic assessment

The DSA results were retrospectively evaluated by three specialized radiologists. The assessment was done retrospectively at different radiology institutions. Double-blinded assessments of the obtained DSA images were conducted by neurologically specialized radiologists not familiar with the cases. 6 patient had dominant inflow from the left anterior cerebral artery (3 female, 3 male), 7 patient had dominant inflow from the right anterior cerebral artery (1 female, 6 male) (Table 1).

First Neuroradiologist (NR-1) evaluations of DSA revealed; no perforating artery of AcoA seen in 2 patients (Group 1); 1-3 perforating arteries of AcoA

seen in 7 patients (Group 2); 4-6 perforating arteries of AcoA seen in 4 patients (Group 3) (Table 2).

Second Neuroradiologist (NR-2) evaluations of DSA revealed; no perforating artery of AcoA seen in 2 patients (Group 1); 1-3 perforating arteries of AcoA seen in 11 patients (Group 2). No patient was evaluated as Group 3 (Table 2).

Third Neuroradiologist (NR-3) evaluations of DSA revealed; no perforating artery of AcoA seen in 2 patients (Group 1); 1-3 perforating arteries of AcoA seen in 6 patients (Group 2); 4-6 perforating arteries of AcoA seen in 5 patients (Group 3)(Table 2).

In our study, it was seen that all three radiological assessments overlap with each other in 6 cases (46.1%) (Case No. 5, 6, 7, 8, 10, 12). On all radiological examinations, PA was found to be the most common (61.5%) between 1 and 3 (Group 2).

**Table 1.** Display of cases according to age, gender, aneurysm filling direction, Fisher Grade, WFNS Grade.

Case No	Age	Gender	Fisher Grade	WFNS Grade	Aneurysm filling direction
01	30	Female	2	3	Left
02	50	Male	2	1	Right
03	38	Female	2	2	Left
04	65	Male	4	2	Right
05	70	Female	2	1	Right
06	63	Male	2	1	Right
07	62	Male	2	1	Left
08	65	Male	2	1	Right
09	40	Male	2	1	Left
10	63	Male	3	2	Right
11	69	Female	2	1	Left
12	44	Male	2	1	Right
13	28	Male	2	2	Left

**Table 2.** Comparison of radiologic data and number of intraoperative perforating arteries. Group 1: 0 (no PA seen); Group 2: PA numbers 1-3; Group 3: PA numbers 4-6 ; Group 4 : PA numbers more than 6.

Case No	Neuroradiologist-1	Neuroradiologist-2	Neuroradiologist-3	Surgical assessment
01	0	1 - 3	4 - 6	4 - 6
02	4 - 6	1 - 3	4 - 6	4 - 6
03	1 - 3	0	0	1 - 3
04	1 - 3	1 - 3	4 - 6	> 6
05	1 - 3	1 - 3	1 - 3	1 - 3
06	1 - 3	1 - 3	1 - 3	4 - 6
07	1 - 3	1 - 3	1 - 3	4 - 6
08	1 - 3	1 - 3	1 - 3	1 - 3
09	4 - 6	1 - 3	4 - 6	> 6

10	1 - 3	1 - 3	1 - 3	1 - 3
11	4 - 6	1 - 3	4 - 6	4 - 6
12	0	0	0	1 - 3
13	4 - 6	1 - 3	1 - 3	4 - 6

### Surgical assessment

Results collected from the exact digital images obtained from intraoperative microscope and from the intraoperative records of two neurosurgeons specialized in vascular surgery; all patients revealed perforating arteries of AcoA, 1-3 perforating arteries of AcoA seen in 5 patients (Group 2), 4-6 perforating arteries of AcoA seen in 6 patients (Group 3), more than 6 perforating arteries of AcoA seen in 2 patients (Group 4) (Table 2).

Result of surgical assessment revealed that 38,4% (5/13) of all cases had 1-3 perforating arteries (Group 2).

### Comparison of assessments

Radiologic and surgical assessments were compared to evaluate preoperative DSA's predictivity and reliability on PA.

Equal or more numbers of perforating arteries (PA); 10/13 (76,9 %) were obtained from surgical evaluation compared to radiological assessment (Case No. 1,2,3,4,6,7,9,11,12,13). Eight (61,5%) cases revealed high PA numbers from surgical assessment compared to two radiological assessments.

In 8 cases (61,5%) at least one of the three radiological evaluation classified perforating artery group (PA) same as surgical assessment. In 5 cases (38,5%) surgical assessments showed more PA numbers than in all radiological assessments.

In one case (Case No. 1) eventhough all radiological evaluations revealed no PA, surgical assessment classified case as Group 2 (1-3 perforating arteries of AcoA).

### DISCUSSION

Cerebral Angiography gives the best possible insight into the cerebral vascular anatomy and pathology of a patient's cerebral saccular aneurysms, hence being the most trusted and used method when encountering these patients in the neurosurgical clinic. Cerebral angiography is gained utilizing several different techniques such as 4-way Digital subtraction angiography (DSA), magnetic resonance angiography (MRA), and computed tomography angiography. DSA is still the gold standard imaging technique in most centers (2, 3).

Our clinic uses the 4-way DSA in our daily practice, leading us to use the said method again in our study to define PA number concentration. The anatomical research conducted by Türe and Serizawa on the numbers of perforating artery (PA) of the anterior communicating artery has immense importance in our study (12, 13). Türe et al. presented results showing 1-6 perforating arteries (average 2,5) with 0,15-2,1 mm diameter on AcoA segment as well as dividing the perforating arteries into three subgroups according to their orientations; hypothalamic, subcallosal, and median callosal (13).

Results obtained from the study of Serizawa et al. was conducted on 30 human cadavers and revealed 2-8 perforating arteries (average 4,1) with 0,1-0,8 mm diameter on the AcoA segment. They also divided the perforating arteries into three subgroups according to their orientation; hypothalamic, subcallosal, chiasmatic (12).

Our study aimed to determine the number of perforating arteries of the AcoA segment parallel to these two studies, which are seen in the sources and constitute the primary reference in this regard.

Our study differs from the previously mentioned two papers, as they describe the results of definitive anatomical research collected from cadavers. Our study, however, focused on the results gathered from the evaluation of DSA images and intraoperatively obtained images from the surgical microscope, giving live-pictures, hence our paper is not an anatomy paper as every patients DSA, AcoA perforators number was tried to be determined.

The existence of the Heubner artery within the arterial system was questioned during surgical interventions. Evaluating the diameter of perforating arteries was another contrasting factor of our study.

All data collected from radiologic evaluations were compared with the acquired intraoperative PA numbers from surgical procedures done by two neurosurgery specialists.

As far as our research has shown, no other PA studies are utilizing intraoperative AcoA images. We believe that our study, being the first of its kind in this field, will help create a database and lead as an example for further research.

According to our literature review, there are three major studies about perforating artery numbers. A study on 20 human cadavers conducted by Türe et al. revealed 1-6 PA (average 2,5), a study on 30 human cadavers conducted by Serizawa et al.

showed 2-8 PA (average 4,1), and study of Marinkovic et al. revealed only 1-5 PA (average 2) respectively. (8, 12, 13). The most common PA number, according to our radiologic assessment, is between 1-3 PA. Although our results fail to measure-up to Serizawa, they are compatible with the findings of Türe et al. and Marinkovic et al. According to surgical observation results, half of the cases were categorized as Group 3. This result is not different from the average results at the sources and appears to be in the upper and lower limits. Four main perforating artery groups of AcoA were defined in the following manner: Group 1 no perforating artery, Group 2 perforating artery number between 1 and 3, Group 3 perforating artery numbers between 4 to 6, Group 4 perforating artery number more than 6. This classification has never been defined before, yet we need a more extensive database to prove PA numbers' radiological and surgical validity between 1-6.

Our study showed that all three radiological assessments overlap with each other in 6 cases (46.1%). In all radiological examinations, PA numbers were most commonly (%61.5) classified as Group 2.

According to the results of the surgical assessment, the rate of having 1-3 PA (group 2) is only 38,4% (5/13), which shows the superiority of DSA, yet during the surgical intervention, the occurrence of PA resulted in being higher when compared to the numbers revealed by the DSA. Perforating artery numbers obtained from the surgical assessment were almost equal to or higher than the radiological assessment results (76,9%). According to surgical evaluations, 61,5% of cases have higher PA numbers than two radiological assessments, which supports the possibility of having higher numbers of PA during surgical observation than results collected from DSA imaging. Furthermore, the surgical observation revealed an even higher PA occurrence (in 38,4% cases) when looking at the previous radiological evaluations.

The numbers of perforators are a highly essential value for preoperative preparations and evaluations for aneurysms surgeries. Especially AcoA aneurysm dome projection changes both surgical approaches and relations between perforators (3, 4). Protecting these perforators is important for favorable postoperative outcomes. Preservation of perforators is necessary for hypothalamic and fornicial blood

supply to preserve memory and endocrine functions (4, 9, 15).

Our observations lead us to believe that perioperative PA encounter was higher than preoperatively taken DSA revealed.

However, to speak of a significant result for either method, a more extensive database and further studies need to be conducted to give meaningful outcome possibilities before going into surgery. Nevertheless, our study showed surgeons need to be aware of the DSA information can be less than the reality. So preoperative evaluations and surgical approach plannings need to be done by considering this.

### CONCLUSION

Perforating artery segments of the anterior communicating artery of the anterior cerebral artery are essential structures to recognize during surgical interventions. Preoperative evaluation of perforating arteries and other vascular anomalies can cause notable differences in the outcome of ACoA aneurysm surgeries. Perforating arteries of ACoA were evaluated according to the criteria defined in previous studies. We aimed to determine the accuracy and reliability of cerebral angiographic evaluation of the ACoA segment's perforating arteries before the surgical procedure.

The DSA results were retrospectively evaluated by 3 different specialized radiologists. The intraoperatively collected recordings and images were evaluated by two neurosurgeons, experienced in vascular surgery. Our observations lead us to believe that perioperative PA encounter was higher than DSA images taken preoperatively. Surgeons should not exclude the possibility that there might be more perforating arteries than detected in DSA to avoid misleading the number of PA seen in the preoperative radiologic assessment.

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# Iatrogenic spinal cord herniation. A rare clinical entity and review of literature with 16 cases

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## ABSTRACT

**Introduction:** Spinal cord herniation occurs idiopathically or is due to defective or weakened dura mater resulting from iatrogenic or traumatic lesions. Although there have been many reports of idiopathic cases, there are few reports of postoperative iatrogenic spinal cord herniation. The authors describe a rare case of postoperative spinal cord herniation in the cervical spine, with an extensive analysis of reported cases

**Materials and methods:** This article reports a documented case of postoperative spinal cord herniation. The case description is followed by an analysis of the literature.

**Results:** A 67-year-old woman who had cervical laminectomy 3 weeks before for cervical laminectomy, presented with neck pain and torticollis after coughing. The MRI findings showed a cervical medulla herniation with cerebrospinal fluid (CSF) leakage. The patient underwent surgery to reduce the herniation and duroplasty with subsequent complete resolution of symptoms. Over the previous 50 years (1973–2023), 16 post-operative spinal cord herniation cases were reported. The mean patient age was 43.3 years (range 15–67 years). There was a male predominance (80%). The mean onset period after surgery was 292 weeks (range, 1 week to 728 weeks). Clinical symptomatology was polymorphic with non-specific signs.

**Conclusion:** Iatrogenic spinal cord herniation is an extremely rare occurrence after spine surgery. The diagnosis must be evoked in case of any neurological degradation after surgery of the cervical spine, thoracic spine or thoracolumbar junction. The surgical management gives satisfactory clinical results.

## INTRODUCTION

Spinal cord herniation occurs idiopathically or is due to defective or weakened dura mater resulting from iatrogenic or traumatic lesions. Although there have been many reports of idiopathic cases, there are few reports of postoperative iatrogenic spinal cord herniation (10).

The authors describe a rare case of postoperative spinal cord herniation in the cervical spine, with an extensive analysis of reported cases focusing on pathogenesis, therapeutic management and outcome.

## Keywords

iatrogenic spinal cord  
herniation,  
spinal compression,  
spinal cord surgery



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## METHOD

This article reports a documented case of postoperative spinal cord herniation. The case description is followed by an analysis of the literature. An extensive review of the literature of the previous 50 years (1973–2023) was performed on PubMed, Google Scholar and EMBASE, using the following keywords: iatrogenic spinal cord herniation, postoperative spinal cord herniation. The review covered documented spinal cord herniation in cervical, thoracic and thoraco-lumbar junction region. Articles in languages other than English or French and articles unavailable in the databases weren't included.

## RESULTS

For our study, we included 13 patients, ages varied from 28-70, 4 patients were female while the remaining 9 were male. 11 patients were classified as Fisher grade 2; 1 patient as Grade 3 and 1 patient as Grade 4. 8 patients were classified as WFNS grade 1, 4 patients as grade 2 and 1 patient as grade 3.

## CASE REPORT

A 67-year-old woman who had undergone a cervical laminectomy three weeks earlier for cervical myelopathy suffered neck pain and stiff neck after coughing.



**Image 1.** Cervical MRI obtained three weeks after a cervical laminectomy showing a spinal cord herniation.

Clinical examination of this patient revealed a 4/5 limb motor deficit with a vivacity of osteostendinous reflexes. Magnetic resonance imaging (MRI) revealed a cervical spinal cord herniation at the level C2-C3 with leakage of cerebrospinal fluid (Image 1).

The patient underwent surgery to reduce the herniation. The intraoperative morphology of the dural defect was a 2 cm one with no adhesion of the spinal cord. After the reduction of the herniation, the dura mater defect was closed indirectly using a dural patch.

The patient recovered completely from his motor deficit a week after surgery with a full resolution of all other signs (Image 2).



**Image 2.** Post operative MRI showing the resolution of the spinal cord herniation.

## REVIEW OF LITERATURE

Over the previous 50 years (1973–2023), 16 post operative spinal cord herniation cases were reported (Table1). The mean patient age was 43.3 years (range, 15–67 years). There was a male predominance (80%). Mean onset period after surgery was 292 weeks (range, 1 week to 728 weeks). The Clinical symptomatology was polymorphic with non-specific signs. The most frequent location was the cervical spine (73.30%). The most repair technique of dural defect was duraplasty with dural patch in 12 case (75%) and direct suture of the dura mater in 4 cases (25%). Almost all patients (86,67%) improved neurologically after surgery.

**Table 1.** Data of 16 post-operative spinal cord herniation in the literature

Author	Age and sex	Level of herniation	Previous surgery	Onset period after surgery	Symptoms	Operative repair technique	Operative result
Cobb et al. 1973	39M	C5-C6	Laminectomy	03 Years	Motor and sensory dysfunction in both upper and lower limbs	Duraplasty	Improvement
Burres et al. 1978	41M	C2	C3-6 posterior decompression (Laminectomy)	18 Years	Motor and sensory dysfunction in left arm function	Duraplasty	Improvement
Dunn et al 1987	33M	C1-C2	C1-2 wire fixation for odontoid fracture	2 weeks	Numbness and weakness in the left hand and leg	Duraplasty	Improvement
Hosono et al 1995	45M	C2-C3	Laminectomy	14 Years	Gait disturbance and clumsiness of the right fingers	fibrin glue	Improvement
Belen et al 2009	22M	C1-C2	FMD with C1 laminectomy for Chiari malformation	07 Years	Worsened hand function in both upper extremities and gait disturbance	Duraplasty	Improvement
Moriyama et al. 2013	51M	C7	Spinal tumor	10 Years	Gait disturbance and urinary incontinence	Duraplasty	Improvement
Zakaria et al. 2013	57M	TH12-L1	Intramedullary cyst resection	8 weeks	Gait disturbance, and numbness of both lower legs	Direct closure of dura	No Improvement
Iencean et al. 2014	51M	C2-C3	Ependymoma resection	5 years	Spastic tetraparesis with impossibility of in standing and walking	Duraplasty	No Improvement
Abd et al 2015	56M	C2-C3	Neurofibroma	05 years	Neck pain and progressive weakness of the right upper limb	Duraplasty	Improvement
Seung-Jae Hyun 2016	51F	T2	Laminectomy for OPLL	01 week	paraparesis (motor grade 2-3)	Duroplasty	Improvement
Hiroaki Nakashima 2020	55M	C4-C5	cervical laminoplasty	08 Years	gait disturbance, paralysis of lower limbs (muscle manual testing, 2-4/5)	Duraplasty	Improvement
Hiroaki Nakashima 2020	60M	C2-C3	Laminectomy for OPLL	03 MONTHS	worsening lower leg numbness with gait disturbance	Duraplasty	Improvement
Hiroaki Nakashima 2020	47F	TH11-TH12	durotomy for resection of a spinal cord tumor	02 MONTHS	left leg numbness	Duraplasty	Improvement
Axumawi Gebreyohanes 2022	15F	T10	Thoracic laminectomy	03 months	reduced lower limbs power and thoraco-lumbar dermal hypoaesthesia	Duraplasty	improvement
Ayesha Arshad 2022	16M	T11-T12	resection of thoracic ependymoma	06 months	weakness in lower limb	Duraplasty	improvement
present case 2023	67F	C3-C4	Cervical laminectomy	03 weeks	neck pain and stiff neck and tetraparesis	Duraplasty	Improvement

## DISCUSSION

Spinal cord herniation is described in the literature as a rare cause of spinal cord dysfunction (4,6,11,19). It can commonly be classified into spontaneous, idiopathic, iatrogenic, and posttraumatic. Spontaneous and idiopathic presentations have been described more commonly in the literature (11)

and herniation due to a traumatically acquired dural defect is the least reported cause (4,11).

The causes of Cervical iatrogenic spinal cord herniation were hypothesized as weakness of the dura mater, cervical lordosis, and physiological damage to the spinal cord that gradually resulted in extrusion of the cord into a pseudomeningocele

through a defect of the dura mater (3,9,10,16).

Anatomically, the spinal cord is not strictly located in the center of the dural sheath. In the cervical spine, it is located more dorsally, whereas in the thoracic spine it is more ventral. The spinal cord also has a certain mobility. During flexion movements, it moves in a craniocaudal direction and during extension, it moves in an anteroposterior direction, as revealed by magnetic resonance imaging studies (1).

Spinal cord herniation is a rather rare phenomenon whose occurrence requires the presence of two hypothetical phenomena presented by Kumar and Onhishi (5,12). First, there must be a dural breach leading to a pseudomeningocele and second, this breach must be located in the concave curvature of the dural sheath (dorsally for the cervical spine and ventrally for the thoracic spine).

In case of a breach that goes unnoticed, a pseudomeningocele is formed with the spinal cord abutting the breach. Then the pulsations of the CSF push the spinal cord further into the pre-existing cyst, causing a herniation of the spinal cord. The dynamic anteroposterior movement of the spinal cord and the flow of CSF into and out of the dural defect with each heartbeat and respiratory movement have been observed intraoperatively (2).

Clinically, approximately two-thirds of reported cases of thoracic spinal cord herniation presented with the Brown-Séquard syndrome, and one-third with symmetrical spastic paraparesis. Isolated sensory deficits and sphincter dysfunctions are less common (15,18).

In the case of cervical spinal cord herniation in general, the clinical manifestation is polymorphic; consisting of a sensory and motor deficit of the limbs and walking disorders (Table 1). In our presented case, the motor deficit of the limbs was associated with neck pain and Torticollis.

In current practice, MRI is the investigation of choice; three dimensional sequences/volume data and thin slice images can be acquired to aid data reconstruction. These may also be of use in surgical planning. In certain cases, computed tomographic myelography can be an aid in establishing the diagnosis of spinal cord herniation or in differentiating pseudomeningoceles from arachnoid cysts or arachnoid bands (13). Once the diagnosis of this rare complication is made, it must be treated surgically.

The goals of the surgical treatment are to reduce the herniation, return the spinal cord to its normal position, and prevent recurrence. Removal of the pseudomeningocele and release of the cord under the microscope are necessary if it is adhering to the dural margin. After reduction of the herniation in the subarachnoid space, the dural defect is repaired using different techniques that have been described (14). The most common technique is to repair the dural defect with using either an autologous graft that can be made of Fascia lata, muscular tissue, or an artificial dural made of dural patch (7,8,14,17). In that presented case, we used fascia lata to perform the duraplasty.

Previous reports showed neurological improvement after surgery for spinal cord herniation in the majority of cases (10). In that present case, The patient recovered completely from his motor deficit one month after surgery with a full resolution of all other signs.

## CONCLUSION

Iatrogenic spinal cord herniation is an extremely rare occurrence after spine surgery. The diagnosis must be evoked in case of any neurological degradation after surgery of the cervical spine, thoracic spine or thoraco-lumbar junction. The surgical management that consists of a reduction of the spinal cord herniation hernia associated with a repair of the dural defect gives satisfactory clinical results.

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# Chronic subdural hematoma in the posterior fossa. A case report and review of the literature

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## ABSTRACT

Chronic subdural hematoma (CSH) in the posterior fossa is extremely rare in the adult population. CT scanning is generally accurate and sufficiently sensitive in the diagnosis of supratentorial subdural hematomas, while MRI has clearly shown its superiority in the detection of subdural collections at unusual locations and particularly in the detailed analysis of the posterior cranial fossa. The surgical strategy is still controversial. We report a case of CSH in the posterior fossa successfully treated with a suboccipital craniectomy. A 70-year-old man; has developed headaches, nausea, cerebellar syndrome and ataxia of walking. Radiological examinations revealed the appearance of a right CSH in the posterior fossa associated with hydrocephalus. Upon rapid deterioration of the patient's consciousness, urgent treatment was required. A small right suboccipital craniectomy was to access the hematoma. Postoperative computed tomography showed that the CSH and hydrocephalus had been successfully treated.

## INTRODUCTION

Chronic subdural hematoma (CSH) in the posterior fossa is extremely rare in adult population [1]. Different from supratentorial CSH, the optimal treatment has not been elucidated yet. CSH in the posterior fossa, associated with hydrocephalus, need an urgent treatment. However, the optimal surgical treatment is still controversial due to its scarcity. We report a case of a right CSH in the posterior fossa associated with hydrocephalus, which was successfully treated with a small right suboccipital craniectomy under general anaesthesia.

## CASE REPORT

A 70-year-old man was admitted to other formation for treatment-resistant headaches, the clinical examination revealed a right kinetic cerebellar syndrome, the haemostasis assessment was normal, the CT-scan showed a small chronic subdural hematoma of the posterior fossa, the patient was treated by conservative treatment, 2 weeks later the patient was referred to our service for worsening headache, nausea, consciousness disorder (Glasgow Coma Scale: 14) and ataxia of

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## Keywords

intracranial hematoma,  
posterior fossa,  
subdural hematoma

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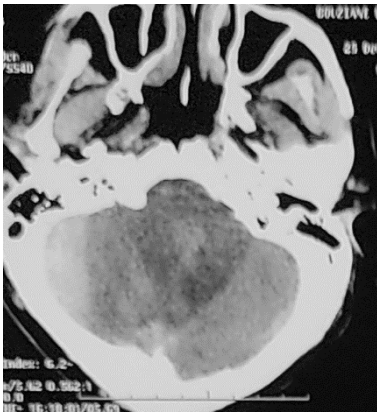
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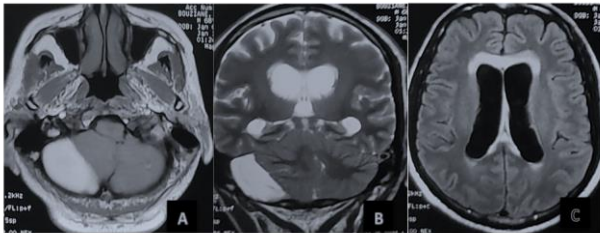
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walking, CT-scan and RMI showed an increase in the hematoma with active hydrocephalus (Fig.1 and 2) , MRI angiography was normal, As his consciousness deteriorated rapidly, the patient was taken to the operating room. A suboccipital right craniectomy was performed and a typical chronic subdural hematoma was drained after opening the dura-mater. On opening the dura, the old liquefied blood gushed out, suggesting hypertension in the posterior fossa, no drain has been put in place since the re-expansion of the parenchyma is asserted. In the postoperative period, the patient improved quickly and was discharged without neurological deficits. The postoperative CT scan was unremarkable.



**Image 1.** Ct-scan showing chronic subdural hematoma of the right posterior cerebral fossa.



**Image 2.** Preoperative head IMR: (A) Axial T1 weighted MRI; (B) axial T2 weighted MRI, showing the chronic subdural hematoma of the right cerebral fossa. (C) Flair weighted MRI showing an active hydrocephalus.

## DISCUSSION

HSC is one of the most common diseases in neurosurgical practice, and the incidence is reported as 1 to 2 cases per 100,000 population per year [1,2]. Supratentorial CSH usually appears a few months after a mild head injury. In contrast, CSH in the posterior fossa is extremely rare in the adult population. Only 16 cases have been reported to date (Table 1). Of these, 3 patients (18%) had a history of head trauma, and 11 patients (71%) had

bleeding disorders or anticoagulant / antiplatelet therapy.

Usually, subdural infratentorial hematomas result from traumatic lesions of the posterior fossa and lesion of the bridging vein, other authors attribute these lesions to the rupture of an aneurysm or to an arteriovenous malformation of the posterior fossa [1], or even to an intracranial hypotension syndrome [3]. It is well known that anticoagulant therapy or coagulation abnormalities are the main risk factor for subdural bleeding [4]. In our case, the bleeding should have been caused by an injury to the bridging veins in the posterior fossa, secondary to mild head trauma not noticed by the patient.

CT scanning is generally accurate and sufficiently sensitive in the diagnosis of supratentorial subdural hematomas, while MRI has clearly shown its superiority in the detection of subdural collections at unusual locations and particularly in the detailed analysis of the posterior cranial fossa. Classically, MRI can evaluate the age of the bleeding through the signal on both T1 and T2 sequences: isoT1/hypoT2 in the acute stage, hyperT1/hypoT2, then hyperT2 in the subacute stage, and hypoT1/hyperT2 for the late stage.

In general, burr hole surgery or twist drill craniostomy on the convexity of the skull under local anesthesia and mild sedation is often performed for symptomatic supra-Tentorial CSH, and is widely used in neurosurgical practice [5,6]. On the other hand, several options therapies should be considered for posterior fossa CSH. Some surgical strategies have been reported for HSC in the posterior fossa. Of the 13 symptomatic cases, 11 underwent surgical procedures, including lateral suboccipital craniotomy, small craniectomy, and burr hole trepanations under general anesthesia or local anesthesia. Surgery performed under local anesthesia carries a lower risk of complications in critically ill or elderly patients, in contrast, general anesthesia is required to perform safe surgery on unilateral and bilateral posterior fossa HSCs [7].

Hydrocephalus caused by HSC of the posterior fossa has been described in 7 cases, including ours. Ventricular drainage was established in 2 of them. In the rest of the cases, the evacuation of the hematoma led to the disappearance of the non-communicating hydrocephalus. As associated hydrocephalus can rapidly deteriorate neurologic status, prompt surgery should be considered.

**Table 1.** Literature review of chronic subdural hematoma in the posterior fossa

No	Author	Year	Age	Sex	Side	Symptoms	Preceding trauma	Coagulation disorder	Hydrocephalus	Treatment	Outcome
1	Kanter	1984	59	F	L	Coma	No	Yes	Yes	Surgical evacuation	MD
2	Izumihara	1993	70	M	L	Gait disturbance	No	No	No	Conservative	GR
3	Izumihara	1993	72	F	Bil	No	Yes	Yes	No	Conservative	GR
4	Ashkenazi	1994	65	F	L	Nystagmus	UK	Yes	No	Craniotomy	GR
5	Lagares	1998	65	F	BIL	No	No	Yes	Yes EVD	Conservative	GR
6	Kachkov	1999	41	F	R	Ataxia	UK	No	No	Surgical evacuation	GR
7	Stendel	2002	70	F	BLT	Vertigo	No	Yes	No	Trépanations	GR
8	Pollo	2003	52	F	BLT	Coma	No	Yes	Yes EVD	Trépanations	GR
9	Costa	2004	64	F	R	Vertigo	No	No	Yes	Craniectomy	GR
10	Berhouma	2007	38	F	R	Vertigo	No	Yes	No	Craniectomy	GR
11	Kurisu	2012	86	F	BLT	Tetraparesis	Yes	No	No	Trepanations	GR
12	Takami	2013	83	F	BLT	Headache	No	Yes	Yes	Conservative	GR
13	Takemoto	2016	69	F	BLT	Ataxia	No	Yes	No	Craniectomy	MD
14	Ryuzaburo	2017	86	F	BLT	Headache	No	Yes		Cranientomy	GR
15	Takuro	2018	74	M	BLT	Somnolence	Yes	Yes	Yes	Trepanation	GR
16	<u>Our case</u>	<u>2020</u>	<u>67</u>	<u>M</u>	<u>R</u>	<u>Ataxia, vertigo</u>	<u>No</u>	<u>No</u>	<u>Yes</u>	<u>craniectomy</u>	<u>GR</u>

## CONCLUSION

Subdural hematoma of the posterior cranial fossa can be a potentially fatal injury. However, if the lesion diagnosed early and treated properly, the prognosis is not always bad [8,9].

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# Cortical blindness and brain stem ischemia following burr hole evacuation of chronic subdural hematoma. A retrospective analysis of five cases

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## ABSTRACT

**Background:** Chronic SDH is commonly performed in neurosurgery. The surgery usually has good surgical outcomes. There have been few cases reports reporting cortical blindness and brain stem stroke as a dreaded complication of the same.

**Materials and methods:** It is a retrospective, observational, descriptive type of study with analysis of patients operated for chronic SDH from March 2021 to March 2023 and reported an untoward outcome of vision loss or brainstem stroke following surgery. The cases have been reported with possible aetiology underlying the unfavourable outcome. The literature was reviewed for similar cases and a comparative analysis was done with possible hypotheses for the outcome.

**Observation and results:** An overall 5 such cases have been reported during this period. Two cases of bilateral and three cases of unilateral chronic SDH have been reported. Out of five, two cases did not have a preceding history of trauma probably spontaneous in nature. Possibility of PRES in one case, transtentorial herniation, thrombosis, and spontaneous intracranial hypotension with kinking of vessels have been proposed. Further studies are required to address this untoward complication following evacuation of chronic subdural hematoma.

**Conclusions:** A high index of suspicion, prompt recognition and management of reversible causes, slow decompression of hematoma especially in bilateral cases, and good hydration to prevent the possibility of thrombosis are key to preventing such complications. Also keeping the possibility in mind add on better counselling and prognostication of case in pre-surgery period.

## INTRODUCTION

Chronic SDH is one of the most encountered emergencies in Neurosurgery practice. The chief management strategy involves surgical intervention although the type of surgery performed may vary

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## Keywords

hematoma,  
chronic subdural,  
cortical blindness,  
spontaneous intracranial  
hypotension,  
brain stem infarction

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with variability in approach. The incidence of disease is 1-5.3 cases per 100000 population, usually disease in unilateral but may involve bilateral side in one in five cases [1][12]. The possible etiology involves trauma most commonly, coagulopathies, antiplatelet use, intracranial hypotension (spontaneous or iatrogenic) etc. The usual prognosis after surgical evacuation is usually good. The common adverse outcomes described in literature includes rebleed, recurrence and requirement of redo surgery [8][11]. However there have been case reports in literature citing bilateral cortical blindness, neurological deterioration because of brain stem ischemia following successful evacuation of CSDH. We here report a retrospective study of five such cases at our institute and discuss the possible basis of such an adverse outcome following optimal surgical management of this common entity.

#### MATERIALS AND METHODS

This is a retrospective, descriptive, observational study carried out at our tertiary care institute with analysis of patient's data who underwent surgery for chronic SDH and had an untoward outcome in form of vision loss or neurological deterioration with brain stem stroke following surgery; operated from March 2021 to May 2023.

All the patients were operated with similar technique involving two burr holes and hematoma evacuation depending on side involved with irrigation and putting subgaleal drain to reduce chances of recurrence. All patients were put on high flow oxygen for next 24 hours with being supine with head at 30 degrees propped up. Intravenous fluids continued till three days post surgery at 2000-2400 ml per day. Patients were discharged on day 4 as per clinical condition with repeat NCCT brain only if required according to patients' clinical status.

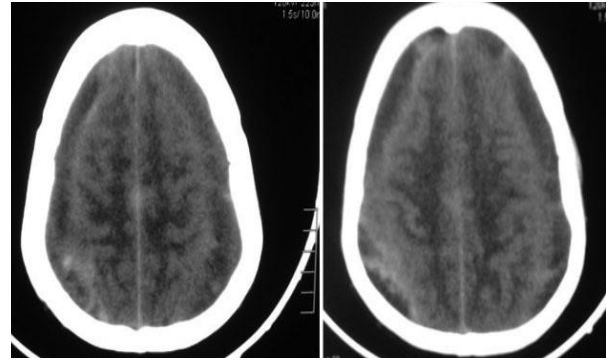
The data so observed were retrospectively analyzed and possible hypothesis for the etiology involved have been proposed. The literature was reviewed for similar case reports and series and our findings were compared with those previously reported in literature.

#### OBSERVATION AND RESULTS

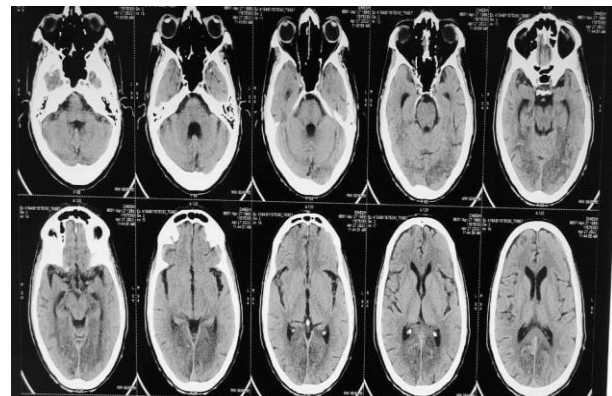
##### Representative Case 1

A 52-year-old alcoholic male patient with history of hypertension for last fifteen years taking on and off medications for the same, presented with chief

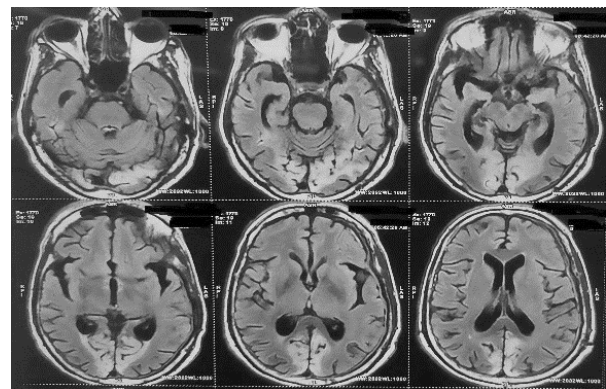
complaints of severe holocranial headache for last seven days, altered sensorium for last 24 hours. There had been a history of road traffic accident one and a half month back. No history of any other comorbidity, not on any anti platelets or anti-coagulant drugs. Upon examination, pulse was 64/min, blood pressure was 160/98 mm Hg, patient was drowsy, pupils equally reacting to light. NCCT brain was suggestive of bilateral frontoparietal chronic SDH (figure 1a).



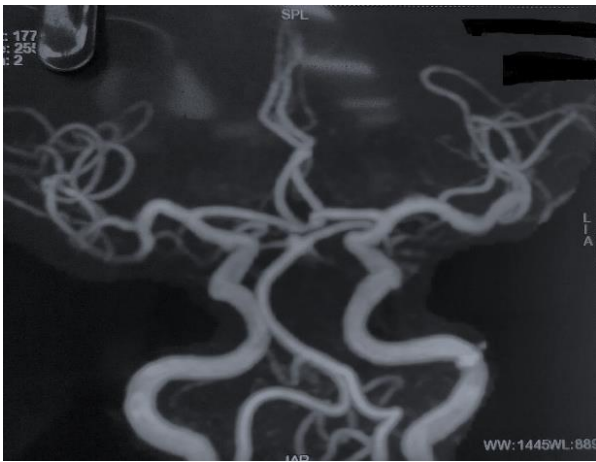
**Figure 1a.** Bilateral frontoparietal Chronic SDH.



**Figure 1b.** Post surgery bilateral occipital hypodensities.



**Figure 1c.** MRI brain suggestive of T2 FLAIR hyperintensities but no corresponding diffusion restriction.



**Figure 1d.** MRA brain suggestive of no vessel cut off or compromise.

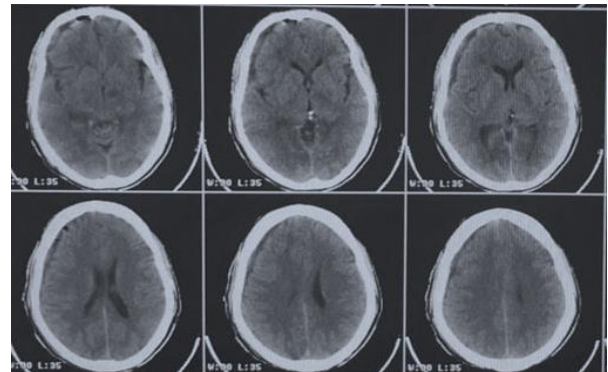
The patient underwent surgery as per protocol and symptomatically improved. Post operative management was also according to our standard practice. Patient was discharged on day 4 of surgery. Upon follow up in OPD on day 8 of surgery, patient was happy with improved symptoms but his relatives complained of difficulty in reaching to and holding the things when passed on to the patient. Although patient denied any diminution of vision.

Patient was readmitted and an NCCT brain was done which revealed good removal of hematoma but hypodensity in bilateral occipital region (Figure 1b). Ophthalmology work up revealed normal fundus findings but no perception of light in both eyes. An MRI brain with MRA brain was done which was suggestive of T2 FLAIR hyperintensities located corresponding to those in NCCT but there was no diffusion restriction and normal ADC findings (Figure 1c). MRA brain suggestive of no vessel compromise (Figure 1d). Blood investigations including lipid profile were normal and 2 D echo was also normal.

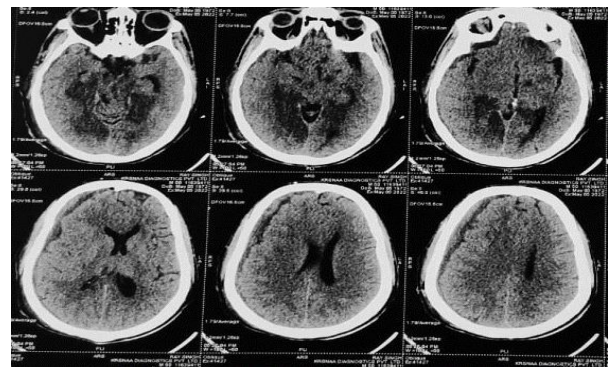
Upon meticulous review of previous admission record, an episode of hypertension to the range of 190/110 mm Hg during surgery was noted which was managed with intravenous labetalol and other anesthetic agents. We presumptively suspected a diagnosis of PCA territory stroke or posterior reversible encephalopathy syndrome (PRES). An EEG was done but it was also normal recording. Patient was started with steroids with strict blood pressure syndrome and an anti-convulsant but there was no improvement in patient vision. In follow up visits, patient was later aware of his vision loss.

### Representative Case 2

A 48-year-old chronic alcoholic male with no known comorbidity and history of fall one month back under alcohol influence presented to emergency room with history of headache on and off for last one week and history of loss of consciousness and altered sensorium for last 12 hours.



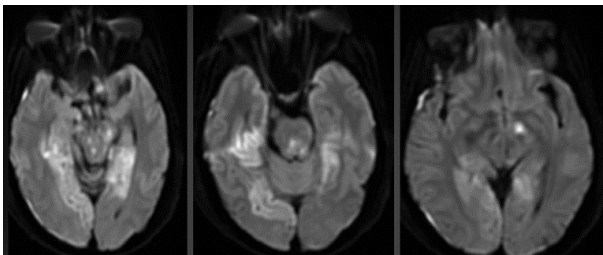
**Figure 2a.** Post Op day 2 NCCT Brain showing resolution of mass effect.



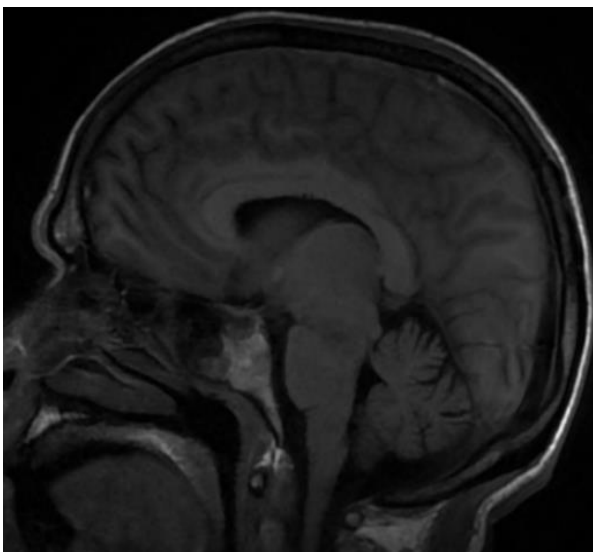
**Figure 2b.** NCCT on day 5 after deterioration; hypodensities in B/L PCA territory.

Upon examination vitals were stable, patient was unconscious with a Glasgow coma score of 5

(E1VetM4) with NCCT brain suggestive of right frontotemporoparietal chronic subdural hematoma with mass effect. Patient underwent burr hole and hematoma evacuation surgery with irrigation and subgaleal drain as per standard protocol. Post surgery phase, patient improved in symptoms, weaned off from mechanical ventilator and extubated on day 2 of surgery with following simple commands. A check NCCT brain on day 2 (Figure 2 a) suggestive of resolution of mass effect and satisfactory removal of hematoma. On day 5 of surgery, there was dip in consciousness again with need to reintubate the patient. A NCCT brain post deterioration, suggestive of hypodensities in PCA territory involving brain stem and an increase in hyperdensity along right frontotemporoparietal convexity as compared to day 2 post surgery scan (Figure 2 b). An MRI brain with MRA brain and neck vessels, suggestive of T2 FLAIR hyperintensity with diffusion restriction in PCA territory involving brain stem suggestive of acute infarct (Figure 2 c). Other routine investigations and 2 D echo was normal.



**Figure 2c.** Diffusion restriction along B/L PCA territory.



**Figure 3.** No sagging of brain in coronal cuts.

### Representative case 3

A seventy-year-old male with known case of Alzheimer's disease and known diabetic for last 10 years, presented to us in altered sensorium for last 48 hours with history of repeated falls. Upon examination, vitals were stable, pupils bilateral reacting, GCS of 6 (E2VetM4). Blood sugar levels were 154mg%. NCCT brain suggestive of bilateral frontoparietal chronic SDH with no mass effect on either side. Patient was taken to OR and underwent surgery under standard protocol as per our practice. Patient improved in post surgery phase on day 1. There was spontaneous eye opening, with patient localizing pain and on oxygen support. Patient was planned for extubation but patient deteriorated same evening and repeat NCCT brain was suggestive dense hypodensities in B/L occipital lobes and brain stem. Patient was put on mechanical ventilator and succumbed on day 4. MRI brain could not be done in view of unstable clinical status of patient.

### Representative case 4

A 45-year-old known alcoholic male with no history of any previous trauma admitted with complaints of sudden loss of consciousness for last 8 hours. The patient had a history of being conservatively managed for a spontaneous right frontotemporoparietal subdural hematoma at outside hospital one month back. NCCT on admission showed a chronic SDH with mass effect and ventricular effacement. Patient underwent surgical evacuation as per our protocol. Patient improved in post-surgery phase well. Patient was discharged on day 5 of surgery. Patient reported in follow up visit again on day 13 post surgery with complains of vision loss in bilateral eye. MRI brain was suggestive of bilateral occipital lobe acute infarcts. Ophthalmology examination was essentially normal apart from no perception of light in both eyes.

### Representative case 5

A 50-year-old male with no preceding history of trauma but history of chronic alcoholism presented with inability to speak and right-side weakness for last 15 days. NCCT brain was suggestive of left Frontoparietal chronic SDH; underwent surgery and improvement in post surgery period with uneventful immediate post-surgery period. On day 4 patient reported diminution of vision in both eyes, patient

fundus was normal, pupils were reacting to light but patient was not able to follow light on examination. Patient was advised further admission stay and further work up but patient and his relatives were not willing for same and gave negative consent for same. The patient went on discharge against medical advice.

## DISCUSSION

The usual complications described in literature following CSDH surgery include seizures, infection, pneumocephalus, recurrence and rebleeding [8] [11] [12]. There have been few case reports only discussing possibility of bilateral PCA territory stroke leading to acute neurological deterioration of vision following surgery of chronic SDH. According to Balasubramanian *et al* in 2017 [1] only four cases had been reported so far having blindness following chronic subdural hematoma evacuation. Table 1 enlists details of cases reported so far having vision loss or bilateral PCA territory stroke following chronic SDH evacuation with possible explanation of findings in all the cases as per the respective authors of reports.

**Table 1.** Cases of vision loss or brain stem stroke reported in literature following chronic SDH evacuation with possible mechanism for the same.

S.No.	Case Report/Series	Case Details	Outcome	Possible explanations as per the author
1)	Kaene <sup>[6]</sup>	Three cases; 2 unilateral 1 bilateral	Bilateral vision loss; anterior pathways as well as occipital cortex both were affected	Trans tentorial herniation
2)	Russeger <sup>[9]</sup>	One case, Unilateral	Bilateral blindness	Altered vasoregulation around optic nerve due to sudden drop in intracranial pressure

				during decompression
3)	Kudo <i>et al</i> <sup>[7]</sup>	Two cases, unilateral	Bilateral occipital lobe infarct	Central trans tentorial herniation
4)	Balasubramanian <i>et al</i> <sup>[1]</sup>	Single case, bilateral	Bilateral blindness	Preexisting chronic ischemia led to chronic SDH; Evacuation led to worsening of ischemia leading to PCA infarction
5)	D. Adam <i>et al</i> <sup>[2]</sup>	Single case, Bilateral	Anton Babinski syndrome	No possible explanation mentioned
6)	Imoumby <i>et al</i> <sup>[4]</sup>	Single case, bilateral	Brain stem stroke	Spontaneous intracranial hypotension following evacuation leading to brain sagging and kinking of bilateral PCA arteries. Another possibility of thrombosis was also postulated as a cause of PCA infarct.

To the best of our knowledge, current series is the only reported series of multiple cases reporting bilateral PCA territory stroke following surgery for chronic subdural hematoma. In our series we propose following possible explanation of blindness or brain stem stroke following successful evacuation of hematoma:

- 1) Tran tentorial herniation, especially in case 2 and case 3 of our series looking at poor GCS at arrival and rapid deterioration. Absence of any PCA territory hypodensity in pre surgery and

immediate post surgery scan (case 2) goes against this possibility.

- 2) Thromboembolic phenomenon in posterior circulation may be one of possible cause leading to bilateral PCA infarcts. Again, normal lipid profile, no atherosclerosis in neck vessels in angiogram and unremarkable 2 D echo goes against this hypothesis. Although in case 3, looking at old age and as patient died in post surgery phase, we could not get a complete work up in view of unstable condition of patient; thrombotic phenomenon may a likely event.
- 3) Spontaneous intracranial hypotension may also be one of the plausible causes. In case 2 there has been a deterioration after decompression noted after initial post-surgery CT, case 3 old age with Alzheimer's, case 4 and case 5 being cases of spontaneous subdural hematomas more point toward possibility of intracranial hypotension leading to kinking of posterior circulation vessels against tent and resulting ischemia. Absence of any brain sagging in any of the MRI picture in coronal cuts (figure 3) contradicts this theory.
- 4) Posterior reversible encephalopathy syndrome (PRES) may be one of the explanations in our case 1. Patient was a known case of hypertension with an episode of hypertension noted during surgery, MRI findings support this hypothesis. Normal EEG recordings and no improvement with steroids disagree this.

Like case 1 reported in this series, J manual et al [5] have reported a case of cortical blindness arising in a patient of posterior reversible encephalopathy syndrome. Although as the cause was identified at the same time, prompt management in that case resulted in improved vision in the patient which was not the case in our patient.

We have reported this series highlighting the undesired and unforeseen complications of what is considered a simple and commonly encountered neurosurgery emergency. The possible explanations for the cause; highlights the importance of slow gradual decompression to reduce chances of sudden intracranial hypotension, maintaining a good hydration perioperatively to reduce chances of any thromboembolism, prompt diagnosis and management of reversible causes like PRES and a high index of suspicion for such unlikely complications in selected cases which might help in

better pre operative counselling and case prognostication.

At the same time, we emphasize here for a large scale multicentric study for reporting of these untoward complications and enlightening of underlying mechanisms.

## CONCLUSIONS

Chronic subdural hematoma evacuation is a routinely performed procedure. The high frequency of cases and simpler techniques at time underestimates the complications associated. There should be consideration of all precautions to prevent such complications and the possibility should be discussed in pre operative counselling and prognostication. More studies are warranted to address these complications further.

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# Till death do us part? The inconspicuous impact of subarachnoid haemorrhage on conjugal status

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## ABSTRACT

A patient's partner plays a significant role in providing care and support after an aneurysmal subarachnoid haemorrhage. After such events, it is observed that conjugal status tends to change, improving in some cases and worsening in others. Despite this, little research exists on its progression after subarachnoid haemorrhage. In this letter, we provide a brief summary of the studied sequelae of subarachnoid haemorrhages, such as fatigue, cognitive decline, and personality changes, and discuss the potential interplays between those and conjugal status. We also report the primary author's series of aneurysmal subarachnoid haemorrhage cases in Iraq as an example of the observation of conjugal status changes after subarachnoid haemorrhage. The hope is to shed light and encourage further research on this topic, considering its significant impact on patient well-being and outcomes.

Multiple published studies briefly considered the impact of aneurysmal subarachnoid hemorrhage (aSAH) on conjugal status.<sup>11,13,20</sup> Specifically, the data tends to show two main patterns of change, the more common being a decline in the relationship, while the other, less common change, is an improvement in their quality. Similarly, we observed the changes in patients recovering from surgery for aSAH in our practice. However, we also noticed that there is a lack of evidence regarding the factors that contribute to this observation, and therefore, further studies to unveil the interplay are warranted.

## Neuropsychological sequelae of aSAH

Beyond the domain of relationships, aSAH is known to be followed by a multitude of changes affecting a patient's personality, behavior, and mood. One such change is increased fatigue, which is associated with sleep-wake disorders, anxiety, depression, and cognitive impairment,

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## Keywords

subarachnoid haemorrhage,  
spouse,  
cognate status,  
neurosurgery

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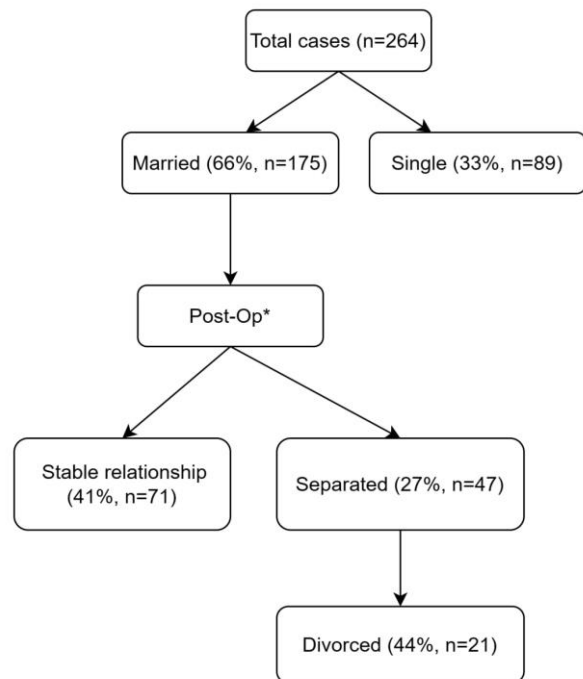
all of which have been reported to decrease Quality of Life (QoL) independently of and in association with fatigue.<sup>2,4,14,15,19,20,21</sup> Further, patients report dissatisfaction after aSAH related to decreased sexual desire and activity, some citing a fear of a recurrent aSAH if intercourse precipitated the initial aneurysmal rupture.<sup>4,11</sup> In line with such concerns, aSAH patients and their significant others are susceptible to symptoms of post-traumatic stress disorder (PTSD) following their experiences.<sup>5,9</sup> Finally, another important change is that of personality.<sup>1,6,16</sup> While some patients are described as becoming more irritable, emotionally labile, or aggressively straightforward, others describe having a new outlook on life and a gratitude for surviving.<sup>7,9</sup>

### Relating sequelae to conjugal relations after aSAH and surgery

While the amount of research culminating in the findings above is abundant, research specifically delineating conjugal relationships after aSAH is lacking, despite the crucial role such relationships play in the support and continued care of patients. Nevertheless, all changes considered, it is not difficult to see the intuitive interplay between them and the developments observed in the close social circles of patients. For instance, relationships could easily become affected in relation to alterations in personality, decreased cognitive function, fatigue, or any other aSAH sequelae. Alternatively, relationships can change as a result of increased financial burden on a partner to accommodate for the decreased productivity or the discontinued employment of the patient, which itself is justified by declining cognitive function or fatigue.<sup>20</sup> Indeed, reports exist of partners becoming estranged or developing a patient-caretaker dynamic after aSAH.<sup>20</sup> However, more research is required before any such connections can be made. Moreover, such research should aim to identify predictive factors of relationship progression after aSAH, considering both clinical outcome and relationship status immediately after aSAH as candidates.

In addition, further work is needed to illuminate the underlying mechanisms contributing to sequelae and changes in conjugal relationships. Here, the literature offers a plethora of candidates but lacks the provision of irrefutable evidence. One example is the occurrence of vasospasms as an independent predictor of fatigue, but how this affects familial

responsibilities, intimate interactions, and relationships, is yet to be uncovered.<sup>21</sup> Vasospasms also disrupt neurotransmission and plasticity in the hippocampus, affecting memory. Yet how this informs the developing patient-caretaker relationship has not been outlined.<sup>17</sup> Subsequent to vasospasms, ischemia and metabolic changes may contribute to cognitive decline, as can the clipping procedure, the volume of blood in the subarachnoid space, and global cerebral edema.<sup>3,7,10,12,18</sup> Moreover, other theories that have been proposed to explain aSAH sequelae include pituitary dysfunction, neurotransmitter imbalance, systematic inflammation, and disruption of brain circuits.<sup>8,21</sup> A direct examination of how these factors affect sequelae and, subsequently, relationships is warranted.



**Figure 1.** Flow diagram of the primary author case series.

Based on the primary author's series in Iraq of 264 cases with aSAH treated via microsurgical clipping, 33% of the cases were single ( $n=89$ ), with the remaining 66% being married ( $n=175$ ). Of the latter group, 27% ( $n=47$ ) reported a significant change in their marital relationship in the form of separation at 25 months mean follow-up (range=9-42 months). 44% of the 47 patients ( $n=21$ ) officially filed for divorce, with a majority doing so because of domestic violence. On the other hand, 41% of the

married patients (n=71) experienced a significantly more stable relationship than the pre-incident status, reported by both the patients and their partners (Figure 1).

To be considered here are the social norms of personal relationships in Iraq, which come solely in the form of marriage. This renders the follow-up of this outcome parameter a relatively straightforward process and emphasizes the impact on the patient's life. One nuance to consider is the underreporting of divorce due to stigma or legal limitations in cultures with certain traditions, such as Judo-Christian, Islamic, or Hindu cultures. Additionally, this observation is expected to be subtle and more difficult to assess in parts of the world with more variable forms of conjugal status.

Based on this, more relationship-focused studies are needed, keeping in mind variance in social norms, to examine this relatively underrated factor. The creation of a parameter to standardize the quantification of conjugal relationships across differing societies is also justified. Further, it is important to recall the contrasting group of the patients who experience improved relationships, wherein the solution to this issue might be identified. The hope for this research would be to shed light on these patterns and to identify efficacious interventions to improve patient QoL and satisfaction, especially when it comes to a pillar of post-intervention care such as the patient's support system.

#### Non-standard Abbreviations and Acronyms:

Aneurysmal subarachnoid hemorrhage (aSAH);

Post-traumatic stress disorder (PTSD);

Quality of life (QoL).

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# Role of intrathecal and topical vancomycin in prevention of ventriculoperitoneal shunt infections

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## ABSTRACT

The objective of this study is to assess the role of intrathecal and topical vancomycin in the prevention of ventriculoperitoneal shunt infection. Infections of the ventriculoperitoneal (VP) shunt are a frequent consequence of shunt surgery. Different strategies, and protocols in addition to prophylactic intravenous antibiotic administration have been described to limit the infection rate, but the burden still remains high. The use of intrathecal Vancomycin along with topical application can be implemented as an additional measure to limit shunt-related infections.

The study includes 105 patients who underwent ventriculoperitoneal shunt insertions for different reasons. Apart from the standard operative protocols used for shunt surgeries, intraoperatively intrathecal and topical vancomycin were administered to all the patients. Postoperatively, all the patients were followed for three months to assess shunt-related infections

The study showed that the infection rate after administration of intrathecal and topical Vancomycin was found to be low, which is 4.7%, which shows a reduction of 5.8% from our baseline infection rate of 10.5%. We also found that patients having tuberculous meningitis were more at risk of developing shunt-related infections, the p-value being significant (0.001\*).

Therefore, we conclude that as part of a standardized shunt operation routine, Intrathecal and topical vancomycin treatment may be an appropriate option for preventing pediatric shunt infections.

## INTRODUCTION

Hydrocephalus is one of the most common clinical conditions presenting in a neurosurgical unit. Different surgical methods have evolved overtime to counteract this, with ventriculoperitoneal shunt insertions gaining widespread popularity [10].

Ventriculoperitoneal shunts provide a sterile, alternate route to the CSF into the peritoneal cavity, however the efficacy of these devices have been hampered by the challenges of shunt infections and obstructions [2]. As with any foreign body, there is a propensity for bacteria to colonize the shunt and develop infection. These biofilm

## Keywords

hydrocephalus,  
intrathecal vancomycin,  
ventriculoperitoneal shunt  
infection



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forming bacteria then can transmit this infection to both the intracranial and intraperitoneal cavities leading to significant morbidity. The culprits in most of the cases are organisms of the normal skin flora like staphylococcus aureus, staph epidermidis and propionobacter acnes [4, 16, and 31].

The shunt infection rate ranges from 5-15% on average [5, 13, and 14] but is higher in the pediatric population approximating at 20% [6, 31]. This higher incidence in children can be attributed to preterm birth, low birth weight, inadequately developed immune system and exposure to certain intrauterine pathogens among other factors [16, 18]. Multiple revision surgeries secondary to shunt obstruction is also an important cause [11] of shunt infections as well as hemorrhage as the primary cause leading to the development of hydrocephalus [8, 26]. Some surgeons argue that open neural tube defects, with communication of the skin flora with the subarachnoid spaces are a potential risk factor predisposing to shunt infections [8, 30]. While others believe that having a meningomyelocele may confer protection from the development of infections [26].

These shunt infections are notorious for being resistant to common antibiotic therapies, in part due to poor CSF penetration, and lead to significant decline in quality of life of the patients, prolonged hospital stays and overuse of resources. They ultimately result in shunt malfunction and high shunt failure rates [2]. These failure rates have been estimated to be around 6% per procedure [28]. This complication can lead to altered level of consciousness, neurological deficits, and seizures as well as reduced IQ levels in the pediatric population [23, 28].

Although the etiological factors cannot be controlled, there are certain modifiable factors that can be taken under consideration to reduce the infection rate. This includes impeccable sterile techniques and abstinence from direct handling of shunt apparatus during surgery, reduced duration of surgical procedure, limited traffic in and out of OR as well as diligent use of antibiotics prophylactically. Intravenous antibiotics have been used widespread as a prophylactic agent owing to its good response against staphylococcal organisms and better CSF penetration. However, recent reports have focused more on intraoperative intrathecal vancomycin administration and have demonstrated a significant impact in decreasing the VP shunt infection rates [3,

20, and 27]. These promising results have convinced our institution to use intrathecal and topical vancomycin intraoperatively in VP shunt placement surgeries in order to control the troubling infection rates.

## METHODOLOGY

This is a prospective cohort study, carried out in the department of Neurosurgery, Jinnah Postgraduate Medical Centre, Karachi, Pakistan from 15th November 2021 till 31st July 2022 for a period of 8 months. A total of 105 patients were enrolled in the study. Before this study was carried out, we determined a baseline infection rate by retrospectively analyzing previous data of patients who had undergone VP shunt placement in the past one year. We assessed for the incidence of infection and determined the rate to be 10.5%.

After obtaining ethical board approval, a proforma was designed and patient data was collected which included, demographics, the type and etiology of hydrocephalus and other details with regards to the ventriculoperitoneal shunt placement. The inclusion criteria defined patients of both genders, pediatric as well as adult population who required a VP shunt placement. Patients already having an infected CSF DR, which would preclude VP shunt insertion were excluded, so were patients who did not adhere to the follow up protocol and those not giving consent to be part of the study.

The patients were divided into 5 age groups, with Group A comprising of children 6 months or less, Group B: More than 6 months till 1 year of age, Group C: More than 1 year till 5 years of age, Group D: More than 5 years till 18 years of age and Group E: More than 18 years of age i.e. the adult population.

Different etiologies resulting in hydrocephalus were included in the study and associations identified. Patients having meningomyelocele, who also had concurrent hydrocephalus which needed ventriculoperitoneal shunting, were also included in the study. Radiological parameters such as Evan's ratio, ballooning of the frontal horns and prominent temporal horns along with Fronto-occipital circumference of the patient were used to determine whether there was a need of shunting in these children.

## Surgical protocol and antibiotic administration

The surgeries were carried out in standard operation

theatres which strictly adhere to the sterility protocols. The surgical site was cleaned using povidone iodine solution thrice, followed by swabs of sterilium. Then opsite was used to cover the cranial and abdominal surgical sites as well as the probable subcutaneous track area. Double gloving was done in all surgeries and once the dissection was complete to expose the burrhole proximally and the peritoneal cavity distally, the top glove was removed before handling the shunt catheters and tubing. Prior to insertion of shunt parts, they were soaked in normal saline impregnated with Gentamicin. Peroperatively a single dose of 2g ceftriaxone is given intravenous, which is followed by three more 2g IV doses administered for three days. This had also been the standard protocol in all patients having ventriculoperitoneal insertions in our institute even before this study was carried out. The only new difference was introduction of intrathecal and topical Vancomycin prophylactically which was not previously practiced.

Once the Proximal catheter was introduced into the ventricular cavity, it was used to inject 10mg of Vancomycin intrathecally. The catheter was then quickly connected to the chamber. Prior to skin closure, additional 10mg of Vancomycin was sprayed onto the site of the Proximal catheter insertion in the dura, as well as the surrounding tissues and then the skin was closed using prolene sutures.

### Follow up protocol

The patients were then followed for a period of 3 months to assess for any ventriculoperitoneal shunt infections as well as any superficial wound infections. Any erythema, edema and Pus discharge from the wound with no infective elements of infection in the CSF DR was labeled as a 'superficial wound infection'. Whereas CSF D/R with increased WBC count (increased neutrophil counts) and abnormal glucose and protein levels, with or without positive CSF cultures, and with or without shunt blockage was labeled as 'Shunt infection'.

Patients having superficial wound infections, were given appropriate antibiotics (culture sensitive in case of positive pus cultures), and then followed for resolution of symptoms. For patients having infected CSF, with clinical symptoms of infection, the VP shunt was removed and an external ventricular drain placed. Cultures were sent and appropriate antibiotics started (IV vancomycin and Meroneum in

case of negative cultures), and patients were regularly followed by daily CSF D/R reports and cultures after every 48 hours. Normal WBC Count and protein and glucose parameters on D/R and three consecutively negative cultures would denote resolution of infection.

## RESULTS

### Age and gender

A total of 105 patients were a part of the study, with the ratio comprising 59 (56.2%) males and 46 (43.8%) females.

The frequency according to the age group distribution is depicted in Table 1, with 44.8% of the patients in the adult age group and remainder in the pediatric age group.

**Table 1.** Age distribution of the patients.

Age Groups	Frequency	Percentage
6 months and less	25	23.8%
>6 months - 1 year	2	1.9%
>1 year - 5 years	11	10.5%
>5 years - 18 years	20	19.0%
>18 years	47	44.8%

### Etiology of hydrocephalus

Communicating hydrocephalus was seen in 59 (56.2%) patients and 46 (43.8%) had an obstructive type of hydrocephalus. However, the etiologies were very variable and have been summarized in Table 2.

**Table 2.** Etiology of Hydrocephalus.

Etiology	Patients	Percentage
Congenital HCP only	5	4.8%
MMC Associated	24	22.9%
Aqueductal Stenosis	8	7.6%
Infectious	15	14.3%
Traumatic SAH/IVH	4	3.8%
Hypertensive IVH	2	1.9%
Tumors	37	35.2%
Postoperative	1	1.0%
Unknown	9	8.6%

Majority of the patients (35.2%) included in the study, had hydrocephalus secondary to brain tumors, both supratentorial and infratentorial. This was followed by Hydrocephalus associated with a meningomyelocele in 22.9% of the cases. 15 of the patients developed hydrocephalus as a result of

infective sequelae i.e. Tuberculosis, with the CSF D/R not showing an active infection. One patient who had undergone prior evacuation of a posterior fossa bleed, developed hydrocephalus 1 month postoperatively and was labeled as 'postoperative'. In 9 cases, the cause of hydrocephalus remained inconclusive.

**Type of VP shunts**

None of the patients had past history of VP shunt placements. Only non programmable shunts were used, with a cylindrical type of chamber used in 90 cases, and spherical ones in the rest.

**Shunt Infections**

Of the 105 patients enrolled in the study, 5 developed infections, denoting an infection rate of 4.7% per procedure.

Out of these five, one patient had a superficial wound infection which developed on the 3rd postoperative day. Shunt was passed secondary to history of tuberculous meningitis. The patient was managed on oral antibiotics and daily dressings. There was resolution of infection within 5 days and he was discharged

Rest of the four patients developed shunt infections with associated ventriculitis and meningitis. The demographics of these patients are discussed in Table 3 below.

**Table 3.** Demographics and etiology of patients who developed shunt infections.

	Age	Gender	Etiology	Type of Shunt	Organism
Patient 1	23	Female	TBM	Cylindrical	None
Patient 2	12	Male	TBM	Cylindrical	None
Patient 3	18	Male	TBM	Cylindrical	Staph. Aureus
Patient 4	14	Male	Tumor	Cylindrical	None

Patient 1 and 4 were brought to ER initially with a low GCS and emergency VP shunt placement was done. The VP shunt blocked almost immediately post op with both patients developing fever and neck rigidity. The shunt was removed and EVD placed. IV antibiotics started. However, the patients were unable to recover and expired within 2 weeks of developing ventriculitis.

Patient 2 developed wound infection with CSF leak at the surgical site. The CSF D/R showed an infective etiology, however the lab was unable to culture an organism. The right sided shunt was removed and EVD placed. Within 2 weeks her infection was resolved and new VP shunt was placed on the left side. On the three month follow up, the patient did not have any active issues.

Patient 3 also developed infection at 2 week follow up with culture showing growth of staph aureus, however, he was successfully managed on antibiotics and did not show any signs of infection at the 3 month follow up.

Table 4 shows in detail the relationship of the outcome with different patient parameters.

**Table 4.** Analysis of outcomes in comparison with different patient parameters.

Variable	No. of surgeries	Infection	No infection	P Value
<b>Gender</b>				
Male	59 (56.1%)	4 (6.7%)	55 (93.2%)	0.26
Female	46 (43.8%)	1 (2.17%)	45 (97.8%)	
<b>Age</b>				
≤ 6 months	25 (23.8%)	0 (0%)	25 (100%)	0.59
>6 months - 1 year	2 (1.9%)	0 (0%)	2 (100%)	
>1 year - 5 yrs	11 (10.4%)	0 (0%)	11 (100%)	
>5 yrs - 18 yrs	20 (19.0%)	2 (10%)	18 (90%)	
>18 yrs	47 (44.7%)	3 (6.38%)	44 (93.6%)	
<b>Etiology</b>				
Congenital HCP only	5 (4.7%)	0 (0%)	5 (100%)	0.07
MMC Associated	24 (22.8%)	0 (0%)	24 (100%)	
Aqueductal Stenosis	8 (7.6%)	0 (0%)	8 (100%)	
Infectious	15 (14.2%)	4 (26.6%)	11 (73.3%)	
Traumatic	4 (3.8%)	0 (0%)	4 (100%)	
SAH/IVH	2 (1.9%)	0 (0%)	2 (100%)	
Hypertensive IVH	37 (35.2%)	0 (0%)	36 (97.2%)	
Tumors	1 (0.95%)	1 (2.7%)	0 (0%)	
Postoperative	9 (8.57%)	0 (0%)	1 (100%)	
Unknown			9 (100%)	
<b>CSF Leak after shunt</b>				
Yes	3 (2.8%)	1 (33.3%)	2 (66.6%)	0.137
No	102 (97.1%)	4 (3.9%)	98 (96.0%)	

Males were more likely to develop shunt infection as compared to females (6.7% vs. 2.17%) in our study; however the p value is not significant ( $p$  Value > 0.5). Three patients out of 5 were adults; the other two were in Group D. None of the children less than 10 years of age developed an infection. Hydrocephalus associated with tuberculous meningitis was most commonly associated with shunt infections (in 80% of the cases). Cylindrical chambers were more prone to getting infected, however there is no significant data supporting this claim. There were two adverse outcomes i.e. death. Three patients recovered and did not show any signs of infection on monthly follow up visit.

Majority of the patients who developed a shunt infection (4/5) had an infective etiology as a cause. Of these 4 patients, all were diagnosed cases of tuberculous meningitis. 4 out of 15 cases of tuberculous meningitis developed a shunt associated infection, with the p value being significant ( $p$  value= 0.001)\*. The last patient had VP shunt surgery done to treat hydrocephalus secondary to a craniopharyngioma.

Out of 3 patients who developed a CSF leak, only one went on to develop a shunt infection. The p value is not significant.

## DISCUSSION

In the past, multiple studies have put weightage behind the use of a standard protocol to reduce shunt related infections with strict measures to control potential environmental, iatrogenic and patient related factors [13, 17]. Nevertheless, with the ever increasing use of foreign materials, such as VP shunts, as well increasing antimicrobial resistance, in addition to the emergence of more pathologically virulent organisms, there is a need for a dynamic and evolving process of strategies to contain the infection rates to acceptable levels.

Multiple studies have been conducted recently to study the role of intrathecal and/or topical vancomycin in preventing shunt infections [20, 29]. The results have been promising with one large clinical series showing a favorable outcome where prophylactic antibiotics were used [20]. The study showed that the infection rate was limited to 3.2% in comparison to multiple studies without the use of intrathecal and topical antibiotics in which the reported infection rates remained higher [7, 21]. Our study also showed an infection rate of 4.7% per

procedure, this shows a 5.8% decrease in the infection rate when compared with the reported baseline incidence of shunt infection in our institute which is 10.5% without the use of prophylactic vancomycin. Other studies have also reproduced this effect, showing a significant net decrease of shunt infection rates with the use of intrathecal vancomycin [3, 19].

In our single institution study, shunt infection was seen in ages 10 and older. This is in contrast to other studies showing higher rates of shunt infections in pediatric patients [9, 13 and 15]. Also, we found the male population to be more prone to develop shunt infections. A large series elsewhere showed that females had a higher preponderance [20].

Tuberculosis is endemic to Pakistan and as such, we do get a lot of patients in our Neurosurgical department having tuberculous meningitis and their sequelae, such as hydrocephalus. In our study, 4 out of 5 patients who developed shunt infections were diagnosed cases of tuberculous meningitis. This finding is significant ( $p$  Value= 0.001) and shows the trend that patients having tuberculous meningitis are more prone to develop shunt related infections. This has also been well documented in other studies [22, 24]. Although the patients were diagnosed as having tuberculous meningitis, no other organism was cultured as a cause of infection. Tuberculosis is also associated with thick exudates which might block the VP shunt [1]. None of the patients have tuberculous meningitis in our study were visibly cachexic. However, in 3 out of 4 patients, the BMI was in the underweight category and all of them developed shunt infections. The one patient having a normal BMI also developed infection.

CSF leak is considered an adverse factor with strong associations with subsequent shunt infections, as seen in the literature [20]. However, in our study, only one patient out of 3 developed an infection.

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## Limitations

This study is a single institution study comprising of both adult and pediatric population with a sample size of 105. This small size may not be fully

representative of the large population of hydrocephalus patients. Another potential limitation is the use of the same intrathecal and topical vancomycin dose in both the adult and pediatric population, which might potentially explain that none of the patients less than 10 years of age developed an infection, but the older population did. In patients having tuberculous etiology, a larger sample size with association to the weight should be carried out to determine a more solid relationship.

## CONCLUSION

Based on our findings, it is safe to say that intrathecal and topical vancomycin with strict adherence to the standard shunt protocol have a good impact on reducing shunt infections and should be practiced in all VP shunt procedures. Even though, the rate of infection still remained high in patients having tuberculous meningitis, larger studies on this particular etiology with dose adjustments is recommended so that a proper and efficient protocol could be generated to minimize shunt related complications in the future.

Although Vancomycin is known to prevent shunt related infections and has been well studied, there are only limited studies carried out in our region. The diversity of the organisms causing these infections as well as high rate of tuberculosis deemed it necessary to conduct a study to document the efficacy.

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# Neurosurgery-centred multidisciplinary team-based decisions. Experience from Iraq

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## ABSTRACT

A multidisciplinary team (MDT) brings together a group of healthcare professionals from different fields at a specific time to discuss a case. People in an MDT can contribute to the decisions and plans for diagnosing and managing the patient. [1].

MDT in healthcare settings is essential; the main aim is to bring together a group of healthcare professionals from different fields and combine their inputs—this assistance in discussing patients' presentations and findings, determining comprehensive treatment plans, and treatment side effects. The physical and psychological effects of impaired of these functions can significantly impact patients' quality of life and social well-being. [1].

In war-torn countries with limited resources and complex specialities like neurosurgery, MDT-based decisions may significantly impact the treatment process and outcome. In this paper, we try to highlight the differences in MDT-based work environments compared to the paucity of such organized decisions in war-torn regions of Iraq.

## MDT IN DEVELOPED VS. WAR-TORN COUNTRIES

Generally, in developed countries, studies suggest that MDTs help improve the offered services in clinical practice by making it easier to maintain local registries, enhancing the treatment planning process, and ultimately leading to better patient outcomes—communication and cooperation between team members and in some instances, patient involvement [1,4]. However, there is a concern regarding

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## Keywords

LMICs,  
low and middle-income  
countries,  
MDM,  
multi-disciplinary meeting,  
MDT,  
multi-disciplinary team

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possible bias. Group thinking MDTs often experience challenges with team-based decision-making. This is a commonly recognized issue. Furthermore, the literature must provide more evidence on whether MDT discussion improves survival. Lamb et al. demonstrated that MDT discussion did alter treatment decisions, but studies generally failed to correlate these changes with actual improvement in patient outcomes. [1-3].

In war-torn and low-and middle-income countries (LMICs), this is not always the case. The relative lack of resources in a country like Iraq, which experienced for many years, has been a series of wars, blockades, and administrative corruption. It has led to serious consequences burdening the healthcare system and its existing resources [5]. There is no conspicuous national protocol for MDT care. However, there are scattered communications between disciplines in an attempt to provide the best possible care available to patients alongside a few trials from the government to enhance the healthcare system's potential. Based on those facts, occasionally, the patient is informed of one treatment plan without knowing there are other options available, and on other occasions, patients may choose the less invasive procedure, despite the risk to the outcome due to several factors, including the cost, and level of education of the patients and their awareness. Therefore, multiple-option treatments are considered a drawback regarding patient treatment and generally result in less than an average standard of care.

#### EXAMPLES IN MDT-DEFICIENT SETTINGS

The MDT approach is of extreme value in the field of neurosurgery for various cases. For example, in vestibular schwannoma treatment, no centers provide gamma knife procedures and surgery options in one setting. Therefore, the neurosurgeon's decision-making process is a random act depending on the geographical location of the patient, the suggestions of the patient's relatives, and sometimes, social media impacts, as well as individual judgment. Another example is that treating Arteriovenous malformation necessitates three options: surgery, endovascular embolization, and gamma knife. In most cases, the treatment usually combines two or three of those options. The above two examples show how the settings need MDT. Therefore, multidisciplinary meetings (MDM) exist nevertheless futile with the potential to be a

cornerstone for the future development of MDT treatment; on the other hand, the unavailability of the MDT may affect the patients, surgeons, and the hospital, and it might have a significant impact on patients' satisfaction due to the unavailability of adequate hospital quality care and effective communication with the healthcare providers, the unfavored outcomes, and the excessive hospital visits and time of each counseling. Furthermore, Neurosurgery requires essential decisions, such as the need for surgery, surgical approach, complications, and risk assessment. These decisions are the responsibility of neurosurgeons. In war-torn regions, Neurosurgeons usually rely on their patients' and colleagues' judgment, hypothetical deductive reasoning, experience, and values to make difficult and risky decisions. However, the demands of a large clinical workload can sometimes make this decision-making process less than ideal. [6].

#### RECOMMENDATIONS

Our experience with the absence of MDT in Iraq as an example of LMICs reveals the profound need for an MDT in all healthcare institutions that deal with complex cases as well as a necessity for a referral system and collaborations in such instances that ease patient access to MDT-based treatment. There is a constant need for more integrated healthcare centers and specialties concerned with providing maximal patient care standards.

Based on the above, MDT has a well-known advantage that impacts patient management plans and outcomes. This advantage can be of critical value when applied to a complex type of surgery such as neurosurgery, especially in a complex setting like the war-torn country of Iraq. Here we emphasize the importance of offering MDT-based treatment for patients with complex pathology in LMICs or worn-torn countries as a necessity rather than a luxury.

#### CONCLUSION

MDT plays an essential role in managing challenging surgeries or complex pathologies and may significantly impact the healthcare system and patient outcomes. In war-torn countries, there's an increasing need to implement MDT-based discussions to compensate for the existing deficits within the healthcare systems.

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# Temporary clipping in intracranial aneurysm surgery. History and development

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## ABSTRACT

**Background:** Neurosurgery's challenging area involves addressing intracranial aneurysms, given the high morbidity and mortality rates associated with them. Safe clipping, a technique that involves the intraoperative temporary occlusion of the arterial supply, is generally used. However, a focused review on the evolution of temporary clipping in intracranial aneurysms hasn't been previously carried out.

**Methods:** We performed a comprehensive literature search on PubMed Medline and Google Scholar, using the combination of terms: [Temporary clip\* AND (Cerebral OR Intracranial) Aneurysm].

**Results:** From an initial pool of 579 results, we excluded unrelated papers, narrowing it down to 25 relevant studies. These ranged from retrospective and prospective studies on the outcome favorability or radiological evidence, to analyses on potential independent prognostic factors, and articles related to the history and evolution of temporary clipping.

**Conclusion:** Temporary arterial occlusion in aneurysm surgery has evolved significantly since its inception in the early 20th century, marked by innovations in instruments and temporary clips. Despite these advancements, the utility and safety of temporary clips continue to be topics of discussion, particularly due to concerns regarding possible complications and their influence on long-term results.

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## Keywords

history,  
intracranial aneurysms,  
temporary clipping,  
clipping

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## INTRODUCTION

Intracranial aneurysms are a health concern affecting roughly 2% of individuals, with their rupture contributing to approximately 3% of all hemorrhagic incidents [9]. A successful therapeutic strategy necessitates not only the comprehensive occlusion of the aneurysm but also the preservation of blood flow in the parent artery, its branches, and the perforating vessels. This is usually achieved through a method known as safe clipping, which is carried out intraoperatively and involves the temporary blockade of the cerebral vasculature both upstream and downstream of the aneurysm [2]. The main purpose of this method is to enable the removal of intramural calcifications and thromboses before definitive clipping in large aneurysms, thereby rendering the aneurysmal wall flexible and adaptable. Moreover, the use of neuroprotective agents, surgical monitoring of cerebral blood flow, and the avoidance of severe and prolonged hypotension can be effective in mitigating cerebral ischemia and extending the safe duration of the temporary clip (TC) application [2].

TC application operates on a principle of safety within a time-limited framework, partly obstructing the nutrient artery, thus enabling back bleeding and retrograde flow through collaterals [6,13]. Although there have been discussions about the repercussions of clipping durations exceeding 20 minutes in terms of vasospasm, the exact impact on the occurrence of delayed cerebral ischemia in patients with aneurysmal subarachnoid hemorrhage remains ambiguous [7,12]. Furthermore, the significance of the clipping duration may be inconsequential given that it can extend up to 90 minutes in intermittent clipping, albeit without a consensus on this aspect as the brain's ischemia tolerance thresholds differ from one individual to another [7,12].

The historical evolution and development of the temporary clipping technique have yet to be fully explored and documented. This review aims to shed light on the journey of temporary clipping from its initial conception and early use to its current day applications.

## METHODS

To accumulate relevant literature, a comprehensive search was conducted using PubMed Medline and Google Scholar databases. The specific search string

employed was: [Temporary clip\* AND (Cerebral OR Intracranial) Aneurysm].

## RESULTS

The initial search yielded a total of 579 records. Following the removal of irrelevant entries, 25 pertinent studies remained for further examination. These selected studies comprised both retrospective and prospective analyses, focusing on outcomes, radiological evidence, and potential independent prognostic factors. They also encompassed articles that pertained to the historical progression and evolution of temporary clip usage in aneurysm management.

### History and development

In the early 1900s, Harvey Cushing pioneered the use of hemostatic clips. He envisioned their broad application in general surgery, highlighting their potential role in arterial procedures to temporarily obstruct smaller collateral vessels. Cushing's unique clip was designed from tantalum wire, forming a diamond shape when one side was opened, which allowed the optimal occlusion of vessels. Despite Cushing's reputation, his clip design did not gain popularity among general surgeons [9].

On 22nd November 1927, Walter Dandy used a method involving temporary vessel occlusion in a patient presenting with progressive hearing loss. An aneurysm was discovered connected to the patient's vertebral artery during surgery, and Dandy temporarily occluded one of the arteries. Postoperative complications led to the patient's unfortunate demise, but this case underscored the concept of temporary vascular occlusion [6].

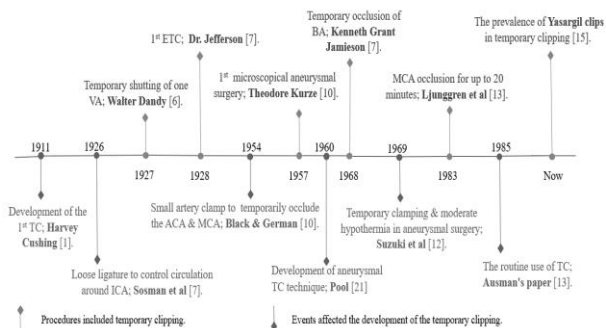
The notion of preventing intraoperative rupture (IOR) using transient clips for local blood flow control evolved gradually. It was traced back to 1926, when a procedure at the Cushing clinic possibly employed a loose ligature around the carotid artery for transient flow reduction. In 1928, the intracranial use of TCs became attributed to Jefferson, who adapted a clip commonly used in thyroid surgeries [18].

Subsequent innovations included the addition of winged blades to the malleable silver clip by Herbert Olivecrona. However, these clips had a risk of damaging the aneurysm neck [15]. Further advancements included a small, light, and effective artery clamp developed by Black and German, allowing temporary vessel occlusion without

compromising its continuity and patency [3]. Later, Schwartz designed a temporary clip that ended up being permanently implanted in many patients due to the lack of alternatives.

In 1952, Mayfield and Kees slimmed the shank's size and created clips of various lengths, adding serrations to increase grip and minimize slippage. Remarkably, Mayfield managed to convince seven volunteers to undergo surgical exposure and temporary clipping of their temporal arteries, confirming the minimal risk of delayed thrombosis [14].

By 1968, Kenneth Grant Jamieson had modified commonly available curl clips to provide temporary occlusion in aneurysm surgeries, finding them superior to the Scoville spring clips then in use [18]. Around the same time, Suzuki et al. reported the benefits of temporary clamping with mild hypothermia, promoting the concept of intermittent reperfusion [21]. From the late 1970s, reports of temporary arterial occlusion for managing large aneurysms increased, and by 1983, Ljunggren et al. noted that occlusion of the middle cerebral artery (MCA) for up to 20 minutes was well tolerated (Fig 1) [4].



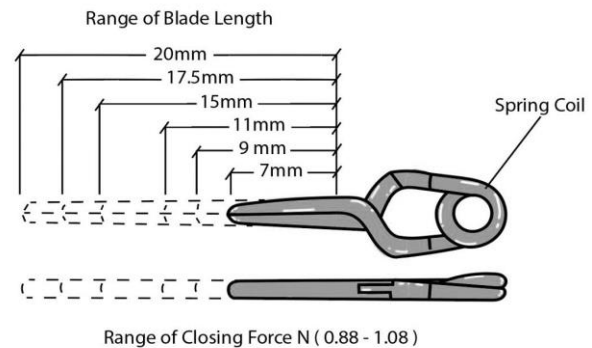
**Figure 1.** Brief history of the intracranial aneurysmal temporary clipping development.

In the same year, 1968, the first Yasargil aneurysm clip was created, marking a significant advancement in clip design [4]. The current safest temporary clips in use are the Sugita or Yasargil models, which apply varying pressures depending on the size of the artery to be occluded [5]. These clips have undergone numerous modifications over the years, with the standard Yasargil TC now featuring an occlusion force range of (0.88-1.08) N (Fig 2).

## DISCUSSION

In the realm of neurosurgery, the act of clipping a

ruptured intracranial aneurysm involves a degree of vessel manipulation, which is suspected to induce vasoconstriction. Employing temporary clipping of the parent vessel during surgery is a technique that is either an elective procedure or a rescue measure. TCs, distinguishable by their golden color, possess approximately two-thirds of the closing force of permanent clips (as illustrated in Fig.1). The literature varies on acceptable durations for TC application, with recorded times ranging from immediate to 93 minutes, inclusive of both continuous and sporadic clip application [12].



**Figure 2.** An Illustration of standard Yasargil clip for temporary vessel occlusion.

Elective temporary clip (ETC) application can serve multiple purposes. These include reducing aneurysm pressure before applying a permanent clip, defining the aneurysm's structure while dissecting complex aneurysms, readjusting a permanent clip for aneurysms undergoing multiple clip applications for optimal occlusion, suction decompression technique, sac remodeling, and removal of atherosclerotic plaque from the neck [13]. Rescue temporary clip application, used to control bleeding during IOR and facilitate further dissection and permanent clipping, unfortunately tends to result in unfavorable outcomes, particularly in patients with severe subarachnoid hemorrhage (SAH) [12].

In 1979, Bernd Richling et al conducted a study comparing the effects of four different clip forces and four periods of clipping on the arterial endothelium of rats. They discovered that the duration of clipping had more impact than the clip force itself, while the vessel diameter did not seem to influence the results. Microscopic examination showed alterations in the inner elastic lamina,

implying damage beyond the endothelium. They established a direct relationship between the degree of inner lesion and duration of temporary occlusion. This result was in 1979 using Heifetz clips and long occlusion durations (10-180) mins. [19]. Contrarily, Kuhnel and Muller, through their experimental studies, argued that trauma resulted more from increased occlusion force than extended clipping time [11].

Sivashanmugam and colleagues demonstrated that using ETCs reduced IOR instances and total clipping time, leading to significantly better outcomes. Notably, repeated rescue clipping and total clipping time of at least 20 mins negatively impacted outcomes [7]. Peter Ka-Hung Pang and team endorsed the use of ETCs in IOR prevention [16].

In a study involving 40 consecutive intracranial aneurysm cases, J. Lawrence Pool and team concluded that temporary clip placement on the circle of Willis's segments was a safe approach. These clips did not halt all arterial blood flow, and any bleeding prior to aneurysm rupture could be easily controlled, demonstrating the effectiveness of proximal and distal vessel clipping. However, use beyond 20 minutes led to postoperative issues, including edema and delayed or insufficient recovery [18].

Fady T. Charbel and team showcased the standard strategy for aneurysm clipping surgery. This involves temporary clipping to isolate the proximal and distal vessels to the aneurysm, followed by aneurysm clipping. They highlighted the need to avoid compressing perforating vessels and ensure that vital or collateral channels remain open to maintain local blood flow [5].

According to Akyuz M. and team, temporary clipping could adversely affect cognitive processes and frontal lobe functions. Therefore, preconditioning the brain for temporary vessel occlusion offers a safety layer for ischemia tolerance [1]. Various methods have been developed for this, such as induced hypothermia, adenosine-induced circulation arrest, raising the mean blood pressure, burst suppression with barbiturates, and the use of etomidate and propofol. However, these procedures can also be detrimental [9].

Nitrous oxide uses during aneurysm surgery with TCs, according to a 2009 post hoc analysis, were linked to a higher risk of delayed ischemic neurologic

deficits, although long-term neurologic or neuropsychological outcomes didn't show significant harm. This may be due to the TC itself or nitrous oxide, which can augment ischemic insult and increase postexposure vasospasm risk due to elevated homocysteine serum concentrations [17].

Induced hypertension during TC application can encourage collateral perfusion to reach ischemic territories but also makes the aneurysm more prone to rupture. Mild hypothermia (31-34 C) as a protective measure is controversial as it is not thought to significantly impact outcomes and is associated with potential cardiologic and hematologic complications [8,9].

Intraoperative monitoring using parameters like regional brain tissue oxygenation (PbtO<sub>2</sub>) and electroencephalography has been evaluated [12]. Peter J. Hutchinson et al. discovered that these variables remained stable during straightforward procedures, but adverse events like prolonged temporary clipping led to notable changes in brain metabolism [10]. Silva et al. identified variations in PbtO<sub>2</sub> decline following temporary clipping, depending on brain regions, with higher falls noted in temporal lobes [20].

Two circumstances require caution during TC application: when a vessel stented proximal to the aneurysm is present and during endoscopic aneurysm clipping. The first may lead to inappropriate occlusion and thromboembolic stroke due to the stent's irreversible deformation after clipping, particularly for cobalt chromium alloy stents [12]. The second may necessitate alternating between microscope and endoscope but enables optimum orientation of operative anatomy [22].

The safety limit of TC duration should ideally be studied on vessels with minimal collateral circulation, like the M1 segment of MCA [10]. A comprehensive analysis in 2005 involving 1694 aneurysms showed that TCs were more commonly used for ruptured aneurysms compared to unruptured ones and were more likely for internal carotid artery, paraclinoid, and ophthalmic aneurysms. Giant aneurysms with thrombosis or calcifications and irregular fundus shape, especially basilar tip aneurysms, are more likely to be repaired under temporary clipping [20,22].

## CONCLUSION

Temporary occlusion of intracranial arteries during

aneurysm surgery has a long history, starting from the early 20th century with pioneers like Harvey Cushing. Over time, specialized tools and TCs have been developed, enhancing the safety and efficacy of aneurysm treatment. However, despite these advances, the use of TCs remains a topic of debate, particularly concerning potential complications and their impact on long-term patient outcomes.

#### ABBREVIATIONS

ACA; Anterior cerebral artery,  
 EEG; Electroencephalogram,  
 ETC; Elective temporary clipping,  
 IOR; Intra-operative rupture,  
 PBtO<sub>2</sub>; Partial pressure of oxygen in brain tissue,  
 MCA; Middle cerebral artery,  
 PComA; posterior communicating artery,  
 TC; Temporary clip.

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# Growth hormone deficiency in the neurocritical patient. Traumatic brain injury perspective

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## Keywords

hypopituitarism,  
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critical illness

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## ABSTRACT

Growth hormone (GH) is synthesized in the anterior pituitary, but its production and release are controlled by two neurohormones found in the hypothalamus: somatostatin and growth hormone-releasing hormone (GHRH). GH supports bone growth, regeneration of neurons, astrocytes, endothelial cells, oligodendrocytes, and even neuronal myelination. It is also responsible for stimulating the growth and differentiation of cells from different tissues and cell types, thereby contributing to protein synthesis. Original research papers, case reports, and case series on GH deficiency among neurocritical patients were thoroughly examined in this review. After extensive study, 13 articles were selected for the analysis. Traumatic lesions are defined by distortion of the brain tissue and subsequent biochemical modifications, which can affect GH secretion. The majority of researchers identified fractures, trauma, and bleeding as the mechanical causes of GH deficiency, and subarachnoid

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haemorrhage (SAH) or traumatic brain injury (TBI) as the etiology. The dysregulation of certain other hormones, including ACTH, Cortisol, Gonadotropin, Prolactin, FSH, TSH, Testosterone, and Hydrocortisone is also related to GH insufficiency. Growth hormone deficiency can cause complications such as hypothyroidism, hypotension, hypoxia, adrenal insufficiency, electrolyte imbalance, hyperprolactinemia, depression, anxiety, concussions, seizures, vomiting, and loss of consciousness. According to previous studies, GH insufficiency is significantly affected by age, body mass index (BMI), pituitary dysfunction, and hypogonadism. GH treatment is widely used in patients with GH deficiency, as it has more benefits than harm. The GH dose should be individualized to minimize side effects and maximize clinical efficacy.

## INTRODUCTION

Growth hormone (GH) is produced in the adenohypophysis and stimulates cell growth and differentiation. Its synthesis and release are influenced by two hormones: growth hormone-releasing hormone (GHRH), which stimulates the synthesis and release of GH, and somatostatin, which inhibits GH and acts as a negative feedback mechanism. It has been established that blood levels of this hormone are at their maximum during sleep. [1, 2] Somatotrophic cells produce GH in the lateral regions of the adenohypophysis. This hormone is a protein that weighs approximately 22,650 Da and consists of 191 amino acids. GHRH and somatostatin, two neurohormones found in the hypothalamus, are necessary for the production and release of these hormones. While the second is inhibiting, the first has stimulating quality. [3] Considering that various trauma-related processes, such as inflammatory or ischemic damage, might harm the brain parenchyma, brain trauma can change the metabolism of GH. [4-6] Traumatic brain injuries can deform brain tissue and subsequently generate biochemical changes. The ischemic changes that occur during brain injuries cause hormonal loss, mainly of somatotropin and gonadotropin; thus, there is an alteration in GH metabolism. In the present article, we review the role of growth hormone in patients with traumatic brain injury.

## PHYSIOLOGY

GH excretion is pulsatile and an ultrasensitive test that can be used to measure blood levels. The somatostatin-induced inhibition was reduced to

control these pulses. It was discovered that on an average, serum GH during the night oscillates between  $1.0 \pm 0.2$  ng/ mL, while daytime concentrations are on average  $0.6 \pm 0.1$  ng/ mL in adults. These levels may be lower in adults with obesity, older adults, and neonates. Therefore, serum GH measurement should be performed in a 20-minute sample for 24 h, which would allow accurate evaluation of serum GH concentrations. [7, 8] The maximum serum GH concentration ranges from  $4.3 \pm 0.7$  ng/ mL at night to  $2.7 \pm 0.5$  ng/ mL during the day, with the highest GH excretion peak occurring 1 hour after the onset of deep sleep. Physical activity, trauma, and septic conditions increased GH secretion by 20–30 ng/mL. [9] GH, in contrast to other hormones secreted by the pituitary gland, affects every cell in the body.

The proliferation and differentiation of cells from diverse tissues and cell types are stimulated by this hormone. It also increases the risk of developing diabetes by lowering peripheral tissue glucose absorption, enhancing liver glucose release, and subsequently increasing insulin secretion. [3] Its role in astrocyte, endothelial, oligodendrocyte, and neuronal myelination regeneration has been investigated. Additionally, it has been linked to various activities, including neuronal migration and survival. [1, 10] Other regulators have been identified, such as IGF-1, which may both mediate the activities of GH in the periphery and limit its secretion. Hormones such as leptin can stop GH production. The intestinal peptide ghrelin, which is expressed in the anterior pituitary gland, has also been linked to these associations. This peptide is synthesized in the stomach and is important because it is a nutritional regulator of GH secretion that maintains blood glucose levels during starvation. [7] When GH binds to a particular homodimer receptor, which is mostly found in the liver, it leads to intracellular signaling by activating the JAK/STAT pathway through the phosphorylation cascade. Its major effect is the promotion of hepatic production and the release of IGF-1, which aids in cell division and development. [11]

## PATHOPHYSIOLOGY

Traumatic lesions initiate an inflammatory cascade marked by the presence of inflammatory cytokines and excitatory neurotransmitters that change the balance of calcium and other electrolytes.

Inflammatory compounds are released into the extracellular medium, causing internal self-destruction pathways, which are represented by proteases and caspases that break down cytoskeleton proteins and irreversibly activate programmed cell death. [4, 12, 13] Although the precise etiology of hypopituitarism following traumatic brain injury is unclear, several pathogenic pathways have been suggested as the cause of this dysfunction. [5, 14] Growth hormone deficiency can cause some complications in patients, such as hypothyroidism, hypotension, hypoxia, adrenal insufficiency, electrolyte imbalance, hyperprolactinemia, depression, anxiety, concussions, seizures, vomiting, abnormal scan results, and loss of consciousness. According to previous research, GH insufficiency is significantly affected by age, BMI, pituitary dysfunction, and hypogonadism. [13, 15] Due to the pituitary's physical position, these individuals have ischemic alterations. These changes result from a decrease in cerebral perfusion, which is ascribed to the fragility of the arteries that supply this region. [12] The dysregulation of certain other hormones, including ACTH, Cortisol, Gonadotropin, Prolactin, FSH, TSH, Testosterone, and Hydrocortisone, etc., is also a symptom of GH insufficiency.

#### DIAGNOSIS

Since GH deficiency might be mistakenly identified in individuals who simply have non-specific clinical symptoms, including lethargy, weakness, and obesity, an examination for GH deficiency should be taken into consideration in patients with illnesses that potentially cause it. Arginine, glucagon, levodopa, and clonidine stimulation tests, as well as the insulin tolerance test (ITT) and growth hormone-releasing hormone (GHRH), are used to identify GH insufficiency because GH is produced in bursts. The fundamental idea behind the GH stimulation test is to repeatedly measure blood GH levels following the introduction of a drug that quickly stimulates GH. The patient's GH reaction was then deduced from the maximum GH levels of the samples. [16, 17] Despite being the gold standard test for GH deficient diagnosis, ITT has been contraindicated in elderly patients, patients with a history of epilepsy, and patients with cardiovascular disease due to its hazards of hypoglycemia. ITT is particularly challenging to duplicate because healthy people

respond differently to ITT on different occasions. [17] Most individuals with idiopathic child-onset GH insufficiency exhibit normal GH secretion when reassessed in adulthood. GH stimulation tests do not need to be repeated in patients with structural problems that cause GH deficits, such as tumors, surgery, radiation, and genetic abnormalities, because these conditions do not improve maturity. [18, 19] GH stimulation tests can be skipped if the patient has structural hypothalamic-pituitary conditions, genetic conditions that affect the hypothalamic-pituitary axis, structural lesions in the hypothalamus or pituitary gland, abnormally low levels of three or more pituitary hormones, and low IGF-1 levels (at least 2.0 standard deviations below normal). [17, 20-22]

#### MANAGEMENT

Patients with GH deficits identified by GH stimulation testing are advised to begin GH replacement treatment. Given that the adverse effects are dose dependent, patients should begin treatment with modest dosages. Typical adverse effects include fluid retention, arthralgia, muscular soreness, sensory abnormalities, carpal tunnel syndrome, sleep apnea, sleep difficulties, and dyspnea. Patients who are elderly, fat rich, or female are more likely to experience adverse effects, but they go away when the dose is reduced. Based on the dosage guidelines for children, the GH doses for adults were first calculated based on body weight. However, when dosage recommendations are made individually rather than solely based on weight, adverse effects are reduced by half. [23-25] Age causes a reduction in GH production; therefore, elderly people are more likely to experience adverse GH effects. Therefore, therapeutically acceptable GH levels are lower in the elderly and greater in the younger population. 0.2 to 0.3 mg/day (0.8 to 1.2 IU/day) is a good beginning dosage for those between the ages of 30 and 60. While a greater dose of 0.4 to 0.5 mg/day (1.6 to 2.0 IU/day) is possible for those under the age of 30, those over 60 should start with a dose of 0.1 to 0.2 mg/day (0.4 to 0.8 IU/day) and gradually raise it over time. The dosage should be increased by 0.1 to 0.2 mg/day (0.4 to 0.8 IU/day) monthly or bimonthly, and the maintenance level should be determined based on an evaluation of the patient's clinical response, side effects, and the normal range of IGF-1 levels for the patient's age group. Although normal IGF-1 levels

are targeted, evidence remains unclear. Clinical responses can usually be observed after 6 months of treatment. [26, 27] Females typically exhibit greater levels of GH resistance, necessitating larger initial and ongoing dosages. In the liver, where 85% of serum IGF-1 is produced, estrogen promotes suppressor of cytokine signaling 2 (SOCS2), a non-competitive suppressor of GH. IGF-1 is suppressed by oral estrogen; therefore, females need to take more GH to maintain their levels at the same level. Indicators of body fat, low-density lipoprotein cholesterol, and bone turnover in women are less affected by GH, even at the same IGF-1 levels. GH levels need to decrease when oral estrogen is switched to transdermal estrogen. [28-31]

#### FOLLOW UP

The adequacy of GH dosage, including an assessment of the patient's clinical response, side effects, and IGF-1 levels, should be checked monthly or biweekly during the adjustment phase. IGF-1 levels should be checked every six months once the maintenance level has been established. Fasting blood sugar and cholesterol levels should be checked annually, and if the first bone mineral density is abnormal, it should be checked every 1.5 to 2 years. Additionally, quality of life and waist size need to be assessed. After GH is administered, the thyroid or adrenal hormone dosage that the patient is already receiving should be changed. These suggestions are supported by the actual data. Although it is not clear exactly how long GH should be administered, therapy can be stopped if there is no noticeable improvement from GH replacement after at least a year. [26, 28] The freshly created long-acting GH is designed to be taken weekly or monthly rather than daily. Because it lessens the bother and discomfort associated with regular GH injections, long-acting GH may be more effective in improving compliance. A recent meta-analysis found that the effectiveness and safety profiles of daily and long-acting GH were comparable. However, in children with GH deficiency who received long-acting GH, IGF-1 levels were noticeably increased. The effects of peak and trough GH and IGF-1 levels on efficacy and safety, modification of the dose, assessment of IGF-1 levels, and assessment of the long-term cost-effectiveness of daily and long-acting GH preparations should be the subject of future studies. [32, 33]

#### FUTURE RESEARCH

In an effort to increase adherence to therapy in GH-deficient individuals, several methods have been developed and researched. These methods range from creating devices that make GH administration less uncomfortable to altering the GH molecule and prolonging its action in the body. Future research should focus on the development of devices for better GH delivery. To replicate pulsatile GH secretion via microfluidic devices, micro total analysis systems (TAS) and microelectromechanical systems (MEMS) have been developed. [34] MEMS are still in the early phases of research and may be used for one day to treat GH insufficiency. To ensure continuous delivery of GH in a pulsatile manner, it is necessary to combine biological alterations of GH to improve its solubility and MEMS. A device that reacts to physiological stimuli and administers GH in a pulsatile fashion is necessary to provide viable MEMS for GH treatment. MEMS are appealing for biological applications owing to their ability to continuously distribute medicine and hence avoid peak-valley oscillations. With innovations based on diagnostics, medical wearables, digital health, and innovative medication delivery methods, MEMS offer significant translational promise. [34-36] Chronic disorders such as type 1 diabetes are successfully treated using microfluidics for medication delivery. Microfluidics-based GH delivery devices are now on the market and are being evaluated for adherence, with better outcomes than routine injections. EasyPod™ is an automated electronic injection device for the delivery of GH based on MEMS, providing benefits for the patient as it causes less pain and has an electronic setup and dosage for proper GH administration, as well as digital follow-up of the patient's injections and information about treatment adherence to the doctor. Great strides have been made in the use of cadaveric GH to rGH and EasyPod™, providing patients with a variety of therapeutic options. [37, 38].

#### CONCLUSION

It has been observed that traumatic brain injuries can lead to endocrine dysfunction that can lead to biochemical changes; permanent lesions have been explained due to the alteration in the shape and function of the blood vessels, finding a compromise in cerebral irrigation; as a result of this and taking into account the anatomical location, the pituitary

gland is an organ susceptible to ischemic damage. Patients with GH deficiency require GH replacement therapy, and age and sex are two important factors that cause GH production. Females typically exhibit greater levels of GH resistance, necessitating larger initial and ongoing dosages. Future research needs to be conducted to develop devices for better GH delivery. Moreover, more research is required to develop innovative treatment strategies for GH-IGF axis diseases and other types of short stature for a better understanding of their pathogenesis.

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# Embolization of middle meningeal artery in chronic subdural haematoma. Scientometrics analysis

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## ABSTRACT

**Background:** Embolization of the middle meningeal artery (MMA) is a non-invasive procedure that is used as an alternative to surgical drainage in the treatment of subdural hematoma. The aim of our study is to represent the top-cited articles discussing the embolization of the MMA in treating chronic subdural hematoma (cSDH).

**Methods:** Scopus database was used in June 2022 to search for the top 50 cited articles related to the embolization of the MMA in cSDH. Articles were assessed using bibliometric parameters, H-indices, impact factor, number of citations per article, and article type. The data was statically analyzed by using SPSS 23 along with Microsoft Excel.

**Results:** Among the top 50 cited articles, the highest citation was 95 (article entitled "Middle meningeal artery embolization for chronic subdural hematoma"). The most productive year was 2020 with 13 articles, followed by 2021 with 11 articles. The United States of America (USA) contributed to 24 articles with 9 neurosurgical institutes. Most articles were case reports and case series (48%).

**Conclusion:** This study collected the top 50 cited articles about embolization of the MMA in cSDH which can be used as a resource for clinicians in their practice and helps them to find the gap in the knowledge about this topic.

## BACKGROUND

A subdural hematoma is a form of intracranial injury where an abnormal collection of blood gets formed beneath the dura mater, typically from a bleeding bridging vein. Even though the hematoma may spontaneously resolve; subsequent bleeding may recur due to angiogenesis and vascularization following inflammatory processes. The newly formed vessels get their blood supply from the middle meningeal artery (MMA). Chronic subdural hematoma (cSDH) forms days or weeks after the initial bleeding and it is considered one of the most common neurological disorders.[6] Symptoms onset is gradual

## Keywords

MMA,  
middle meningeal artery,  
embolization



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and appears after three weeks. The most common etiology for cSDH is trauma, other causes include intracranial hypotension, coagulopathy, and the use of antiplatelet or anticoagulant medications. Chronic subdural hematoma incidence ranges from 1.72 to 20.6 per 100000 people annually. [17] It's more common among the elderly age group and it is more common in males compared to females with a ratio of three to one. [1]

Treatment options for cSDH are various and there is no standardized treatment among neurosurgeons. Multiple factors such as the presence of symptoms or signs of cerebral compression on imaging affect the treatment choice which ranges from conservative to medical and/or surgical. Conservative management may be considered in asymptomatic patients with small cSDH. Neurosurgical intervention options include minimally invasive surgery, traditional surgery, and other methods. For the minimally invasive surgery, twisted drill (TD) craniotomy and burr hole (BH) trephination followed by closed system drainage are used. Rapid symptom resolution and shorter hospital stays are associated with TD and BH, thus it is considered as the mainstay of treatment of cSDH. [12] As for traditional surgery, craniotomy and craniectomy are utilized. In addition to that, uncommon methods for cSDH management include subdural tap, subduperitoneal shunt, subgaleal reservoir, reduction craniotomy, and MMA embolization. [5, 12]

The use of MMA embolization has been introduced as an alternative to surgery for the management of acute or recurrent SDH, mostly those which recur more than two times. A case report by Hashimoto et al. in 2013 revealed that patients treated with MMA embolization for recurrent cSDH had no repeated recurrence after the procedure based on head CT imaging. This was attributed to the fact that MMA embolization suppresses the blood supply to the CSDH membrane and therefore controls the bleeding and formation of the hematoma, which later results in its resolution of it. [10]

Bibliometrics analysis or Scientometrics analysis refers to the statistical evaluation of published research to trace the relationships between academic journal citations. It is used to evaluate the impact, quality, and reliability of an academic publication. [10]

The aim of this study is to perform a detailed bibliometric analysis of publications about the role of MMA embolization in treating cSDH.

## METHODS

In June 2022, we performed a Scopus database search to identify highly cited articles on embolization of the MMA in cSDH, keywords that were used in our search were "middle meningeal artery" "embolization" and "chronic subdural hematoma" "MMA" "SDH" respectively.

For each keyword, we selected the top 100 articles and then we assessed those articles for eligibility by title or by abstract and full text in case of ambiguity respectively, criteria for included articles were all articles that speak about cSDH and MMA embolization, all study design was selected, articles excluded if they are not in the scope of SDH and MMA embolization

Then top 50 selected articles were categorized by rank number, title, first author, country of origin, and neurosurgical institutions that contributed to the largest number of publications as well as annual distribution of published articles

H-indexed is used to measure journal source impact factors which include the journal title, category, quartile, impact factor, and the number of articles.

Statistical analysis was performed using SPSS version 23 and Microsoft excel, descriptive statistical analysis was performed, and descriptive data were quantified as counts or percentages of parameters.

## ANALYSIS

Table 1 lists the top 50 cited articles on MMA embolization in cSDH demonstrating the number of citations and first author, the highest citation was 95 [2] and the lowest was 1. [3, 7, 8, 9, 15]

Ban, S.P., et al, studied the effect of embolization of MMA in cSDH compared to conventional therapy and they conclude that cSDH responds favorably to MMA embolization. In addition to that, they concluded that the embolization was more effective than conventional treatment. Mandai, S., et al who is the 2nd top-cited reported a case with chronic SDH due to liver coagulopathy treated successfully with MMA embolization after several standard care procedures like drainage. [14] The top 3rd cited article [13] showed a case series, which had 6 patients with 7 recurring, chronic SDHs, 6 of the 7

patients were effectively treated with MMA embolization, indicating that this minimally invasive method may be a viable alternative to surgery. Tempaku, A., et al in 2015 was the 4th top-cited aimed to determine the efficacy of MMA embolization, no patient experienced a recurrence of cSDH, so MMA embolization with close attention to

the process may be the preferred therapy for recurrent chronic SDH. [16] According to Kim, E., et al, the 5th most cited, in comparison to conventional therapy, a perioperative MMA embolization may be the least intrusive and most effective form of therapy for patients with resistant chronic SDHs who have experienced one or more recurrences. [11]

**Table 1: Top 50 Articles with Their Total Citations and name of first authors**

Rank	Title	First Authors	Total Cit.
1	Middle meningeal artery embolization for chronic subdural hematoma	Ban, S.P.	95.0
2	Middle meningeal artery embolization for refractory chronic subdural hematoma. Case report	Mandai, S.	75.0
3	Middle Meningeal Artery Embolization for Chronic Subdural Hematoma: A Series of 60 Cases	Link, T.W.	67.0
4	Usefulness of interventional embolization of the middle meningeal artery for recurrent chronic subdural hematoma: Five cases and a review of the literature	Tempaku, A.	50.0
5	Embolization Therapy for Refractory Hemorrhage in Patients with Chronic Subdural Hematomas	Kim, E.	49.0
6	Middle meningeal artery embolization for chronic subdural hematoma: Endovascular technique and radiographic findings	Link, T.W.	38.0
7	Embolization of the middle meningeal artery in patients with chronic subdural hematoma—a systematic review and meta-analysis	Haldrup, M..	28.0
8	Middle meningeal artery embolization for refractory chronic subdural hematoma: 3 Case reports	Takahashi, K.	27.0
9	Embolization of the middle meningeal artery for refractory chronic subdural haematoma. Usefulness for patients under anticoagulant therapy	Hirai, S.	24.0
10	Middle meningeal artery embolization as an adjuvant treatment to surgery for symptomatic chronic subdural hematoma: A pilot study assessing hematoma volume resorption	Ng, S.	23.0
11	Chronic Subdural Hematoma: Toward a New Management Paradigm for an Increasingly Complex Population	Iorio-Morin, C.	23.0
12	Middle meningeal artery embolization reduces the post-operative recurrence rate of at-risk chronic subdural hematoma	Shotar, E.	22.0
13	Middle meningeal artery embolization as treatment for chronic subdural hematoma: A case series	Link, T.W.	22.0
14	Middle Meningeal Artery Embolization for Chronic Subdural Hematoma: A Multi-Center Experience of 154 Consecutive Embolizations	Kan, P.	18.0
15	Chronic subdural hematoma associated with middle meningeal arteriovenous fistula treated by a combination of embolization and burr hole drainage	Komiyama, M.	18.0
16	Middle Meningeal Artery Embolization for Recurrent Chronic Subdural Hematoma: A Case Series	Link, T.W.	16.0
17	Middle meningeal artery embolization for chronic subdural hematoma: An institutional technical analysis	Catapano, J.S.	15.0
18	Middle meningeal artery embolization treatment of nonacute subdural hematomas in the elderly: a multiinstitutional experience of 151 cases	Joyce, E.	15.0
19	Midterm Follow-Up of Patients with Middle Meningeal Artery Embolization in Intractable Chronic Subdural Hematoma	Okuma, Y.	15.0
20	Enhanced Hematoma Membrane on DynaCT Images During Middle Meningeal Artery Embolization for Persistently Recurrent Chronic Subdural Hematoma	Nakagawa, I.	13.0
21	Transradial middle meningeal artery embolization for chronic subdural hematoma using Onyx: Case series	Rajah, G.B.	12.0

22	Meningioma with Intratumoral and Subdural Hemorrhage as an Immediate Complication of Therapeutic Embolization	Watanabe, K.	11.0
23	Middle meningeal artery embolization for chronic subdural hematoma with high risk of recurrence: A single institution experience	Yajima, H.	8.0
24	To drill or not to drill, that is the question: nonsurgical treatment of chronic subdural hematoma in the elderly. A systematic review	Scerrati, A.	7.0
25	A propensity-adjusted comparison of middle meningeal artery embolization versus conventional therapy for chronic subdural hematomas	Catapano, J.S.	6.0
26	Recurrence and conglobus volumetric resolution of subacute and chronic subdural hematoma post-middle meningeal artery embolization	Tiwari, A.	6.0
27	Angiographic Anatomy of the Middle Meningeal Artery in Relation to Chronic Subdural Hematoma Embolization	Shotar, E..	5.0
28	Risk of recurrence of subdural hematoma after EMMA vs surgical drainage – Systematic review and meta-analysis	Dian, J.	5.0
29	Upfront middle meningeal artery embolization for treatment of chronic subdural hematomas in patients with or without midline shift	Gomez-Paz, S.	5.0
30	Application of Absolute Alcohol in the Treatment of Traumatic Intracranial Hemorrhage via Interventional Embolization of Middle Meningeal Artery	Fan, G.	5.0
31	DynaCT Enhancement of Subdural Membranes After Middle Meningeal Artery Embolization: Insights into Pathophysiology	Mureb, M.C.	5.0
32	Transradial embolization of the left middle meningeal artery and accessory middle meningeal artery for treatment of subacute-chronic subdural hematoma	Rajah, G.B.	5.0
33	Embolization of a traumatic arteriovenous fistula between the middle meningeal artery and middle meningeal vein in a child with pulsatile tinnitus	Martinez, M.	5.0
34	Chronic subdural hematoma infected by Propionibacterium acnes: A case report	Yamamoto, S.	5.0
35	Delayed presentation of traumatic cerebral and dural arteriovenous fistulae after a BB gun accident in a pediatric patient: Case report	Abla, A.A.	5.0
36	High frequency of ophthalmic origin of the middle meningeal artery in chronic subdural hematoma	Fantoni, M.	4.0
37	Middle meningeal artery embolization using combined particle embolization and n-BCA with the dextrose 5% in water push technique for chronic subdural hematomas: a prospective safety and feasibility study	Al-Mufti, F..	3.0
38	Recurrent Bilateral Chronic Subdural Hematoma After Interventional Embolization Combined With Drilling and Drainage Treatment	Wang, H.	3.0
39	Contrast enhancement of chronic subdural hematomas after embolization of the middle meningeal artery	Entezami, P.	3.0
40	Perspective on Safety and Effectiveness of Middle Meningeal Artery Embolization for Chronic Subdural Hematoma	Srivatsan, A.	3.0
41	Middle Meningeal Artery Embolization for Chronic Subdural Hematomas: Cautious Optimism for a Challenging Pathology	Foreman, P.	3.0
42	Subdural and intracerebral hemorrhage caused by spontaneous bleeding in the middle meningeal artery after coil embolization of a cerebral aneurysm	Kohyama, S.	3.0
43	Middle meningeal artery embolization with subdural evacuating port system for primary management of chronic subdural hematomas	Carpenter, A.	2.0
44	Refractory Chronic Subdural Hematoma Associated with Dural Metastasis of Lung Adenocarcinoma Treated with Endovascular Embolization for the Middle Meningeal Artery: A Case Report and Review of the Literature	Kosaka, T.	2.0
45	Chronic headaches and middle meningeal artery embolization	Catapano, J.S.	1.0
46	Dural venous system: Angiographic technique and correlation with ex vivo investigations	Shapiro, M.	1.0
47	Perioperative prophylactic middle meningeal artery embolization for chronic subdural hematoma: a series of 44 cases	Schwarz, J.	1.0
48	Outpatient management of chronic expanding subdural hematomas with endovascular embolization to minimize inpatient admissions during the COVID-19 viral pandemic	Entezami, P.	1.0

49	Middle Meningeal Artery Embolization Versus Conventional Treatment of Chronic Subdural Hematomas	Enriquez-Marulanda, A.	1.0
50	Pediatric middle meningeal artery embolization for chronic subdural hematoma: A case report	Faber, R.	1.0

Table 2: Distribution of the 15 major journals according to the source impact measured by H-index:

journal title	journal category	quartile	impact factor	number of articles	h-index
Neurosurgical focus	Medicine (miscellaneous) (Q1); Neurology (clinical) (Q1); Surgery (Q1)	Q1	4.047	2	102
Radiology	Medicine (miscellaneous) (Q2); Radiology, Nuclear Medicine and Imaging (Q2)	Q1	11.1	1	307
Journal of NeuroInterventional Surgery	Medicine (miscellaneous) (Q1); Neurology (clinical) (Q1); Surgery (Q1)	Q1	5.836	7	64
Journal of Neurotrauma	Neurology (clinical) (Q1)	Q1	5.269	1	156
Journal of Neurosurgery	Neurology (clinical) (Q1); Surgery (Q1)	Q1	5.115	3	219
Neurosurgery	Neurology (clinical) (Q1); Surgery (Q1)	Q1	5.115	3	207
Frontiers in Neurology	Neurology (clinical) (Q1); Neurology (Q2)	Q2	4.003	1	80
American Journal of Neuroradiology	Medicine (miscellaneous) (Q1); Neurology (clinical) (Q1); Radiology, Nuclear Medicine and Imaging (Q1)	Q1	3.86	1	185
Diagnostics	Clinical Biochemistry (Q2)	Q2	3.706	1	35
Clinical Neuroradiology	Neurology (clinical) (Q2); Radiology, Nuclear Medicine and Imaging (Q2)	Q2	3.649	1	31
Operative Neurosurgery	Surgery (Q1); Neurology (clinical) (Q2)	Q1	2.703	1	26
Acta Neurochirurgica	Surgery (Q1); Neurology (clinical) (Q2)	Q1	2.216	1	100
World Neurosurgery	Surgery (Q1); Neurology (clinical) (Q2)	Q1	2.104	7	101
Clinical Neurosurgery	Neurology (clinical) (Q1); Surgery (Q1)	Q1	1.876	1	38
Clinical Neurology and Neurosurgery	Medicine (miscellaneous) (Q2); Surgery (Q2); Neurology (clinical) (Q3)	Q2	1.876	1	77

Figure 1 displays the overlay visualization of the keywords for the top 50 cited articles related to the embolization of the MMA in cSDH in the Scopus database. Out of the 922 keywords used, 145 had a minimum occurrence of five times at least. The size of each circle indicates the weight of occurrence. The larger the size, the more the occurrence. For example, the occurrence of the keyword “subdural hematoma” was 138 times, “human and humans” was 138 and 105 respectively, and “meningeal artery” was 121 times. The keywords “embolization” had an occurrence of 178 times which was the highest occurrence. The color density indicates the year of publication. The line connected to the circle shows

the links between the keywords. Figure 2a shows the total links of the keyword “human”. There was 2939 total connected with the other keywords. The second keyword with the highest connection was “meningeal artery” with 2645 connections (figure 2b). In comparison, the keywords “arterial embolization” had 1824 connections (figure 2c).

There was a total of 779 authors involved in the top 50 cited articles. The authors grouped into 13 clusters based on the connection with a total of 2338 connections between all authors (figure 3). The color density indicates the year of publication. The size of the circle shows the number of documents published per author. The highest number of



American Journal of Neuroradiology ((IF)=3.86 ), Diagnostics ((IF)=3.706 ), Clinical Neuroradiology ((IF)= 3.649 ), Operative Neurosurgery ((IF)=2.703 ), Acta Neurochirurgica ((IF)=2.216 ), World Neurosurgery ( (IF)=2.104 ), Clinical Neurosurgery and Clinical Neurology and Neurosurgery ((IF)=1.876).

A total of 32 articles were published in these 15 journals, with the Journal of NeuroInterventional Surgery and World Neurosurgery having the highest number of articles (n=7), followed by the Journal of Neurosurgery and Neurosurgery (n=3). Two Articles were published in the neurosurgical focus journal (n=2), and the rest of the included journals all published one article (n=1). The mean H-index of the top 15 journals is 115.2 and the range is from 26 to 307. Radiology scored the highest source impact (H-index=307), followed by the Journal of Neurosurgery and Neurosurgery (219 and 207 respectively). On the other hand, the lowest source impact was scored by Diagnostics (H-index=35), followed by Clinical Neuroradiology (H-index=31), and Operative Neurosurgery scored the lowest (H-Index=26).

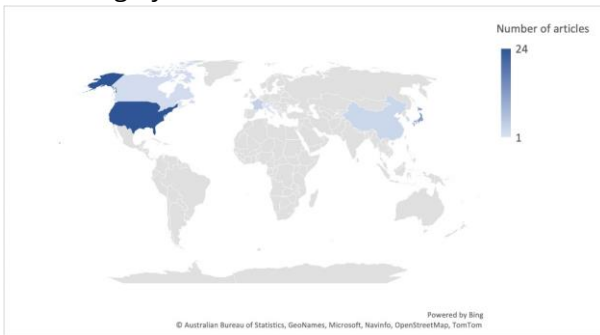


Figure 5.

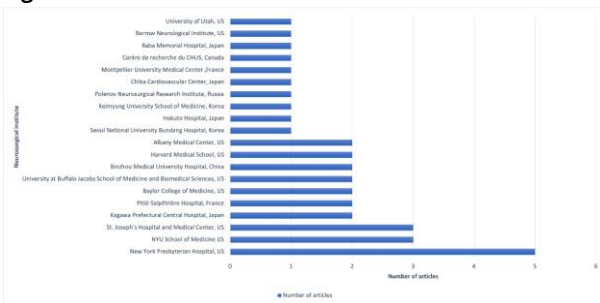


Figure 6.

**Geographical trends**

The top 50 articles originated from 9 countries were displayed in the figure 5, with the United States of America (USA) contributing to 24 articles, followed by Japan with 12 articles, France (4 articles), China (3 articles), Canada (2 articles), South Korea (2 articles),

Austria (1article), Denmark (1 article), and Italy (1 article).

Figure 6 illustrated the top 20 neurosurgical institutes contributing the largest number of articles. Most of the institutes were from the USA (N = 9) followed by Japan (N=4). The top neurosurgical institute was New York Presbyterian hospital contributed to 5 articles. One of their articles [13] cited 67 times, represents a series of 60 cases of embolization of MMA in new subdural hematoma, recurrent cSDH and as prophylaxis, the outcome showed 91% long-term success rate. The second institutes were NYU School of Medicine and St. Joseph’s Hospital and Medical Center with 3 articles from each.

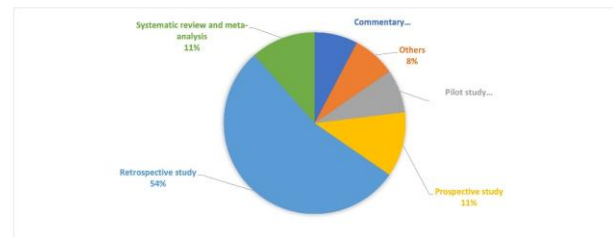


Figure 7.

As represented in the Figure 7, most articles were case reports and case-series, which is expected because of the nature of the intervention. The top cited case report of Mandai, S., et al, in 2000 that cited 75 times, represents successful embolization of the MMA after multiple attempts of surgical drainage in a patient who was 59 years old with coagulopathy secondary to liver cirrhosis. Retrospective studies accounted for more than a quarter of the articles that involved in this analysis. Three articles were systematic reviews and meta-analyses. An example of highly cited review was by (Dian, J., et al, 2021) that was cited 5 times concluded that the risk of recurrence of cSDH was reduced by 20% in those treated with embolization of MMA compared to those treated with surgical drainage alone. [4]

**LIMITATIONS**

First of all, bibliometric analysis is counted as a quantitative type of study not qualitative. Second, we use the SCOPUS database only, other databases were not involved. Third, the number of citations will change over time. Finally, we include the articles in the English language only, other articles in different languages were not included.

## CONCLUSION

Our study includes the top 50 cited articles related to the embolization of the middle meningeal artery in chronic subdural hematoma. It helps the readers and researchers in their clinical decision and to find the unanswered questions in order to be answered in the future by further researches.

## ABBREVIATIONS

**MMA:** middle meningeal artery  
**cSDH:** Chronic Subdural Hematoma  
**SDH:** Subdural Hematoma  
**TD:** Twisted Drill  
**BH:** Burr Hole  
**CT:** Computerized Tomography  
**SPSS:** Statistical Package for the Social Sciences  
**N:** Number  
**USA:** United State of America  
**NYU:** New York University  
**COVID 19:** Coronavirus disease 2019

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# Fahr's syndrome revealed by convulsive seizures. A case report

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## ABSTRACT

Fahr's syndrome is a fairly rare antomo-clinic entity, it is defined by the existence of bilateral and symmetrical cerebral calcifications, especially of the central grey nuclei and is often associated with dysparathyroidism. We report the case of a young 29-year-old patient who presented with seizures and headaches. A CT scan of the brain showed calcifications of the central grey nuclei, the periventricular and subcortical white matter as well as the dentate cerebellar nuclei. The biological assessment showed hypoparathyroidism and hypocalcaemia. Substitutive medical treatment based on calcium and vitamin D allowed a clear rapid clinical improvement.

## INTRODUCTION

Fahr's syndrome, described in 1930 by Théodor Fahr, is defined radiologically by the presence of striato-pallido serrated calcifications, no arteriosclerotic, bilateral and symmetrical (1). It is a rare condition characterized by a clinical polymorphism made essentially of neuropsychiatric disorders. The etiologies are dominated by dysparathyroidism. Fahr's triad is defined by the association of bilateral and symmetrical intracerebral calcifications of the basal ganglia, disorders of phosphor-calcium metabolism and neuropsychiatric manifestations (2).

## CLINICAL CASE

A 29-year-old female patient was seen in consultation 3 years ago for episodes of non-clonic and very invigorating convulsive seizures followed by a brief loss of consciousness and partial functional of the left hemibody which resolved spontaneously in 30 minutes. All this evolved in a context of chronic headaches. The interrogation found a history of the death of his older brother in the context of convulsive seizures after several years.

The clinical examination found a sluggish patient, communicates very little and presents a frozen look at times. MRI and Brain CT (Pictures A, B, C) showed multiple symmetrical and bilateral intracerebral calcifications of the basal ganglia (striatum and thalamic nuclei),

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## Keywords

Fahr's syndrome,  
seizures,  
hypo-parathyroidism

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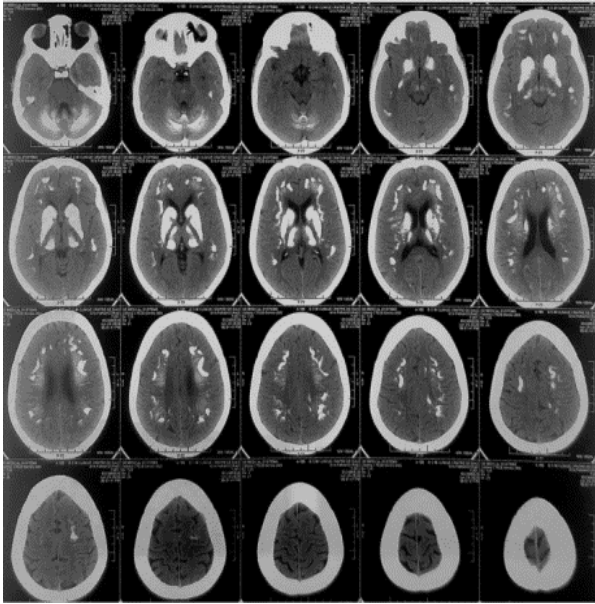
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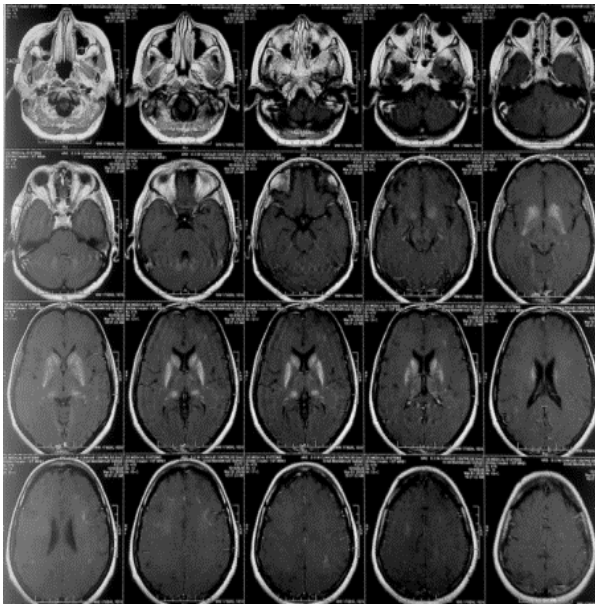
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periventricular and subcortical white matter, and dentate cerebellar nuclei. This radiological appearance was strongly suggestive of Fahr's syndrome.



**Figure 1.** Initial brain scan in axial section without injection of contrast product.



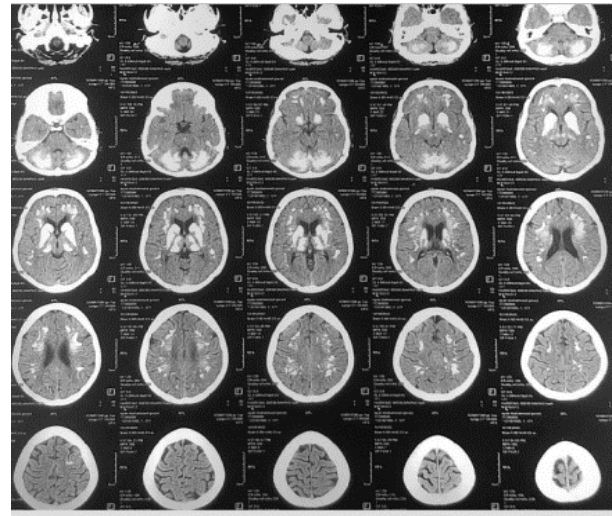
**Figure 2.** Initial IMR in axial section without injection of contrast product.

Laboratory tests revealed a profound hypoparathyroidism and hypocalcemia (Table N°1). The rest of the assessment, in particular the blood count (CBC), 24-hour proteinuria, thyroid

assessment, cervical ultrasound, abdominal and pelvic ultrasound, returned to normal.

The patient was put on an anticonvulsant (sodium valproate at 30 mg/kg/day), on calcium (2.5 g/day) and vitamin D (2 µg/day) and an adapted diet, in particular in terms of calcium intake.

The evolution during these 3 years was favorable and marked by the complete cessation of the crises even under low doses of 15 mg/kg/day of sodium valproate, the headaches decreased considerably, the calcemia was corrected, the parathyroid hormone remained low and imaging unchanged.



**Figure 3.** Brain scan after 3 years of medical treatment.

**Table 1.** Evolution of the biological assessment under medical treatment.

	Initial Value	At 18 months	At 36 months
Calcemia	50,90 mg/l	103,04 mg/l	102,60 mg/l
Parathyroid hormone	5,54 pg/ml	2,24 pg/ml	5,19 pg/ml
Vitamin D	36,82 ng/ml	41,78 ng/ml	23,61 ng/ml
Phosphoremia	61,4 mg/l	56,12 mg/l	-
Magnesiumemia	15,77 mg/l	26,68 mg/l	-

## DISCUSSION

Intracerebral calcifications have been described by several authors since 1855 before Théodor Fahr (1930) gave his name to the syndrome (1). Fahr's syndrome is a rare anatomico-clinical entity,

determined by the presence of intracerebral, bilateral and symmetrical, non-arteriosclerotic calcifications, located in the central gray nuclei. It is usually associated with disorders of calcium phosphate metabolism, and mainly with hypoparathyroidism (3). The physiopathological mechanisms of intracerebral calcifications in Fahr's syndrome are poorly understood. Most authors mention a metabolic disorder of oligoglial cells with deposits of muco-polysaccharides and secondary appearance of vascular and perivascular lesions and calculus encrustations. (4).

It is important to distinguish Fahr's syndrome from Fahr's disease, the latter is a genetic disease to be sought in front of a Fahr's syndrome without found etiology (5) and would be autosomal recessive or dominant (6).

The occurrence of calcifications is possible from infant age (5) to advanced age (7). The average age of symptom manifestation would be around 29 years (8) as in the case of our patient. The male sex would be more affected (1, 8, 9).

Fahr's syndrome can remain asymptomatic and be discovered during brain imaging (3, 10). The clinical manifestations are polymorphic (3, 11, 12) and are made up of neuropsychiatric disorders, essentially cognitive disorders, psychiatric disorders and abnormal movements. Neurological signs are dominated by seizures (1, 4, 5, 9, 13) as in the case of our patient in whom it was the discovery of the syndrome following episodes of seizures. Parkinsonian syndrome (7, 11), myoclonus (12), cerebellar syndrome, intracranial hypertension syndrome and pyramidal syndrome are also described in neurological manifestations. Neuropsychiatric and cognitive signs may be indicative of the syndrome (5). Dermatological (14), ophthalmological (cataract and exophthalmos) (15) and signs related to hypocalcaemia (muscle cramps, tetany attacks) should be sought in the context of Fahr's syndrome.

The cerebral scanner makes it possible to make the diagnosis of calcifications. These calcifications are bilateral and symmetrical and may involve the central gray nuclei, the cortex, the vessels and the cerebellar gray nuclei (1).

The phosphor-calcic balance, constantly disturbed, manifests itself essentially by hypoparathyroidism, hypocalcaemia and hyperphosphoremia (1).

The treatment is medical, based on the treatment of the cause and that of the symptoms. Phosphocalcic disorders (in particular hypocalcemia) and hypovitaminosis D are treated by the replacement intake of calcium and vitamin D due to 1 to 2g/day of calcium in adults, 40 to 60 mg/Kg/ day in children and 1µg/day of OH-Vitamin D3 (3, 4, 1, 13). As in our patient, the case of epilepsy, antiepileptic drugs could be offered while avoiding those that can induce or aggravate hypocalcemia. Extrapyramidal manifestations generally respond poorly to dopa therapy (5).

The evolution under treatment is very favorable with complete disappearance of clinical manifestations and biological abnormalities, from the first months of medical treatment (11, 7). The precocity of the medical treatment is a guarantee of the considerable improvement of the neurological clinical signs in particular the convulsive crises, the cerebellar syndrome and even extrapyramidal. Mental disorders, when established, are not improved by medical treatment, nor are cerebral calcifications (16).

## CONCLUSION

Fahr's syndrome is a rare pathology and its pathophysiological mechanisms are not yet well understood. Despite its clinical polymorphism, the prognosis remains good, especially if medical treatment is started early. Hence, the interest of looking for anomalies of calcium phosphate metabolism and intracerebral calcifications in the event of neuropsychiatric disorders.

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# Endoscopic third ventriculostomy in post traumatic hydrocephalus. Institutional experience

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## ABSTRACT

**Background:** Hydrocephalus is a known sequelae in traumatic brain injury patients. It may occur early or late and presents with dementia, urinary incontinence and difficulty in walking. There are two distinct types of normal pressure hydrocephalus one is idiopathic most commonly seen in the elderly age groups and the other is secondary due to a CerebroVascular Accident, trauma or surgery. The idiopathic type may not respond to the cerebrospinal fluid diversion procedure, but the secondary type responds to the cerebrospinal fluid diversion procedure. Our study aims at exploring the option of Endoscopic third ventriculostomy in these patients not making them shunt dependent.

**Materials and methods:** The patients with traumatic brain injury admitted to the department of neurosurgery between January 2012 and January 2018 were included in the study. Congenital hydrocephalus and secondary hydrocephalus due to spontaneous Sub arachnoid haemorrhage and tumours were excluded. 14 patients were identified and if there was some improvement in their condition after cerebrospinal fluid tap tests were planned for endoscopic third ventriculostomy.

**Results:** Out of the 14 patients 2 were females and the remaining 12 were males. 2 did not improve at all. 12 had some improvement out of which 3 had a failure and underwent a ventriculo peritoneal shunt. Hence there were 5 failures out of 14 which made 35.7%.

**Conclusion:** Endoscopic third ventriculostomy is an option which can be offered to patients with secondary hydrocephalus. The chances of failure though present the procedure is minimally invasive and improves cerebrospinal fluid dynamics.

## BACKGROUND

Traumatic brain injury has many a sequele of which hydrocephalus is one<sup>1,3</sup>. The causes of hydrocephalus maybe due to intra ventricular hemorrhage, infection, hence it is referred to as secondary hydrocephalus<sup>2</sup>. The morbidity causes decrease in the quality of life in these patients. The treatment for this CSF diversion procedure<sup>2</sup>. The procedures practiced are Endoscopic third ventriculostomy and Ventriculoperitoneal shunt<sup>3,4</sup>.

There is limited literature available on this topic. 0.7% to 51% is the incidence of post traumatic hydrocephalus<sup>5</sup>. The studies prove that

## Keywords

secondary hydrocephalus  
due to trauma,  
endoscopic third  
ventriculostomy,  
trauma induced  
hydrocephalus.



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surgical mode of treatment is the mainstay and the gold standard.

We being a tertiary care centre come across many such patients, being in a tier II city these patients and their families are financially and emotionally challenged. This study aims to evaluate the outcomes of both the procedures and a comparison as to which of these procedures can be offered to these patients.

## MATERIAL AND METHODS

### Aims

- To evaluate symptomatic post TBI patients for raised intra cranial pressure.
- To evaluate the neurological outcome of ETV patients
- To evaluate the neurological outcome of VP shunt patients
- To establish an economical modality of treatment.

### Study design

This was a prospective study which was conducted from January 2014 to January 2019. As per the institutional policy ethical clearance was sought from the institutional ethics committee. The inclusion criteria were as follows:

- A. All patients above 18 years of age
- B. Both male and female patients were included.
- C. Moderate and severe traumatic brain injury patients
- D. Hydrocephalus proven on CT scan brain.

The exclusion criteria were:

- A. Children
- B. Mild traumatic brain injury patients (as the incidence of hydrocephalus in such patients is very low)
- C. Patients previously treated for hydrocephalus or those who have undergone prior brain surgery.
- D. Malnourished patients with low serum albumin, total protein levels or hyperbilirubinemia as wound healing will not be optimum.

3000 patients were admitted during this period with traumatic brain injury were included in the study. 622 patients were diagnosed to have hydrocephalus. The option of procedure was given to the patient to

decide on which procedure to opt for. The pros and cons of the procedure were discussed with the patient relatives in detail.

246 patients consented for ETV and 362 consented for VPS. The remaining 14 did not want any further intervention. These 14 patients were lost to follow up.

## PROCEDURE

Both the procedures were done by a single surgeon without any change in the steps of procedure in each surgery. Standard procedure as stated in Schmidek and Sweet operative neurosurgical techniques were followed. For the

endoscopic third ventriculostomy the patient is put in supine position with the neck in minimal flexion. Kochers point is identified. Vertical incision is made at the Kochers point. Periosteal flap is raised. Brain canula is introduced and the ventricle tapped tractis established. Scope is introduced in ,the foramen of Munro is identified with the venous anatomy. Third ventricle is entered and mammillary bodies identified , anterior to the mammillary bodies perforation is made in the membrane, Lilquist membrane is identified and opened to see the basilar artery. Complete hemostasis confirmed and closure done in two layers.

## Ventricle peritoneal shunt

Patient put in supine position under anaesthesia, patient is positioned with the head turned to the left side with a sand bag under the shoulder and the hip. Incision is made at the Keen's point and the abdomen. Tunnelling is done from the Keen's point to the abdomen and the peritoneal catheter placed in situ. Through the burr hole the dura is cauterised and opened. Ventricle is tapped and ventricular catheter placed. Ventricular and peritoneal catheter is connected. Peritoneal catheter is placed into the peritoneum after confirming the flow. The skin incisions are closed in layers and occlusive dressings done.

## RESULTS

The total number of patients identified was 622 out of which 246 underwent ETV and 362 underwent VPS, the rest 14 got discharged against medical advice (Table 1).

**Table 1.** Showing the type of procedure done.

Total Number of patients with Post traumatic Hydrocephalus	ETV	VPS	No procedure
622	246	362	4

**Table 2.** Showing the results of ETV.

Total no. -ETV	Successful	Failed
246	137	106

**Table 3.** Complications of ETV

ETV	CSF leak	Ventriculitis	Failure Of procedure
246	3	3	109

**Table 4.** Showing results VPS.

VPS	Successful	Failed
362	344	18

**Table 5.** Complications of ETV

Etv	Shunt Malfunction	Distal Catheter Block	Infection	Proximal Catheter Block	Shunt Migration	Ventriculitis
362	18	3	2	4	3	6

Out of the 246 cases who underwent ETV 109 cases failed and underwent VPS (Table-2). The majority symptoms were patient being the same after procedure, CSF leak from wound site, altered third ventricular anatomy, 3 patients had ventriculitis and succumbed to it. These 3 patients underwent EVD after the ventricle was tapped. (Table 3)

Out of the 362 who underwent VPS 18 patients had shunt malfunction (Table 4). The malfunction ranged from 3 had distal catheter block which needed VPS revision, 2 had infection and had to be removed after which ETV was done. 4 had proximal catheter block which was managed with ETV out of which 1 case the third ventricular floor could not be identified hence underwent ventriculo atrial shunt. The 3 patients had shunt migration hence it was replaced. 6 patients had ventriculitis and succumbed to it. (Table-5)

## DISCUSSION

The condition of post traumatic hydrocephalus is a sequelae to brain trauma and the treatment is also clearly a CSF diversion procedure<sup>6,7</sup>. The 2 modalities available have good outcomes but the success rates differ. The cause of hydrocephalus is due to blockage of draining arachnoid villi<sup>8,9</sup>. Due to the pathology the VPS group has better outcomes as it does not have to depend on the arachnoid villi for draining the CSF as compared to the ETV group. Post procedure both the groups had their own set of setbacks with the failure rate in the ETV group being 44.3% compared to the VPS group being 4.97%.

## CONCLUSION

The results show that VPS is a better procedure with relatively lesser complications, hence only intervention will help improve the quality of life thereby reducing hospital stay.

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# Dual trained endovascular neurosurgeons. A boon or a necessity?

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## ABSTRACT

**Objective:** The aim of this research study is to emphasize the necessity to train neurosurgeons in both endovascular procedures as well as microsurgical clipping in the management of intracranial vascular lesions.

**Material and methods:** In this study, the retrospective data collected from our institution from 2021-2022 is presented. Here we present six cases of intracranial vascular lesions that were initially planned for endovascular procedure and later ended up being managed by microsurgical clipping/ excision. Written informed consent was obtained from relevant individuals for publishing the data.

**Results:** All six patients recovered well in the postoperative period. Therefore, a neurosurgeon who is adequately trained in vascular neurosurgery along with endovascular tutoring shall have an extensive grasp of cerebral vascular diseases and all the available treatment alternatives. Since we live in a result-oriented scenario - patients shall be best served by a hybrid neurosurgeon in the long run.

**Conclusion:** This study provides the intra-operative difficulties faced during endovascular management of intracranial vascular lesions. These difficulties require real-time management. Any delay in the process of intra-procedural decision-making, the non-availability of trained neurosurgeons can have devastating consequences. Hence, this study further fortifies the want for a dual-trained neurosurgeon to handle cerebrovascular lesions.

## INTRODUCTION

With the advent of endovascular therapeutic options for the management of cerebrovascular lesions, there has been a radical shift in trend that has been followed by young neurosurgeons. Piazza et al (26) in his study of intracranial aneurysms being managed by microsurgical clip application and endovascular coiling at several teaching medical institutions from 2001 to 2011 found that there was 16% per year decrease in likelihood of residents clipping an aneurysm and 19% increase in likelihood of residents coiling an aneurysm over the study period. This trend was supported by the Barrow Ruptured Aneurysm Trial (25) 6 year results, Rajan Kumar et al (21) and many similar studies.

## Keywords

hybrid neurosurgeon,  
cerebrovascular surgery,  
clipping vs coiling,  
endovascular neurosurgery,  
aneurysm,  
A-V malformation



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Comparison of microsurgical clipping and endovascular coiling is an ongoing debate with each modality having some advantage and disadvantage over the other. The contest between clipping and coiling in the management of intracranial aneurysmal bleeds has been going on for decades now, as the data supporting both perspectives is pouring in every day. The concluding indicator is however the patient outcome.

The question being addressed in this article is the need for giving equal importance to microsurgical clipping and endovascular coiling in training young neurosurgeons.

We shall enumerate cases of intracranial aneurysm that were planned for endovascular procedures which ended up being managed by microsurgical clipping or combined modality. The technical reasons for abandoning the endovascular procedure, combining the microsurgery and the intra-procedural decision making shall be discussed briefly.

#### MATERIAL AND METHODS

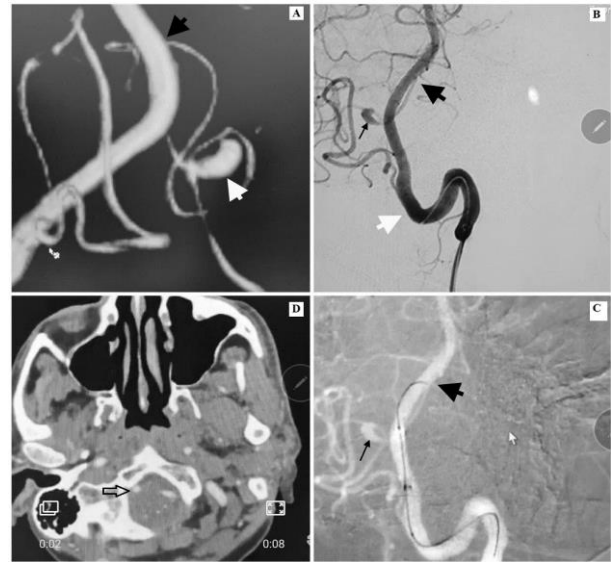
In this study we present the retrospective data collected from our institution from 2018-2022. Criteria for including patients presenting with ruptured intracranial aneurysm / AVM - the ones that were found suitable for endovascular procedures on pre-procedural investigations like DSA and CT - angiography of brain. Who later ended up undergoing microsurgical clipping or combined procedure for various reasons. The team managing the patient has experience in both endovascular procedures as well as microsurgical treatment of these lesions.

#### REPRESENTATIVE CASES

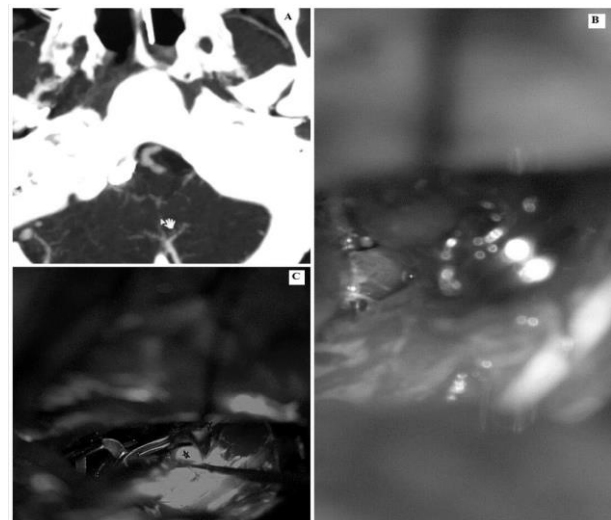
##### Case 1 (Right Posterior Inferior Cerebellar Artery – PICA aneurysm)

A 55-years-old male patient presented with sudden onset severe headache associated with loss of consciousness 20 days prior to presentation. At presentation Glasgow Coma Score (GCS) was E4V4M6, Hunt and Hess grade 2 with no sensory, motor or autonomic neurological deficit. Non-contrast computed tomography (NCCT) Brain showed minimal sub-arachnoid hemorrhage (SAH) in prepontine cistern. CT Angiography and Digital

subtraction angiography (DSA) showed right PICA aneurysm (size 7.1mm x 2.1mm x1.4mm). Right vertebral artery was hypoplastic and both PICA were arising from dominant left vertebral artery. (Figure 1A) Right PICA took an 180 degree turn after its origin from left VA and crossed to opposite side.



**Figure 1(A).** clockwise: 3D(A) & DSA image(B) of Left Vertebral angiogram Showing origin of right PICA (Black arrowhead) After origin PICA was taking a U turn and crossing to opposite side. A saccular aneurysm was identified at the junction of first and second loop bifurcation.(white arrowhead) . Micro wire (Syncro-14) tip negotiating the origin of right PICA(C) (Black arrowhead) from the left vertebral artery at acute angle.CT angiography axial image (D) confirms the location of aneurysm (Arrowhead).



**Figure 1(B).** clockwise: axial image of right PICA aneurysm post clipping(A); intra-op image of the PICA aneurysm post clipping

with permanent clip in-situ(B) , intra-op fluorescence angiography image(C) post-clipping with permanent clip in-situ and preserved flow in bifurcation branches( star)

A saccular aneurysm was identified at the junction of first and second loop. Endovascular coiling with neuromonitoring support was attempted. Balloon support was taken to hook the PICA due to acute angle but procedure was abandoned due to fall in EMG reading of facial nerve and heart rate, following cannulation of PICA (Figure 1B). Right extended retromastoid-suboccipital (RMSO) craniotomy with clipping of aneurysm was done on same day. Post op period was uneventful barring grade facial nerve palsy. Patient discharged in a stable condition on postoperative day 11. At the time of discharge patient GCS was E4V5M6 with a modified Rankin Scale (mRS) score of 1.

### Case 2 (Basilar top aneurysm)

A 75 years old female patient presented with sudden onset of severe headache along with loss of consciousness and seizure episode 2 days before the presentation. She is known case of systemic hypertension on irregular medication. Patient has a history of ischemic stroke 6 years back which was managed conservatively. At presentation GCS was E3V2M4, Hunt and Hess grade



**Figure 2.** clockwise - CT angiography mid sagittal image (A)shows basilar top aneurysm(white arrow); left subclavian

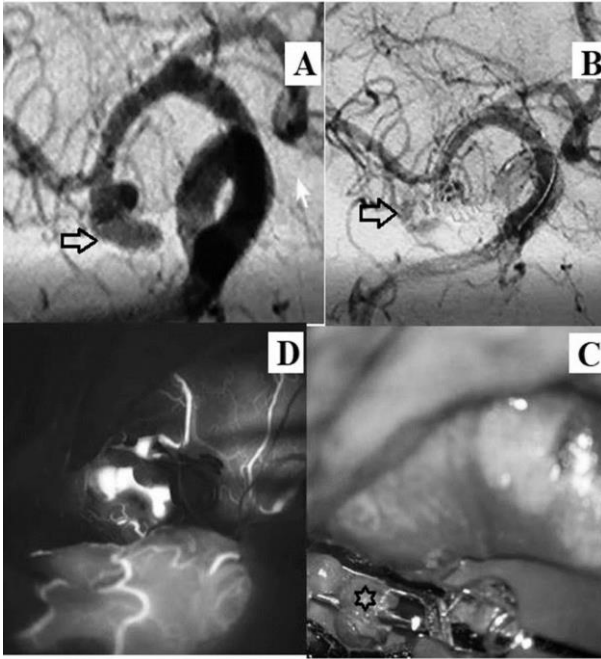
artery dissection (Arrow)at the origin of vertebral artery during the endovascular procedure(B) , Aneurysm clipped through trans-sylvian corridor(C), 3<sup>rd</sup> nerve(star). Post-operative CT angiography mid sagittal image showing successful clip obliteration (arrow) of aneurysm (D).

NCCT Brain showed SAH in prepontine cistern. CT Angiography and DSA showed basilar top aneurysm (size 8.1mm x 5.8mm x 6.9mm). Left vertebral artery was dominant. Endovascular coiling was attempted but procedure was abandoned due to inadvertent dissection into the arterial wall of subclavian artery at the origin of left vertebral artery, owing to its highly tortuous anatomy (Figure2). Right extended pterional craniotomy with zygomatic osteotomy with clipping of aneurysm was done on same day. In post op period patient was put on mechanical ventilation and tracheostomy was done. Low dose ecosprin and atorvastatin combination (75mg+20mg) was started on 4th post-operative day. Patient was gradually weaned off from ventilator and was discharged after three weeks with tracheostomy in-situ. At the time of discharge patient's GCS was E4VtM6. She also has right third nerve paresis. Patient tracheostomy was removed on 2nd follow up visit at 2 months and her mRS score was 3 at 4 months.

### Case 3 (Left Middle Cerebral Artery- MCA bifurcation aneurysm)

A 65 years old female presented with sudden onset of severe headache associated with loss of consciousness 10 days before the presentation. At presentation GCS recorded as E3V3M5, Hunt and Hess grade 3. NCCT Brain showed minimal SAH in left sylvian fissure. CT Angiography and DSA showed Left MCA bifurcation aneurysm (size 3.1mm x 1.9mm x1.5mm). Endovascular coiling was attempted but procedure was abandoned due to intra-operative rupture of the aneurysm during the endovascular procedure.(Figure 3) Temporary balloon occlusion (Transform 2\*10) was unsuccessfully tried to control aneurysmal leak.

Patient blood pressure was immediately lowered down and heparanization was reversed using protamine sulfate. Immediately left pterional craniotomy and successful clipping of aneurysm done using 6mm straight Yasargil clip (Figure 3). Post-operative period uneventful. Patient discharged after 2 weeks with right hemiparesis (MRS grade 3). Her weakness was completely resolved at 3 month follow up visit.

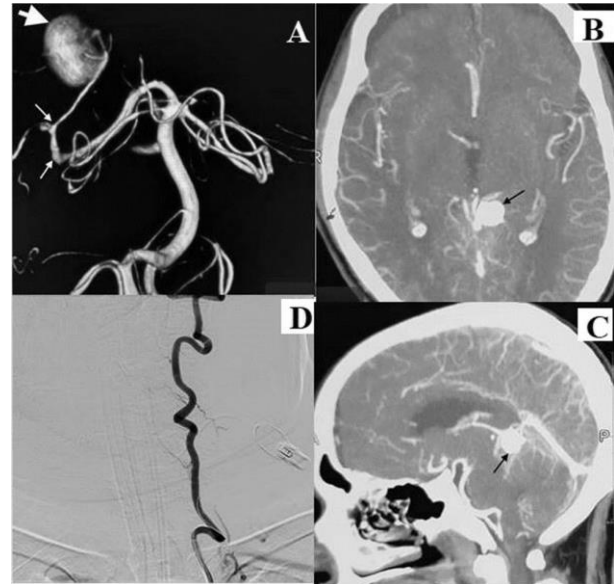


**Figure 3.** clockwise: Diagnostic angiography (A) showing Left MCA aneurysm (arrow); intra procedural rupture occurred (B) during attempted endovascular coiling, contrast leak is evident (arrow), intra-operative image (C) after successful clipping of Left MCA aneurysm (star); intra-operative ICG image (D) showing preserved distal flow at MCA post-clipping.

#### Case 4 (Left distal posterior cerebral artery-PCA aneurysm)

A 70 years old male presented with sudden onset severe headache along with vomiting 12 days prior to presentation. At presentation GCS recorded as E4V4M6, Hunt and Hess grade 2. There was no sensory/motor/autonomic neurological deficit. NCCT Brain shows minimal SAH in the perimesencephalic cistern. CT Angiography and DSA showed Left distal PCA aneurysm (lateral posterior choroidal artery aneurysm-LPChA) (size 7.2mm x 3.1mm x 1.6mm). Endovascular coiling was attempted but procedure was abandoned due to excessive tortuosity of the left vertebral artery and inability to gain the distal access in PCA close to aneurysm (Figure 4A).

In view of vital supply of LPChA, endovascular sacrifice of parent artery was not attempted. Left parietal-occipital craniotomy was done and aneurysm was successfully clipped using Poppens approach (Figure 4B). In the post-operative period patient recovered well. And he was discharged on postoperative day 9. At the time of discharge patients GCS was E4V5M6 and mRS score of 2 without any new neurological deficits.

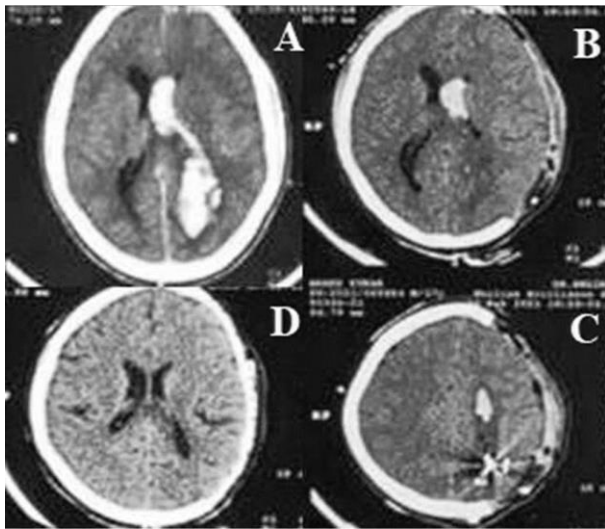
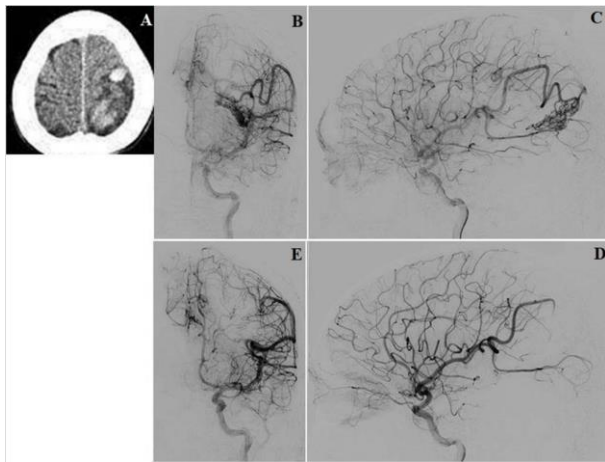


**Figure 4.** (A) clockwise: 3D-DSA image (A) showing left distal PCA aneurysm (arrow); axial (B) & Sagittal (B) CT angiography images showing the location of LPChA aneurysm in quadrigeminal cistern; DSA image (D) showing narrow caliber of left vertebral artery with tortuous course and several acute bends (B) clockwise: Intra-operative microscopic image through occipital transtentorial approach showing aneurysm in quadrigeminal cistern; Post-operative Axial (B), Sagittal (C) and Coronal (D) CT angiography images showing successful clipping.

#### Case 5 (Left Parietal arterio-venous malformation-AVM)

18 years old male, presented with sudden onset of loss of consciousness with weakness on the right side of the body since one day. At presentation GCS was E4V5M6; with right side hemiparesis (MRC grade 4). NCCT shows small left parietal hematoma. DSA brain revealed left parietal AVM (spetzler martin grade 2) with arterial feeders from MCA (Figure 5A). Endovascular embolisation using onyx-18 was done and complete immediate obliteration of nidus was achieved. On post-operative day one patient developed seizures with right side hemiplegia and there was sudden deterioration in his consciousness. NCCT brain showed left parieto-occipital hemorrhage with intraventricular extension. Left fronto-temporo-parietal decompressive craniectomy with evacuation of hematoma was done. Post-operative period was uneventful and patient was discharged on post-op day 14 with GCS E4V5M6 and right hemiparesis (MRC grade 3). His right side weakness was resolved completely at 3 month follow up visit, following

which he was readmitted and cranioplasty was done (Figure 5B).



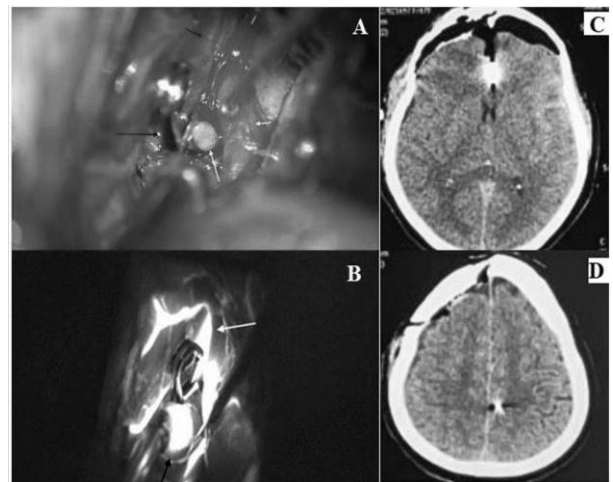
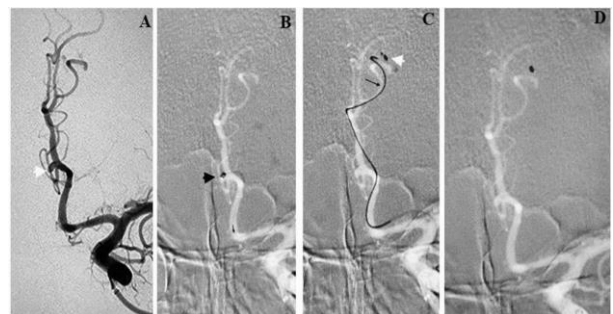
**Figure 5.** (A) clockwise:NCCT brain (A)showing small left parietal hematoma. DSA image frontal (B) and lateral(C) view showing AVM in left parieto –occipital region with feeders from left MCA. Post-embolisation DSA lateral (D) and Frontal (E) view showing complete angiographic obliteration of nidus.

(B): NCCT brain post-embolisation day one (A) showing increase in size of parieto-occipital hematoma with intraventricular extension. NCCT brain post decompressive craniectomy(B) and (C) showing hematoma evacuation with onyx cast(C). NCCT brain at three months follow up after cranioplasty (D).

**Case 6 (Left distal anterior cerebral artery-DACA aneurysm)**

A 48 years old female patient presented with sudden onset of severe headache associated with vomiting 10 days earlier to presentation. At the time of presentation GCS recorded as E2V4M5 with Hunt

and Hess grade 2. NCCT Brain S/O SAH in anterior interhemispheric fissure. CT Angiography and DSA showed Left distal ACA aneurysm (size 2.5mm x 2.1mm x1.9mm). Endovascular coiling was attempted. After detachment the coil loop migrated into the parent artery (Figure 6A). All the attempts to retrieve the coil remained unsuccessful. With the help of microcatheter (SL-10, Stryker), the migrated coil was pushed till distal end of left ACA. Right frontal craniotomy with clipping of left DACA aneurysm was done after reversal of heparinisation(Figure 6B). Post-operative course uneventful and she was discharged on 8th day after in GCS 15 without any neurological deficit (MRS gr 2).



**Figure 6. (A):** DSA brain image (A) showing left Distal ACA aneurysm (white arrow); coil (Black arrow) inside the aneurysm (B)with microcatheter in parent ACA; After coil migration, microcatheter was used to push the coil(white arrow) distally till terminal end of DACA(C); Final position of coil(D)

(B): intraoperative-ICG image (A) of clipped DACA aneurysm(White arrow), small black arrow - ipsilateral proximal A3 segment, black long arrow- ipsilateral distal A3 segment, white small arrow- right ACA ; intra-operative ICG image(B) showing preserved flow after clip application; Post-operative CT scan(C) showing clip in situ and(D) showing location of distally pushed coil.

## DISCUSSION

All the available data currently in the literature regarding Endovascular coiling versus Microsurgical clipping in cerebrovascular lesions-management gives generic data supporting micro surgical clipping / excision over endovascular management and vice versa. In our study we have given the details of intra-procedural difficulties that arise during the endovascular management of intracranial vascular lesions, insight into the decision making as to when to abandon the endovascular procedure and choose microsurgical management of the aneurysm/AVM.

## Background

### Shift of treatment from open microsurgical clipping to endovascular era

Coiling is currently used to treat more than 50% of ruptured intracranial aneurysms in the western countries, asia including metropolitan regions of India (11) (2)

In a 25 year observational study (starting in 1991) which included 1306 patients who presented with subarachnoid hemorrhage to a major tertiary teaching hospital, progressively increasing percentage of patients were treated by endovascular methods (2). The percentage of patients embolized was 3% from 1991- 1996. And the percentage increased to 42% in the most recent five-year period. This shift was noted to be most dramatic for posterior circulation aneurysms. 71% of posterior circulation aneurysmal conditions are now treated by endovascular methods. Incidentally the majority of MCA aneurysms (78%) continue to be treated by open surgery (2)(4). Endovascular and open surgical treatment are approaching equivalence for ruptured aneurysms along the ICA and ACA (4).

This trend has progressed steadily towards enhancing the endovascular treatment of ruptured aneurysms at major international centers as well (4). In a case series reported on 2411 aneurysm treatments, 62% was in the setting of a SAH, between 1998 and 2009. In general, endovascular treatment as an option progressed from 8% to 28% of interventions. The increase was greatest for basilar apex aneurysms, which increased from 22% endovascular to 88% during that period of study (4)(5)(6)(8). Endovascular interventions have made similar inroads in posterior circulation territory. Payner and colleagues have reported that endovascular treatment of anterior and posterior

communicating artery aneurysms increased from 6% and 5% to 38% and 31% respectively by the end of the study period (6)(8). Without giving out specific numerical data. The authors noted that microsurgical clipping was favored for MCA aneurysms throughout the study period.

Microsurgical clipping still remains the mainstay of treatment for ruptured MCA aneurysms, for various reasons like relative accessibility of the MCA superficially within the sylvian cistern (15). Ruptured MCA aneurysm is most likely to present with intraparenchymal hematoma, which can be evacuated during open surgery. The geometry of MCA bifurcation aneurysms, wherein a majority (88%) are broad-necked and nearly half (40%) incorporate a major branch vessel in the dome. These issues pose a challenge to traditional coiling (9)(10). Over a period of time, there have been drastic technological improvements, including three-dimensional CT angiography to visualize. Compliant balloons and self-expanding stents that protect branch vessels, all these have increased the percentage of MCA aneurysms that are amenable to coiling (13)(15).

Endovascular management of ruptured intracranial aneurysms and A-V malformations has steadily increased at major academic institutions. Although endovascular management has assumed a primary role in the treatment of posterior circulation aneurysms, while a majority of ruptured aneurysms arising along the MCA continue to be clipped. Incidentally, coiling and clipping are approaching parity as a management option for treatment of ruptured aneurysm at other locations in the anterior circulation (13).

### Difficulties in endovascular management of intracranial aneurysms

Given the existing healthcare system of developing world, the incidence of disease is higher than the resources available to tackle them. A recent survey on neurovascular intervention had 82% of their participants from urban hospitals while only 18% were in the semi-urban or rural hospitals and showed that endovascular management is performed more frequently in private or nonteaching hospitals, than in government or teaching institutes, where clipping is preferred (3).

Another major hurdle with aneurysm coiling is the durability. Inadequate packing of the aneurysm neck

raises the chances of aneurysm recurrence (Raymond and Roy, 1997). The Clinical outcomes of aneurysm coiling are better for small to medium size aneurysms in comparison to giant and fusiform aneurysms (1). In a review of 46 studies encompassing 8,161 coiled aneurysms showed 91% rate of adequate occlusion at initial treatment (Ferns *et al.*, 2009) (12). Recanalization reported in 21% of aneurysms. And retreatment was performed in 10%.

There are other factors like (14)(17)

1. small aneurysms
2. ruptured aneurysms with large hematoma
3. difficult geometry of the aneurysm
4. difficulty to access the aneurysm with the available hardware
5. giant and partially thrombosed aneurysms
6. non-compliant patients
7. Affordability.

#### **Advantages of Microsurgical clipping of intracranial aneurysm**

Microsurgical clipping is overall more economical (14). Neurovascular specialists are more concentrated in larger cities at the disposal of that layer of society that can afford the advancements. However, there are more people in the country who belong to the semi-urban and rural demography and have easier access to centers that can manage them by microsurgical clipping rather than higher centers that facilitate coiling (14)(21).

As we stress on the importance of time in the salvation of the brain, the above fact makes it clear that patients, who sometimes travel long distances for treatment, are able to save and so perhaps gain a lot more time, if they are to opt for a center where clipping is offered, as compared to coiling (17). The best possible option is a dually trained neurosurgeon, who is well versed in both the procedures.

Beyond doubt, clipping is more affordable than the cost of the stent or coil. While one may argue that endovascular management is associated with a shorter duration of hospital stay, the time spent outside the hospital in the follow-up period must also be taken into account. Both arms of treatment are associated with the risk of ischaemic stroke, but the coiled patient may require lifelong anti-coagulation and rigorous monitoring of hematological parameters alongside regular consultations, the financial and social burden of

which has to be borne for a longer period (7)(22). It has been recorded that overall cost burden at 2-year and 5-year follow-up is significantly higher for patients treated by endovascular coiling as compared to microsurgical clipping, which may be considered natural, considering the cost of anti-platelets alone (7).

It has been observed that complication rates from microsurgical clipping, be it intra-operative or post-operative, are higher than from coiling; however, it has also been observed that the risks for need for reoperation and recurrence are higher in coiling (17). The durability, that is provided by clipping, over coiling, is another major point that favors the practicality of its use in semi-urban and rural world.

#### **Dually trained neurosurgeons**

The evolution of neuro-endovascular therapies has led to three versions of task sharing in the management of intracranial aneurysm (1)(16)(18)(19). In a few setups, devoted centers are developed for endovascular management, while others subspecialized in microsurgical management. Most other centers organised themselves into multi-role teams and subspecialized into micro and endovascular surgeons. They consult and consider patients together and recommend treatment strategies based on concurrence on best interest of individual patients. As per this particular prototype, the patient is offered both management options in a single center, but the decision-making will depend on the concurrency of all team members. Reciprocal information about pros and cons of all management options is compulsory. The most important factor is practical experience of the treating doctors in both prototypes.

The third version is the single-doctor with dual capability prototype. It is called as the hybrid neurosurgeon. This version is supposedly cost efficient, wherein both treatments is offered by one treating neurosurgeon. Dually trained neurosurgeons will deliver consistent positive results. Concurrently, several publications from across the globe have proven the better results of hybrid neurosurgeons.

Due to the quick development of neuroendovascular treatment options, there is an incessant transfer of indications for intracranial aneurysm treatment towards endovascular options

over the past decade. This evolutionary phase is probably troublesome for a subgroup of patients who cannot be treated by endovascular therapy alone or complicated by endovascular therapy, those patients that need microsurgical management (very small but bleeding aneurysms, intraprocedural perforations, MCA aneurysms with unfavorable anatomy, ruptured aneurysms with intraparenchymal hematoma, giant and partial thrombosed aneurysms, young patients who shall perhaps be noncompliant with follow-up imaging, high-grade SAH) in emergency fashion and might also risk the continuity of neurovascular microsurgical dissection skills.

The decision for treatment options will positively be influenced by the hybrid surgeon's capacity to assess and compare the advantages, disadvantages, complications of both therapeutic options in detail. Avoiding wrong decisions because of the "availability of a hammer so let's look at all targets like nails" (20). The hybrid version offers several advantages: firstly, single-decision maker concept gives freedom to make independent decisions devoid of institutional bias; secondly, equivalent indications lead to selection of tailor-made tools. Finally, preservation of neurovascular microsurgical skills. It is extremely essential to preserve vascular microneurosurgery in the present and future (1)(23)(24).

Therefore, adequate training in vascular neurosurgery followed by essential endovascular training will result in a broad understanding of cerebrovascular diseases and its management options at the level of treating doctor itself. Patients shall be best served by a hybrid vascular neurosurgeon in the short and long run.

## CONCLUSION

In contrast to developed countries only a substantial number of Indian vascular neurosurgeons work under "hybrid conditions"; at present the majority of neuro-endovascular procedures is performed by neuro-radiologists. As a result of this development, the numbers of microsurgical aneurysm surgical procedures have decreased. As a consequence, experience and skills in aneurysm surgery and cerebrovascular surgical procedures in general are at risk. The results of dually trained- hybrid neurosurgeon, with equal exposure towards surgical and endovascular techniques, are comparable to

those reported by mono-therapeutic neurosurgeons and centers with multimodal teams.

With this case series there is promising evidence to prove, that dually trained neurosurgeon is a necessity rather than a luxury who would not only perform surgical and/or endovascular therapeutic procedures effectively, but also switch over safely in need, there are other benefits like - equivalent and specifically suited indication concepts, the continuation of vascular microsurgical skills (as endovascular management therapy has not penetrated deep into semi-urban and rural setups). And also, the availability of both management options in the hands of a neurosurgeon is a significant factor in the overall hospital management.

In the domain of cerebrovascular surgery, endovascular surgery has definitely got several advantages over open surgery. Yet it is common sense to assume that endovascular surgery has its own place and micro surgical clipping of intracranial aneurysms has its own roll in the overall management, and the tendency to get carried away with 'recent advances' should be discouraged.

So far in the literature, comparison of endovascular surgery versus microsurgical clipping of intracranial aneurysms has largely shown data regarding the peri-operative parameters including the geographic and economic variables. This study provides the intra-operative difficulties faced during endovascular management of intracranial vascular lesions. These difficulties require real-time management. Any delay in the process of intra procedural decision making, or non-availability of trained neurosurgeon can have devastating consequences. Hence, this study further fortifies the want of a dual trained neurosurgeon to handle cerebrovascular lesions in most efficient manner.

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# Successful recovery of a young man with traumatic brainstem ischemia in a motor vehicle accident. A case report

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## ABSTRACT

**Introduction:** The most common etiological factors of brainstem stroke and ischemia are atherosclerosis, thromboembolism, tumours, arterial dissection, and trauma. Infarction of the medulla oblongata in 73% of cases occurs as a result of stenosis of the vertebral arteries, 26% due to arterial dissection, while the topic of traumatic brainstem ischemia is still under-researched and under-represented.

**Case report:** We present a case of a 26-year-old male patient who was admitted to the Emergency Department due to multiple injuries of the head, chest, and upper, and lower extremities sustained as a motorcyclist in a traffic accident. A cranial CT scan revealed the presence of a minor subdural hematoma, traumatic brainstem ischemia, and a ruptured peduncular artery. From a neurosurgical perspective, surgical treatment was not indicated, thus a conservative therapeutic approach was adopted. After five days after admission, initial radiographic signs of ischemia regression were recorded, followed by complete absence.

**Conclusion:** Timely patient transportation from the accident site to the Emergency Center, followed by an appropriate multidisciplinary treatment approach and intensive neuroprotective and neuroregenerative therapy, along with organism reperfusion, played a pivotal role in the neurological, and subsequently, overall patient recovery in this case presentation.

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## Keywords

brainstem ischemia,  
ICU,  
neurosurgery,  
radiology,  
neurology

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## INTRODUCTION

The brainstem is located in the posterior part of the brain and consists of the medulla oblongata, pons, and midbrain. It represents the connection between the cerebrum, cerebellum, and spinal cord. The brainstem is vascularized by the vertebrobasilar system (8).

A lack of oxygen to any part of the brainstem causes a brainstem stroke. Timely detection and intervention reduces the rate of morbidity and mortality (7).

Stenosis and occlusion of the posterior circulation cause significant hypoperfusion of the brainstem. The most common etiological factors of brainstem stroke are atherosclerosis, thromboembolism, tumors, arterial dissection, and trauma. Infarction of the medulla oblongata in 73% of cases occurs as a result of stenosis of the vertebral arteries, 26% due to arterial dissection (2).

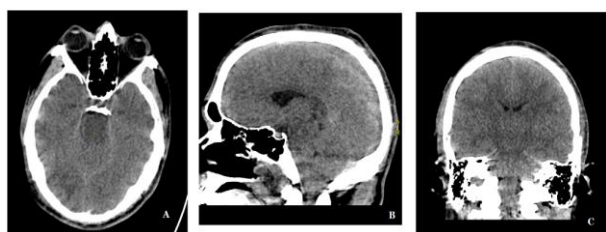
## CASE REPORT

A 26-year-old male patient was admitted to the Emergency Department due to multiple head, neck, chest, upper and lower extremity injuries sustained in a motor vehicle accident. The transportation from the accident site to the Emergency Department lasted 45 min. A CT scan of the head was performed on the day of admission, 21.06.2023., which showed multiple punctate hemorrhages, a left-sided laminar subdural hematoma, a tentorial subdural hematoma, and brainstem ischemia (Figures 1A, B, C).



Figure 1.

Figure 2.



A follow-up CT scan of the head and CT angiography were performed on day 26.06.2023., showed a trace of subarachnoid hemorrhage in the interpeduncular cistern, and early signs of regression of brainstem ischemia. The right vertebral artery was not opacified in the V1 and proximal V2 segments, and was heterogeneously opacified distally. A hematoma was seen retroclavicularly in the prescapular segment of the right subclavian artery (Figures 2 A, B, C, and 3 A, B).

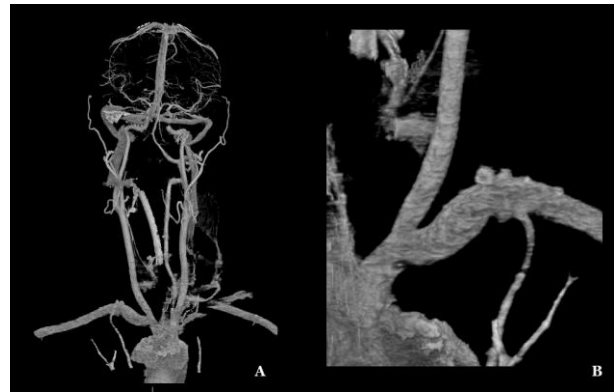


Figure 3.

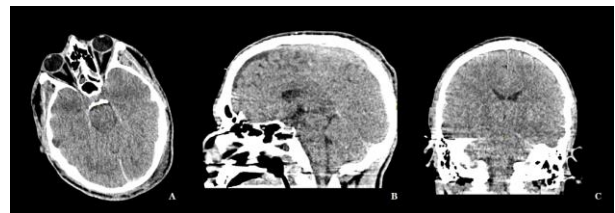


Figure 4.

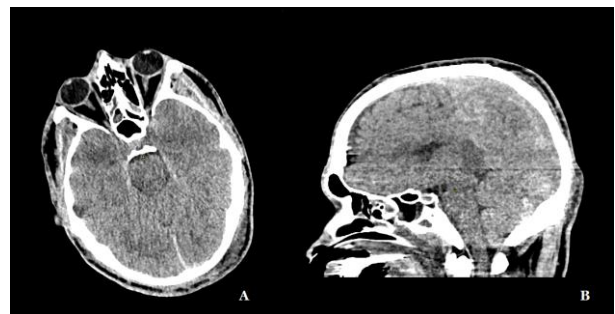


Figure 5.

A follow-up CT scan of the head was performed on day 7, which showed further resolution of the hemorrhagic collection (Figure 4 A, B).

A follow-up CT scan of the head was performed on day 10, which showed no evidence of brainstem ischemia (Figures 5A, B, C).



**Figure 6.**

The patient was treated conservatively with medication and adapted treatment modality due to other injuries. Antibiotics were administered the whole time during the hospitalisation, while intensive polyvitamin therapy, receiving vitamin B1 and B6 for the first three days, along with vitamin C in high doses and MgSO<sub>4</sub> were administered. The patient was continuously sedated with midazolam, while propofol was used three times per day, also noradrenaline, and anti-edema therapy with mannitol for the first five days of hospitalization were administered alongside with phenobarbital. In addition to this therapy, the patient was administered infusion solutions to replenish fluids and stimulate the body's perfusion, as well as the necessary doses of blood transfusions and blood products.

On the fourth day of hospitalization, the patient was given dexamethasone, for the next seven days. On the fifth day of hospitalization, folic acid was added to the therapy, and mannitol was excluded from the therapeutic module with the last dose given. The homocysteine level of this patient was normal the whole time.

During the first three days of hospitalization, no anticoagulant therapy was administered, as it was

contraindicated. The patient showed neurological progress with a visible regression of the radiographic findings of brainstem ischemia.

Anticoagulant therapy was started on the fourth day of hospitalization. The patient did not show any radiographic or neurological deterioration until the end of hospitalization. The patient remained on a multivitamin therapy, and adequate infusion solutions according to the patient's metabolic needs until discharge from the hospital with full neurological recovery (Figure 6.).

## DISCUSSION

### Pathophysiology

The pathophysiology of all infarctions is the lack of oxygen in the tissues, which consequently leads to tissue death. Although the human brain accounts for only 2% of the total body mass, it requires 20% of oxygen (4).

The blood flow through the brain is regulated by autonomic mechanisms, thus maintaining constant perfusion and adequate venous drainage. The brain is also unique in that it has no or very little energy stores and uses glucose as its primary source of energy, with ketone bodies as metabolic products that are only used during starvation (5).

The cellular cascade processes that occur are: depletion of ATP due to lack of aerobic respiration of mitochondria; loss of membrane ion pump function and disturbance of the voltage gradient along the membranes with subsequent cellular edema; excitotoxicity of neurons due to the release of glutamate and synaptosomal-associated protein 25, causing further deterioration of energy levels and membrane potentials; production of free radicals; subsequent cell death (1).

The previously mentioned apoptotic and necrotic pathophysiological pathways activate protective pathways such as: expression of heat shock protein 70, B-cell lymphoma 2 gene family, and prion protein to prevent activation of the apoptotic cascade; release of Neurotrophin-3, Interleukin-10, and Granulocyte-colony stimulating factor; aimed at helping to activate survival pathways and reduce pro-inflammatory cytokine activities (1).

The cellular cascade is potentially reversible, which can lead to subsequent vasogenic edema within the next few hours. Vasogenic edema causes an increase in pressure in the surrounding tissue,

resulting in a mass effect and worsening of the clinical state of the patient (3).

Traumatic brainstem ischemia, if diagnosed, is predominantly fatal. The case report by Yoshikuni Mimata *et al.* showed us that there are 38 reported cases of ischemia in the vertebrobasilar region as a result of cervical spine trauma, with men being predominantly represented. The age range was from 20 to 83 years (average 40.5 years) at the time of the trauma. Of these, 18 cases were of traffic accident origin, falls in 10 cases, sports injuries in 5 cases, while the remaining cases were of origin using brute force. In the aforementioned study, a 69-year-old male patient was presented who was injured in a fall down the stairs and sustained head injuries. A C5-C6 level injury and ventral epidural hematoma were diagnosed on MRI. CT angiography of the neck showed occlusion of the right vertebral artery at the C4 level of the spine. Anticoagulant therapy was applied after the diagnosis of arterial occlusion. The patient died 52 hours after the injury (6).

The second case report by Pengyu Huang *et al.* showed us a 26-year-old patient who was diagnosed with brainstem infarction. The patient fully recovered after 5 months (9).

Our patient, in comparison to the previous ones, can be distinguished by the therapeutic approach and the origin of brainstem ischemia. We used a wide pharmacological spectrum, considering the origin of polytrauma.

Midazolam and propofol in combination with intensive multivitamin and antioxidant therapy, and anticoagulant therapy, proved to be beneficial.

Midazolam exhibits its neuroprotective effect in certain neuropathological conditions. An experimental study conducted by Zhiyin Tang *et al.* showed the neuroprotective effect of midazolam. They showed that dysregulation of EAAT2 expression may be associated with neural injury induced by H/R in rat pups (10).

Propofol also exhibits a neuroprotective effect. In an experimental study conducted by Felix Ulbrich *et al.* the mechanism of propofol was investigated by modulating the TLR-4-NF- $\kappa$ B pathway. Propofol preserved the integrity of the mitochondrial membrane in oxygen-glucose deprivation injured cells. Propofol diminished TLR-4 surface expression and preserved the DNA-binding activity of the protective hypoxia inducible factor 1 (HIF-1) transcription factor (11).

Our case report of a 26-year-old patient with traumatic brainstem ischemia leaves room for thought about how much the multidisciplinary approach had an impact, together with the timely transport of the patient from the accident site to the Emergency Department, on the withdrawal of ischemia. Numerous studies are needed on both spontaneous and traumatic brainstem ischemia in order to gain knowledge from different experiences and achieve improvement for our patients.

## CONCLUSION

Timely patient transportation from the accident site to the Emergency Center, followed by an appropriate multidisciplinary treatment approach and intensive neuroprotective and neuroregenerative therapy, along with organism reperfusion, played a pivotal role in the neurological, and subsequently, overall patient recovery in this case presentation.

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# Lymphorrhoea - a rare complication of thoracic outlet syndrome surgery

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## ABSTRACT

The thoracic duct injury is an extremely rare entity and is sometimes seen in the surgery of the oesophagus or the heart. This injury can result in the formation of chylothorax e.g. chylous pleural effusion and can cause significant patient morbidity and mortality. Thoracic duct injury is an extremely rare complication of thoracic outlet syndrome surgery with only a few cases described in the literature so far. We present a 29-year-old female patient operated on for thoracic outlet syndrome with resection of the anterior scalene muscle on the left side. During the first postoperative day, the patient had more than 1.5 L of chyle leak drainage without signs of chylothorax. The patient was successfully treated conservatively with bed rest and total parenteral nutrition.

## INTRODUCTION

The thoracic duct injury can result from trauma or it can be developed iatrogenically during chest surgery procedures. Surgery of the esophagus and the heart are the most common source of iatrogenic injury. Injury to the thoracic duct can result in formation of chylothorax e.g. chylous pleural effusion and can cause significant patient morbidity and mortality (1). Thoracic duct injury is extremely rare complication of thoracic outlet syndrome surgery (2). We describe a case of a 29-year-old female patient who was operated on due to thoracic outlet syndrome, during which a thoracic duct injury occurred and was managed conservatively.

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## Keywords

thoracic duct injury,  
thoracic outlet syndrome,  
lymphorrhoea

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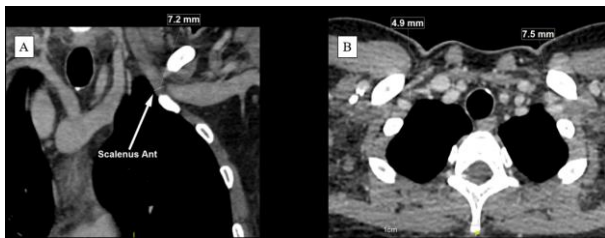
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### CASE REPORT

A 29-year-old female patient developed pain, numbness and tingling in her left arm which progressed to upper limb intermittent claudication at any sustained upper extremity activity such as opening and closing the left hand or lifting a weight. She also had cyanotic discoloration of the left hand in the abduction position of the arm. The arterial pulses of the left hand were weaker than on the right, especially in the abduction position. The electrophysiological examination indicated that patient developed thoracic outlet syndrome on the left side. CT scan of the chest showed narrowing of the costoclavicular spaces on both sides when the arms are elevated above the head with visible compression on both subclavian veins, more pronounced on the left side. In addition, a slightly voluminous anterior scalene muscle on the left was demonstrated, which was suspected as a probable cause of patient's thoracic outlet syndrome (picture 1).



**Picture 1.** Chest CT scan showing voluminous anterior scalene muscle on the left side (A), and difference between left and right side on the transversal plane (B).

Patient was operated with supraclavicular approach and a resection of the fibrous and thickened anterior scalene muscle was performed (picture 2). During the procedure a small amount of milky fluid discharge was observed in the operative wound, however, no clear injury to a major lymphatic vessel was observed. The patient tolerated the surgery well, the pain syndrome was reduced and the color of the hand returned to normal. Peripheral arterial pulses on the left hand were significantly more pronounced than before the operation.

During the first postoperative day, about 1.5 L of milky fluid discharge accumulated in the drain, and biochemical analysis of the content indicated chyle leak (picture 3).

Chest X ray was performed and showed normal finding without signs of chylothorax (picture 4).

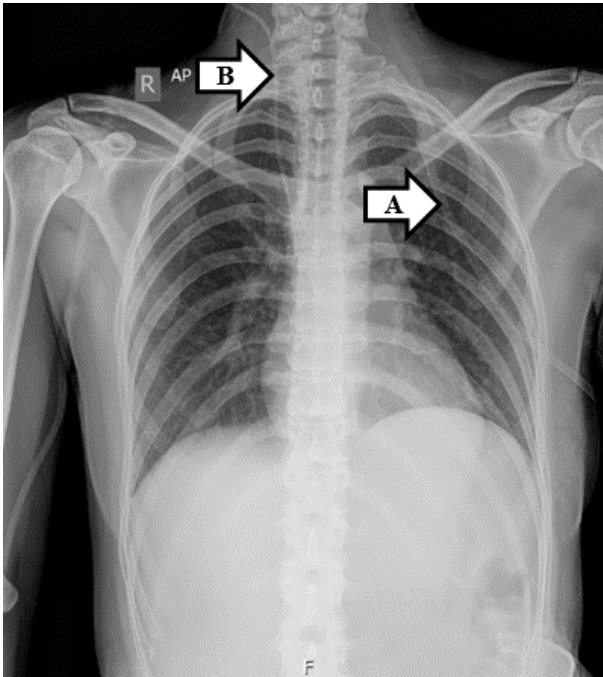
The high output chylorrhoea was successfully treated by conservative measures, bed rest, and total parenteral nutrition. Complete blood count, electrolytes, serum glucose, total proteins, CRP, albumin, triglycerides, and LDH were done routinely and any differences from reference values were corrected with appropriate therapy. Except for slightly lower albumin values which were corrected with albumin infusions, no other disbalances occurred. The patient was discharged after 15 days of hospital stay with a complete resolution of chylorrhoea and with normal neurovascular status of the left hand with complete resolution of preoperative symptoms. At the first control, one month after the operation patient is completely recovered without complaints.



**Picture 2.** Intraoperative view. Patient was operated with supraclavicular approach.



**Picture 3.** The content of the drain indicated lymphorrhoea.



**Picture 4.** Chest X ray showed normal finding. Arrow A is indicating wound drainage, and arrow B central venous catheter which was used for parenteral nutrition.

## DISCUSSION

About 50% of thoracic duct leaks are the result of a traumatic injury. The majority of traumatic injuries are iatrogenic (3), and about 20% are caused by penetrating or blunt trauma, hyperextension of the spine or forceful emesis and cough (4). Iatrogenic injury occurs during surgery on the esophagus, pleura, aorta, lung, vagotomy, spine surgery, and others. Thoracic duct injury is extremely rare complication of thoracic outlet syndrome surgery. Bowden *et al.* reported a case of chylothorax after transaxillary resection of the first rib for the treatment of thoracic outlet syndrome (2). Similarly, Schroeder *et al.* reported a case of a 31-year-old postal worker who was operated because of thoracic outlet syndrome with removal of the right first cervical rib and resection of the anterior and middle scalenes. On postoperative day 4, patient developed shortness of breath due to a chylothorax as a result of thoracic duct injury (5). We reported a similar case of a 29-year-old female patient who was operated for thoracic outlet syndrome with a resection of anterior scalene muscle on the left side. However, our patient did not develop chylothorax, since active tube drainage was placed at the end of the procedure.

If lymphatic leakage goes unnoticed dangerous complications can occur. Large losses of chyle can lead to hypovolemia if the fluid volume is not adequately replaced. Chyle is rich in nutrients and lymphocytes and continuous loss of these cells and molecules can lead to immunosuppression and malnutrition (3). Typically, there is a delay between the time of injury and the presentation of a chylothorax, since it takes time for the chyle to leak into the mediastinum cavity and the pressure to be large enough to enter the pleural space and cause symptoms. Typically, this delay can be from 1 to 7 days. Approximately half of patients initially present with dyspnea, however about 35% of patients may experience no symptoms at the time of diagnosis. The mortality rate of untreated traumatic chylothorax is about 50% (3, 7). In our case chylothorax did not develop since drainage tube was placed at the end of the operation. Daily monitoring of complete blood count, electrolytes, serum glucose, total proteins, albumin, and triglyceride enabled quick response and appropriate therapy if signs of malnutrition and immunosuppression occur, which was not the case in our patient, except for small protein disbalance, which has been corrected with albumin infusions.

Thoracic duct leak is classified as low output if the volume of lymphorrhoea is less than 1 liter and high volume if the volume is over 1 liter per day. If chyle output is less than 0.5 liter per day, the literature suggests a conservative therapy, initially involving dietary measures to decrease chyle production. Insertion of a thoracostomy tube to relieve pressure in the pleural cavity facilitates lung re-expansion and sealing of the leak in cases of chylothorax. A high-protein, medium-chain triglyceride diet with the restriction of long-chain triglycerides can be initiated. Medium-chain triglycerides fail to be absorbed by the lymphatic vessels and pass directly through the portal vein to the liver. In contrast, long-chain triglycerides enter the lymphatic system as chylomicrons. Reduced chyle production supports the spontaneous resolution of the chylous fistula (5). In case of a failure of diet therapy, a nil per os (NPO) regimen can be started while the patient is maintained with total parenteral nutrition (TPN). Octreotide or Somatostatin can be started because they can slow the production of chyle if TPN regimen is unsuccessful (2, 8). Although therapy of thoracic duct leak is best tailored to individual patient's

overall clinical picture, and in otherwise healthy patients, conservative management is most likely to be the best course of action, in cases of conservative therapy failure, more aggressive treatment with ligation of the thoracic duct may be the best strategy (9). If the chylous drainage last longer than 2 weeks despite conservative therapy or if lymphorrhoea is greater than 1 liter per day for more than 5 days, percutaneous or open surgical approaches with ligation of thoracic duct are required (10). In our case, conservative management with early start of TPN resulted in the cessation of lymphorrhoea.

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# The efficacy of Levetiracetam compared to Phenytoin in prevention of post-traumatic seizures. A prospective cohort study from a low-middle-income country

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## ABSTRACT

**Objectives:** To compare the efficacy of Levetiracetam (LEV) versus Phenytoin (PHY) in the prevention of post-traumatic seizures in a low-middle-income country.

**Materials and Methods:** A prospective cohort study was conducted from 25<sup>th</sup> December 2021 to 24<sup>th</sup> June 2022 at the Pakistan Institute of Medical Sciences, Islamabad, Pakistan. A total of 140 patients presented with traumatic brain injury, both male and female, aged between 15 to 60 years were included. Patients with a history of epilepsy, acromegaly or hypogonadism, history of brain tumour or abscess were excluded. LEV was given to group A patients as a 1000 mg intravenous (IV) loading dose, followed by a dose of 500-1000 mg (orally) twice daily. PHY was given to group B patients as an IV loading dose of 15-20 mg/kg, followed by an oral dose of 4-8 mg/kg divided into three doses per day. All the patients were followed and the efficacy of the drugs was noted.

**Results:** The mean age of patients in groups A and B was  $43.69 \pm 9.05$  SD years and  $43.07 \pm 9.46$  SD years, respectively. The majority of the patients i.e., 108 (77.1%) were between the ages of 41 to 60 years. Out of the total 140 patients, 87 (62.1%) were males and 53 (37.9%) were females with male to female ratio of 1.6:1. LEV had an efficacy of 63 (90%) and PHY had an efficacy of 46 (65.7%) in this study, both having a p-value of 0.0005.

**Conclusion:** According to the results of this study, LEV is superior to PHY at preventing post-traumatic seizures.

## INTRODUCTION

Traumatic brain injury (TBI) has an incidence rate of 91 to 546 per 100,000 people worldwide, making it a common cause of mortality and morbidity. TBI is more common in underdeveloped countries, accounting for one-quarter to one-third of all accidental deaths. Traumatic brain injuries are more common in those aged 15 to 30, and men are the most common victims.<sup>1,2</sup> Mechanical forces in head injured patients at the time of impact may affect neuronal and vascular

## Keywords

traumatic brain injury,  
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Phenytoin,  
developing countries



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tissue function. A chain of pathologic events can have a negative impact on the patient's neurologic state and worsen their clinical outcomes.<sup>1</sup>

The two basic mechanisms that cause primary injury are contact (such as a head-on collision with an object or the brain impacting the interior of the skull) and acceleration-deceleration. The primary effects of contact can include injuries to the scalp, skull fractures, and brain surface contusions. Unrestricted head movement causes primary injury from acceleration-deceleration, which results in shear, tensile, and compressive strains.<sup>2</sup> These forces can cause intracranial hematoma, diffuse vascular injury, and cranial nerve and pituitary stalk damage. Contusions are swollen areas of brain tissue. They are most commonly found on the frontal lobe poles, inferior frontal lobes, the cortex above and below the operculum of the sylvian fissures, and the lateral and inferior temporal lobes.<sup>3</sup>

Seizures are common in patients who have suffered a head injury and are frequently associated with adverse outcomes.<sup>2</sup> Controlling post-traumatic seizures is essential because these acute insults can exacerbate secondary brain injuries, altering intracranial pressure, rebleeding, and oxygen delivery to cerebral tissue.<sup>3</sup> Prophylactic antiepileptic drugs (AEDs) are commonly used to reduce the risk of seizures.<sup>4</sup>

LEV received medical approval in 1999, whereas PHY received approval in 1953.<sup>5</sup> In the past, PHY was the drug most frequently recommended for seizure prophylaxis. LEV, on the other hand, is a more recent antiepileptic drug with substantially less adverse effects than PHY and fewer drug-drug interactions, as well as a simple dosing regimen.<sup>6</sup> Although PHY often works in most situations, it also has a high frequency of detrimental consequences and is significantly impacted by several other drugs.<sup>7</sup> According to a study conducted by Younus SM et al, the efficacy of LEV in contrast to PHY was determined to be 91.30% and 75.76%, respectively.<sup>8</sup>

In local practices, PHY is the most commonly used drug, and LEV has recently been introduced. The ease of administration of LEV, as well as the lack of drug level monitoring, contribute to its increased use. PHY has also been linked to a number of adverse effects, including cutaneous hypersensitivity and CYP-450 induction, which LEV does not have. That is why this study was designed to compare these two drugs in order to find the better agent

among them for the prevention of post-traumatic seizures. Although there have previously been many studies on this subject, they are currently unavailable in our area, and there is a need for such research in our population. Our study will provide empirical evidence for a better drug for the management of post-traumatic seizures in order to reduce mortality and morbidity of population.

## MATERIALS AND METHODS

**Study design:** A prospective cohort study.

**Setting:** Department of Neurosurgery, Pakistan Institute of Medical Sciences, Islamabad, Pakistan.

**Duration of study:** 25th December 2021 to 24th June 2022.

**Sample size:** Sample size of 140 (70 in each group) cases was calculated by using World Health Organization (WHO) calculator with 5% level of significance, 80% power of study and taking efficacy of LEV as 91.30% and PHY as 75.76%.

**Sample technique:** Non-probability consecutive sampling.

### Sample selection

#### a. Inclusion Criteria:

- All patients who presented with traumatic brain injury.
- Duration of trauma  $\leq 24$  hours.
- Age 15-60 years of both genders.

#### b. Exclusion Criteria:

- Patients with history of epilepsy (assessed on history and medical record).
- Patients with acromegaly or hypogonadism (as there may be seizures in these conditions that interfered with our results).
- Patients with history of brain tumour or abscess (assessed on history and medical record) as it may be a cause of seizures and interfered with our results).

### Data collection procedure

Following approval from the institutional ethical committee, 140 (70 in each group) patients admitted to the Department of Neurosurgery, Pakistan Institute of Medical Sciences, Islamabad, Pakistan who met the inclusion criteria were chosen. For inclusion in the study, informed consent was obtained from each patient's attendant. All cases were divided into two groups. LEV was given to group

A patients as a 1000 mg IV loading dose, followed by a dose of 500-1000 mg (orally) twice daily. PHY was given to group B patients as an IV loading dose of 15-20 mg/kg, followed by an oral dose of 4-8 mg/kg divided into three doses per day. All patients were followed, and efficacy was determined. On a predesigned proforma, all data were recorded.

**Data analysis procedure**

Statistical Package for Social Sciences (SPSS) version 25.0 was used for statistical analysis. The mean and standard deviation for age, trauma duration, and Glasgow Coma Scale (GCS) score were presented. Gender and efficacy (yes/no) were presented in the form of frequency and percentage. The chi-square test was used to compare the efficacy of both groups, and a p-value of  $\leq 0.05$  was considered significant. Age, gender, duration of trauma, and GCS score were all stratified. The post-stratification chi-square test was used to determine their effects on efficacy, and a p-value of  $\leq 0.05$  was considered significant.

**RESULTS**

The age range in this study was from 15 to 60 years with mean age of  $43.32 \pm 9.26$  SD years. The mean age of patients in group A was  $43.69 \pm 9.05$  SD years, and  $43.07 \pm 9.46$  SD years in group B. The majority of the patients i.e, 108 (77.1%) were between 41 to 60 years of age as shown in Table-I. Out of these 140 patients, 87 (62.1%) were males and 53 (37.9%) were females with male to female ratio of 1.6:1 (Table-II). The average duration of trauma was  $14.78 \pm 4.79$  hours (Table-III). The average GCS was  $11.68 \pm 1.48$  (Table-IV). As shown in Table-V, the efficacy of LEV was seen as 63 (90%) and that of PHY as 46 (65.7%) with a p-value of 0.0005. Table-VI depicts efficacy stratification based on age, gender, trauma duration, and GCS score.

**Table 1.** Age distribution in both the study groups.

Age (years)	Group A (n=70)		Group B (n=70)		Total (n=140)	
	No. of patients	%age	No. of patients	%age	No. of patients	%age
15-40	15	21.4	17	24.3	32	22.9

41-60	55	78.6	53	75.7	108	77.1
Mean $\pm$ SD	$43.69 \pm 9.05$		$43.07 \pm 9.46$		$43.32 \pm 9.26$	

**Table 2.** Gender distribution in both the study groups.

Gender	Group A (n=70)		Group B (n=70)		Total (n=140)	
	No. of patients	%age	No. of patients	%age	No. of patients	%age
Male	43	61.4	44	62.9	87	62.1
Female	27	38.6	26	37.1	53	37.9

**Table 3.** Distribution of patients according to duration of injury in both the study groups.

Duration (hours)	Group A (n=70)		Group B (n=70)		Total (n=140)	
	No. of patients	%age	No. of patients	%age	No. of patients	%age
$\leq 12$	17	24.3	24	34.3	41	29.3
13-24	53	75.7	46	65.7	99	70.7
Mean $\pm$ SD	$15.23 \pm 4.72$		$14.16 \pm 5.03$		$14.78 \pm 4.79$	

**Table 4.** Distribution of patients according to GCS in both the study groups.

GCS	Group A (n=70)		Group B (n=70)		Total (n=140)	
	No. of patients	%age	No. of patients	%age	No. of patients	%age
10-12	47	67.1	52	74.3	99	70.7
13-15	23	32.9	18	25.7	41	29.3
Mean $\pm$ SD	11.83 $\pm$ 1.51		11.56 $\pm$ 1.47		11.68 $\pm$ 1.48	

**Table 5.** Comparison of the efficacy of LEV versus PHY in prevention of post-traumatic seizures.

Comparison between LEV and PHY on the basis of efficacy		Group A		Group B	
		No. of patients	%age	No. of patients	%age
Efficacy	Yes	63	90	46	65.7
	No	7	10	24	34.3

**Table 6.** Stratification of efficacy with respect to age, gender, duration of trauma and GCS score.

Parameters		Group A (n=70)		Group B (n=70)		P-value
		Efficacy		Efficacy		
		Yes	No	Yes	No	
Age (years)	15-40	15 (100%)	0 (0%)	11 (67.4%)	6 (35.3%)	0.011
	41-60	48 (87.3%)	7 (12.7%)	35 (66%)	18 (34%)	0.009
Gender	Male	40 (93%)	3 (7%)	25 (56.8%)	19 (19.2%)	0.0001
	Female	23 (85.2%)	4 (14.8%)	21 (80.8%)	5 (19.2%)	0.667

Duration of trauma (hours)	$\leq 12$	16 (94.1%)	1 (5.9%)	15 (62.5%)	9 (37.5%)	0.020
	13-24	47 (88.7%)	6 (11.3%)	31 (67.4%)	15 (32.6%)	0.009
GCS score	10-12	43 (91.5%)	4 (8.5%)	33 (63.5%)	19 (36.5%)	0.001
	13-15	20 (87%)	3 (13%)	13 (72.2%)	5 (27.8%)	0.237

## DISCUSSION

Anti-epileptic drug (AED) prophylaxis is frequently used in the management of patients with brain injury because certain sub-groups have been shown to benefit from seizure prophylaxis.<sup>9</sup> The drug PHY has been shown to be significantly more effective than placebo in preventing post-traumatic seizures during the first 7 days (risk ratio, 0.27; 95 percent confidence interval, 0.12 to 0.62).<sup>10</sup> However, PHY displays a wide array of side effects including induction of the hepatic cytochrome P450 system, cutaneous hypersensitivity reactions and inducing drug-drug interactions.<sup>11,12</sup> LEV, on the other hand, is a newer non-enzyme inducing AED with far fewer potential side effects.<sup>13</sup> Furthermore, unlike PHY, it does not necessitate close monitoring via serial blood sampling due to a wider therapeutic index. However, it is significantly more expensive than PHY.<sup>14</sup>

There is disagreement about the efficacy of LEV versus PHY in seizure prevention. Various trials have yielded disparate results in terms of the relative efficacy of the two drugs. In our study, the efficacy of LEV was 63 (90%) and that of PHY was 46 (65.7%) with p-value of 0.0005. According to a study done by Younus SM et al., the efficacy of LEV compared to PHY was found to be 91.30% and 75.76%, respectively.<sup>8</sup> Jones et al. found no significant difference in efficacy between PHY and LEV for early post-traumatic seizure prophylaxis (p=0.556), despite the fact that patients in the LEV group had a higher incidence of abnormal EEG findings.<sup>15</sup> Regarding the long-term effects of both, Szafarski et al. found that patients receiving LEV had better long-term outcomes than those receiving PHY.<sup>16</sup>

One study found that patients taking PHY had an increased tendency to have seizures on EEG, but

there was no difference in actual seizure activity. PHY use is also associated with an increased risk of gastrointestinal upset and neurologic deterioration. The patients treated with LEV improved their GCS scores in Gregg *et al.*'s study, but the reliability of the results cannot be determined due to the small sample size in their study.<sup>17</sup> Another study found that using PHY reduced the incidence of early post-traumatic seizures in children.<sup>18</sup>

Guidelines issued by the Brain Trauma Foundation in 2007 and the American Academy of Neurology in 2003 support the provision of post-traumatic seizure prophylaxis for the first 7 days only, with PHY being the most appropriate drug for this purpose. The Food and Drug Administration has approved PHY for the treatment of generalized tonic-clonic and complex partial seizures, as well as the prevention and treatment of seizures that occur during or after neurosurgery.<sup>19</sup>

Our study found that using LEV reduced the likelihood of seizures and abnormal EEGs. A number of studies show that LEV is superior due to its lower risk of side effects and better long-term outcomes.<sup>20</sup> In acute TBI, the use of LEV rather than PHY is associated with better 6-month cognitive outcomes.<sup>21</sup> LEV also improves the brain's higher integrative mechanisms. In fact, studies have shown that LEV improves a variety of cognitive abilities, including visual short-term memory, working memory, motor functions, psychomotor speed and concentration, and fluid intelligence.<sup>22,23</sup>

A previous meta-analysis compared seizure rates with LEV to those treated with PHY in patients with TBI who were at increased risk of seizures.<sup>24</sup> The findings suggested that different TBI patients may have a different underlying tendency to seizures, which may be associated with different functional outcomes when using an AED. The use of AEDs may aid in the prevention of post-traumatic seizures. Seizure prevention medications, on the other hand, are not without side effects. Aside from the debate over the efficacy of LEV and PHY, there are serious human side effects. Four of the studies reported side effects, and there were no significant differences in terms of side effects. This finding is consistent with previously reported rates of PHY side effects versus LEV.<sup>25</sup>

The incidence of seizures seven days after a TBI in patients receiving PHY and LEV was assessed in a retrospective observational study by Kruer *et al.* The

study also described the selection of AEDs in clinical practice. Patients under the age of 18 were barred from participating in the study. 89 of the 109 patients were given PHY, while 20 were given LEV. In total, two patients, one from each group, had post-traumatic seizures. Kruer *et al.* concluded that following the approval of IV LEV, there was a trend favouring LEV for seizure prevention.<sup>26</sup> Radic *et al.*<sup>27</sup> conducted a separate retrospective cohort study to compare the efficacy and risk of using LEV versus PHY for seizure prophylaxis following an acute or subacute subdural hematoma diagnosis. A total of 124 patients were assigned to the PHY group, while 164 were assigned to the LEV group. There was no significant difference in clinical and/or electrographic seizure risk, but the LEV group had a lower risk of adverse events. When compared to PHY users, LEV was associated with an increased risk of electrographic seizures during hospitalization and a decreased risk of adverse drug effects in subjects with a midline shift of  $>0$  mm. So, according to Radic *et al.*, LEV is associated with a lower risk of adverse drug effects.

The goal of Chakravarthi *et al.*<sup>28</sup> was to compare the safety and efficacy of IV LEV versus IV PHY in the treatment of status epilepticus. In this study, 44 patients were randomly assigned to either PHY or LEV treatment. The primary endpoint was successful clinical seizure activity termination within 30 minutes of drug administration. Secondary endpoints included seizure recurrence within 24 hours, drug-related adverse effects, mortality during hospitalization, and the need for ventilatory assistance. LEV only controlled status epilepticus in 13 patients compared to 15 patients who took PHY. In terms of outcome measures, this study concluded that LEV is as effective as PHY. LEV is popular because of its ease of administration and lack of continuous monitoring. In the treatment of status epilepticus, LEV is an appealing alternative to PHY. Khan *et al.*<sup>29</sup> conducted a separate randomized controlled trial to compare the efficacy of PHY and LEV in the prevention of early post-traumatic seizures in patients with moderate-to-severe TBI. The 154 patients in this study were divided into two equal groups. In 73 patients, PHY was effective in preventing post-traumatic seizures, while LEV effectively controlled seizures in 70 cases. The researchers concluded that there is no statistically significant difference between PHY and LEV in the

prevention of early posttraumatic seizures in patients with moderate-to-severe TBI.

Noureen et al.<sup>30</sup> compared the clinical efficacy and safety of IV LEV versus IV PHY as second-line drugs in the treatment of paediatric status epilepticus. In this open-label, randomized controlled trial, 300 children with status epilepticus received LEV, while another 300 received PHY. LEV was effective in 278/300 cases, while PHY was effective in 259/300 cases. In addition, eight children in the PHY group experienced adverse events. The study concluded that LEV is far more effective than PHY in treating paediatric status epilepticus. Besli et al.<sup>31</sup> recently published a study comparing the efficacy and safety profile of LEV and PHY as second-line treatment agents in children with convulsive status epilepticus and acute repetitive seizures. LEV was given to 141 of the 227 patients, while PHY was given to 86. In children with convulsive status epilepticus, LEV was effective in 77.6% of cases, while PHY was effective in 57% of cases. However, there was no statistically significant difference between LEV and PHY efficacy rates for acute repetitive seizures (55.8% vs. 58.8%, respectively). The study concluded that LEV appears to be as effective as PHY in treating children with acute repetitive seizures, but it is more effective in treating children with convulsive status epilepticus.

## CONCLUSION

LEV is more effective than PHY at preventing post-traumatic seizures, according to this study's findings. Therefore, in order to lower the morbidity and mortality of these particular individuals, we advise using LEV as a main therapy agent in the prevention of early post-traumatic seizures in traumatic brain injury.

## ABBREVIATIONS

LEV: Levetiracetam

PHY: Phenytoin

IV: Intravenous

TBI: Traumatic brain injury

AED: Antiepileptic drug

AEDs: Antiepileptic drugs

WHO: World Health Organization

SPSS: Statistical Package for Social Sciences

GCS: Glasgow Coma Scale

EEG: Electroencephalography

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