15 Temporal Bone Trauma

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Key Points

In this chapter, we will learn:

- Three main conditions involved in temporal bone trauma.
- Types of temporal bone fractures and their clinical presentation, investigations, and management plans.
- Middle ear trauma and its clinical presentation, investigations, and management plans.
- Barotrauma causes, clinical presentation, investigations, and management plans.

15.1 Temporal Bone Fractures

15.1.1 Introduction

- Temporal bone is the strongest bone of the body and at the same time one of the most complex bone as it contains many important structures, including the vestibulocochlear apparatus, carotid artery, jugular vein, and the facial nerve. Also, it is surrounded by the brain and other cranial nerves.
- Temporal bone as part of skull base has many foramina and openings causing weakness points which are involved by head trauma leading the fracture to follow these weak points.
- Temporal bone may involve none or all of these structures, and also can involve other structures like cranial nerve (6th, 9th, 10th, and 11th).
- The head is the most commonly injured part of the body (75% of all motor vehicle accidents).
- Approximately 30% of head traumas have skull fracture, and the ear is the most frequently sensory organ damaged.
- Temporal bone injury happens in up to 22% of all skull fractures and is caused mainly by motor vehicle accidents (around 30%).
- Temporal bone fracture is a common manifestation of head trauma, and 90% of temporal bone fractures are associated with intracranial injuries and 9% with cervical spine injury.
- Bilateral temporal bone fractures are present in 8–29% of all fractures.
- These can be due to blunt or penetrating trauma, and stab and gunshot wounds are the most common penetrating wounds. Gunshot wounds medial to the geniculate ganglion are usually fatal because it is associated with big vessels bleeding.

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15.1.2 Types

- Ulrich was the first to classify temporal bone fractures into longitudinal and transverse fractures in 1926 [1].
- Ghorayeb and Yeakley studied 150 temporal bone fractures and found the majority is actually oblique or mixed [2].
- Other classification is otic capsule involvement or sparing.
- Ishman and Friedland classified them into petrous and non-petrous involvement, where the petrous-involved fractures have greater correlation with sensorineural hearing loss (SNHL) presence [3].
- All these classifications are arbitrary but useful to predict the type of injury expected. Although temporal bone fractures are irregular and non-uniform in their pathway.
- Despite the recent classifications, Ulrich's is the most commonly used due to its simplicity.

15.1.2.1 Longitudinal Fractures

Longitudinal fractures involve 80% of all temporal bone fractures. They are usually caused by a lateral force over the mastoid or temporal squama (temporal or parietal blows). The fracture line parallels the long axis of the petrous pyramid. It starts in the pars squamosa (mastoid or external auditory canal), extends through the posterosuperior bony external canal, continues across the roof of the middle ear space anterior to the labyrinth, and ends anteromedially in the middle cranial fossa in close proximity to the foramen lacerum and ovale (Table 15.1).

15.1.2.2 Transverse Fractures

Transverse fractures involve 20% of all temporal bone fractures. They are usually caused by a frontal, parietal, and less likely occipital blow. The fracture line runs at a right angle to the long axis of the petrous pyramid and starts in the middle cranial fossa (close to the foramen lacerum and spinosum). It then crosses the petrous pyramid transversely and ends at the foramen magnum. It may also extend through the internal auditory canal and injure the nerves directly (Table 15.1).

Table 15.1 Comparison of longitudinal and transverse temporal bone fractures with their main corresponding features

Feature	Longitudinal fractures	Transverse fractures
Incidence	80%	20%
Mechanism	Temporal or parietal trauma	Frontal or occipital trauma
CSF otorrhea	Common	Occasional
Tympanic membrane perforation	Common	Rare
Facial nerve damage	20% (temporary and delayed)	50% (severe, permanent, and immediate)
Hearing loss	Common (CHL)	Common (SNHL)
Hemotympanum	Common	Possible
Nystagmus and vertigo	Common (mild and temporary)	Common (severe and prolonged)
Otorrhagia	Common	Rare

15.1.2.3 Oblique or Mixed Fractures

They are a mixture of both longitudinal and transverse.

15.1.3 Clinical Presentation

15.1.3.1 Bleeding

Into the ear canal from skin and tympanic membrane laceration, hemotympanum (Fig. 15.1), external auditory canal fractures.

15.1.3.2 Hearing Loss

Conductive hearing loss (*CHL*) due to ossicular chain disruption [4, 5]:

- Incudostapedial joint separation (82%)
- Incus dislocation (57%)
- Fracture of the stapes crura (30%)
- Fixation of the ossicles in the attic (25%)
- Incudomalleolar joint separation (<3%)

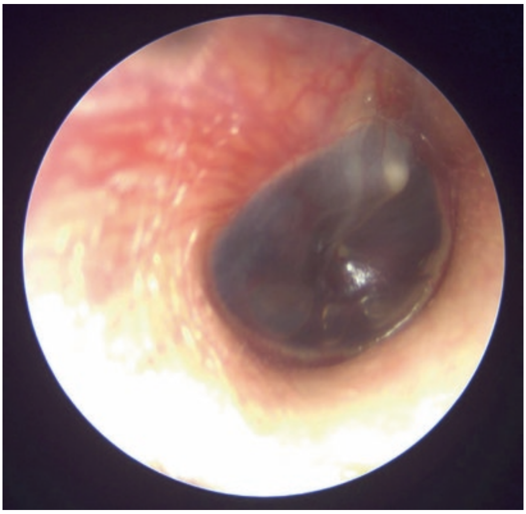

Fig. 15.1 Right ear hemotympanum

Also, it could be due to effusion of the middle ear by blood or cerebrospinal fluid (CSF), ear canal filled by debris, blood, or discharge.

Sensorineural hearing loss (*SNHL*) may occur as a result of concussive damage to the inner ear, and cochlear and vestibular structures are usually destroyed, producing a profound sensorineural hearing loss and tinnitus.

Rarely, a mixed hearing loss may occur.

15.1.3.3 Facial Nerve Paralysis

Twenty percent of longitudinal fractures and 50% of transverse fractures injure the facial nerve and cause paralysis. The injury site is usually the horizontal segment of the nerve distal to the geniculate ganglion in longitudinal fractures. The injury site is from the internal auditory canal to the horizontal segment distal to the geniculate ganglion in transverse fractures.

15.1.3.4 Vertigo and Nystagmus

Vertigo occurs but is not related to the severity of the fracture.

The intensity of the vertigo will decrease after 7–10 days and then continues to decrease steadily over the following 1–2 months, leaving an unsteady feeling that lasts approximately 3–6 months.

15.1.3.5 CSF Otorhinorrhea

It is common but usually temporary.

15.1.4 Physical Examination

- Ear examination: auricle, ear canal, and tympanic membrane complete examination including Rinne and Weber's tests.
- Look for battle sign and Racoon eyes for other skull base fractures.
- Nystagmus and fistula test.
- Dix–Hallpike test.
- Facial nerve examination and other cranial nerves.

15.1.5 Investigations

- Hearing tests: pure tone audiometry and even auditory brainstem response.
- Fluid collection from the ear or nose and testing for Beta2 transferrin.
- CT scan: High-resolution Ct scan (HRCT) is the imaging of choice in temporal bone fractures, best to identify temporal bone fractures type, direction, presence (pneumolabyrinth) or absence of otic capsule involvement, complications like hemotympanum, tympanic membrane perforation, ossicular injury, perilymphatic fistula, CSF leak, cochlea-vestibular injury, facial nerve injury, and vascular injury (Figs. 15.2, 15.3, 15.4, and 15.5).
- Angiography can be requested if major vascular injury is suspected.
- Magnetic resonance imaging (MRI) cannot identify temporal bone fracture. MRI has both poor sensitivity and specificity in this respect. It is best used to identify and assess the intracranial contents and/or a nerve palsy, bleeding inside the otic capsule, vestibular apparatus, vestibular nucleus, and brainstem. It also can identify nerve compression and herniation of intracranial contents into the mastoid cavity.

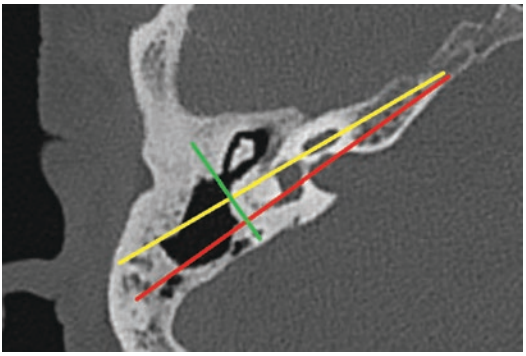

Fig. 15.2 Axial CT of temporal bone showing the axis of temporal bone (yellow line) the line of longitudinal fractures (red line) and transverse fractures line (green line)

- Nerve conduction study for facial nerve like electromyography (EMG) or electroneurography (ENoG).

15.1.6 Treatment

15.1.6.1 Medical

- Most middle ear effusion (Fig. 15.6), CSF, or perilymphatic fistula can be treated by head elevation, avoidance of straining and prophylactic antibiotics.

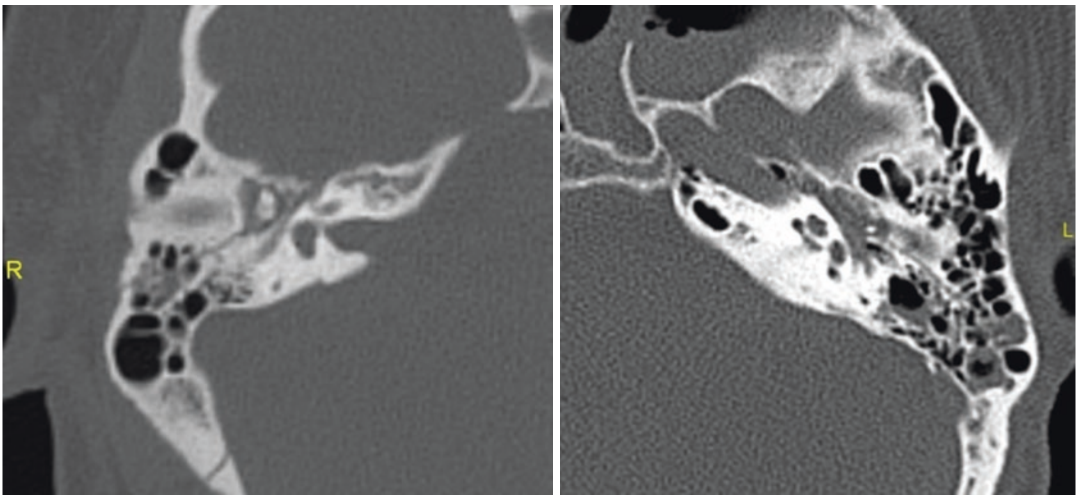

Fig. 15.3 Axial CT sections of the temporal bones in two different patients (Right and Left) showing longitudinal fractures associated with hemotympanum and hemomastoid

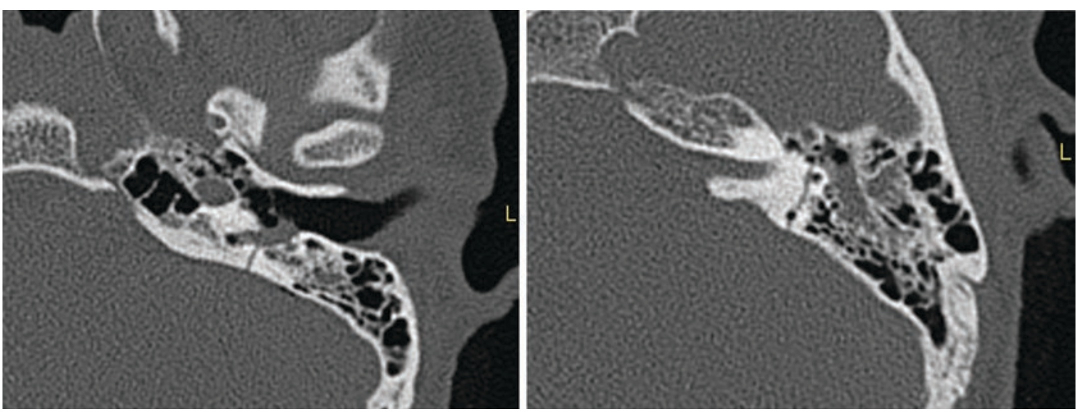

Fig. 15.4 Transverse fractures are seen involving the left temporal bone and passing through the superior semicircular canal

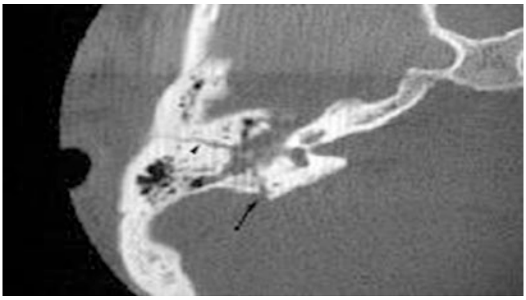

Fig. 15.5 Axial non-contrast CT with bone windows demonstrates a complex fracture with a transverse (arrow) and oblique (arrowhead) component

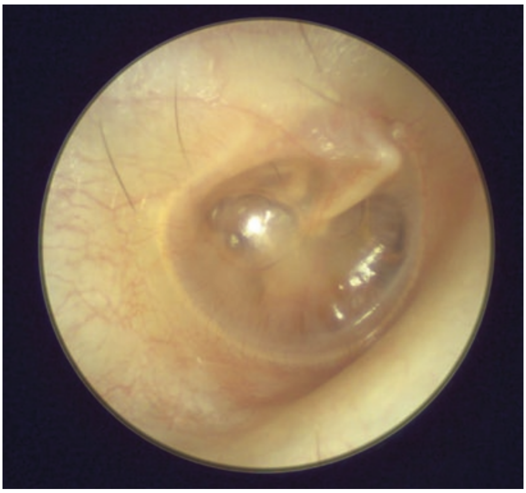

Fig. 15.6 Right middle ear effusion

- Small tympanic membrane perforation (Fig. 15.7) can heal spontaneously within 4 weeks by water avoidance and antibiotics ear drops if contamination of middle ear happened.
- Corticosteroid therapy for facial nerve weakness or sensorineural hearing loss might be necessary.
- Epley for posttraumatic benign paroxysmal positional vertigo and vestibular rehabilitation.
- Antibiotics for meningitis and CSF leak (controversial).

15.1.6.2 Surgical

- Myringoplasty with or without ossiculoplasty for non-healing perforations of the ear drum or to repair ossicular chain disruption.

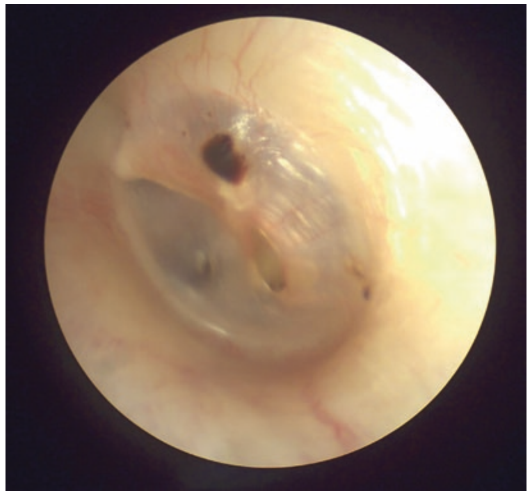

Fig. 15.7 Left traumatic tympanic membrane perforation

- Middle ear exploration for repair of perilymphatic fistula from round or oval window.
- Facial nerve decompression for complete immediate facial nerve paralysis or >90% degeneration by ENoG.
- Cochlear Implant, but before considering it, labyrinthitis ossificans must be considered when bilateral severe sensorineural hearing loss is present.

15.2 Middle Ear Trauma

15.2.1 Introduction

- Middle ear trauma or injury to inner ear compartment or both happens in up to 33% with severe head trauma and over 50% of temporal bone fractures [6, 7].
- Injury can be shown as hemotympanum, decreased hearing, CSF otorrhea, perilymph fistula, and otic capsule injury.
- Inner ear injury is more frequently seen with temporal bone fractures with facial paralysis and CSF otorrhea.
- Middle ear trauma can also happen after blunt trauma to the ear canal (punched ear, slap, direct fall to the ear, road traffic accidents, and sport injury) or by penetrating injury by Q-tip and gun shot or even by welding spark.

15.2.2 Clinical Presentation

Otalgia from injury to the ear canal, middle ear, or inner ear.

Hearing loss:

- Most injuries result in conductive hearing loss which can be mild in tympanic membrane perforation or hemotympanum or CSF effusion or can be severe in ossicular chain disruption (most commonly at the incudostapedial joint).
- Sensorineural hearing loss happens as a result of cochlear concussion, otic capsule fractures, or by impingement of cochlear nerve in the auditory canal fracture.

Vertigo: due to concussion or perilymph fistula.

Otorrhea: which can be clear fluid (CSF or perilymph), bloody, or purulent (from infection by contamination).

Tinnitus: due to inner ear involvement.

Rhinorrhea: clear or bloody by escape of ear fluids to the nose through Eustachian tube or by an independent direct fracture of the anterior skull base. Usually aggravated by Valsalva manoeuver or bending the head down.

Facial paralysis: unlikely to happen in isolated middle ear injury, usually as part of temporal bone trauma.

15.2.3 Physical Examination

- Ear examination: auricle, ear canal, and tympanic membrane complete examination including Rinne and Weber's tests.
- Look for battle sign and Racoon eyes for other skull base fractures.
- Nystagmus and fistula test.
- Facial nerve examination and other cranial nerves.

15.2.4 Investigations

- Hearing tests: pure tone audiometry and even auditory brainstem response.
- Fluid collection from the ear or nose and testing for Beta2 transferrin.
- CT scan: for skull fractures and ossicular chain disruption (preferably by temporal bone CT with thin cuts). Angiography can be requested if major vascular injury is suspected.
- MRI: only for facial nerve injury (preoperatively), otherwise wouldn't add anything to CT.
- Nerve conduction study for facial nerve like EMG or ENoG.

15.2.5 Treatment

15.2.5.1 Medical

- Most middle ear effusion (Fig. 15.6), CSF, or perilymphatic fistula can be treated by head elevation avoidance of straining and prophylactic antibiotics.
- Small tympanic membrane perforation can heal spontaneously within 4 weeks by water avoidance and antibiotics ear drops if contamination of middle ear happened.
- Corticosteroid therapy for facial nerve weakness or sensorineural hearing loss might be necessary.

15.2.5.2 Surgical

- Tympanoplasty with or without ossiculoplasty for non-healing perforations (Fig. 15.7) of the ear drum or to repair ossicular chain disruption.
- Middle ear exploration for repair of perilymphatic fistula from round or oval window.
- Facial nerve decompression for complete facial nerve paralysis or >90% degeneration by ENoG.

15.3 Barotrauma

15.3.1 Introduction

- The middle ear is an air-filled space. The middle ear pressure is preserved from the atmospheric pressure by the function of Eustachian tube and the tympanic membrane.
- The Eustachian tube acts as a valve to eliminate the extra pressure of the middle ear to the

nasopharynx passively with the help of absorption of gases through middle ear mucosa and also allows air to pass through the nasopharynx to equalize the pressure of the middle ear actively by the contraction of the soft palate muscle.

- Any severe changes to the middle ear pressure without these protective mechanisms will cause damage to the middle ear structures in a condition called barotrauma.
- The Eustachian tube consists of two parts bony [posterolateral] and cartilaginous [inferomedial] parts lined by respiratory mucosa.
- Eustachian tube opens temporarily during swallowing and yawning allowing air to pass from the nasopharynx to the ear by the contraction of tensor veli palatini muscle. And this muscle also helps to isolate the nasopharynx during the swallowing to prevent oropharynx content to go to the nasopharynx and the ear, thus preventing spread of infection to the middle ear, and also helps to keep the Eustachian tube closed all the time to prevent the eardrum from moving with respiration like what happens in the condition called patulous Eustachian tube.
- Eustachian tube dysfunction happens mainly due to mucosal edema causing dysfunction like in infection by an upper respiratory tract infection, allergy, or acid reflux, or by mechanical obstruction in conditions like adenoid enlargement in children and nasopharyngeal tumor in the adults.

15.3.2 Etiology

There are many causes of barotrauma

(a) Flying

The most common is flying. The atmospheric pressure decreases as the airplane is ascending and increases during descend.

Middle ear pressure has to be equalized during these events to compensate that change.

As long as these changes are gradual, normal equalization happens by swallowing, Valsalva, or middle ear gas absorption.

If for any reasons the change in altitude is fast, the pressure equalization mechanism fails to equalize and barotrauma happens.

Injury happens by stretching, bruising, or even bleeding from the tympanic membrane and middle ear mucosa.

In more severe conditions, ear drum perforation, ossicles fractures or dislocation, and injury to inner ear by round and oval window membrane rupture with perilymph fistula occur [8, 9].

(b) Diving, the other common condition is Diving; the mechanism is similar to flying but usually the pressure change is more severe [10].

(c) Blast injury

Blast injury has become more frequently seen after the increased number of wars and terrorist attacks. After a blast explosion, a pressure wave travels to a certain distance causing movement of the structures in its way. This pressure changing causes the barotrauma.

Because of the high energy of the blast, most of the presentation is severe (i.e. tympanic membrane perforation, ossicles fractures or dislocation, or inner ear fistula) [11].

(d) Decompression chamber: it occurs due to difference in volume and circulation of both cochlea and vestibule (vestibule has 30% more volume and 25% less circulation than the cochlea) which reduces any compensation to pressure changes and causes barotrauma, and most of the symptoms are sensorineural hearing loss (SNHL) and vertigo [12].

(e) Sky diving: although a fast descent happens and the middle ear pressure should change, but symptoms doesn't seem to occur frequently [13].

15.3.3 Clinical Presentation

1. *Ear block* or pressure feeling in the ear (most common).
2. *Hearing loss*

(a) Conductive hearing loss: in case of serous effusion (Fig. 15.6) or bleeding in the middle ear (Fig. 15.7), ear drum perforation, and ossicles injury.
(b) SNHL: inner ear trauma or perilymphatic fistula.

3. *Vertigo*
4. *Otalgia*
5. *Tinnitus*: most commonly pulsating but can be constant, frequently temporary but sometimes can be persistent.

15.3.4 Diagnosis

- Diagnosis is made by good history (any scenario of sudden pressure change) and confirmed by physical examination.
- Hearing test (Rinne and Weber's) or pure tone audiometry to differentiate between CHL and SNHL is recommended.
- Radiological investigations are usually not needed.

15.3.5 Treatment

- Most of simple conditions of barotrauma just need conservative treatment (observation and symptomatic treatment), and even edema, bleeding or effusion, tympanic membrane perforation, and minor fistula heal spontaneously.

15.3.5.1 Medical

- Analgesic for pain management.
- Decongestant to open Eustachian tube although no good evidence to fasten the recovery.
- Antibiotics: only when ear drum perforation and contamination of middle ear.
- Steroid: no evidence of benefit except with SNHL or facial nerve injury.

15.3.5.2 Surgical Treatment

- Myringoplasty for tympanic membrane perforation.
- Ossiculoplasty for ossicular chain fracture or dislocation.
- Middle ear exploration and patching of fistula from the round or oval window, although hearing restoration results are not promising despite early intervention.
- Myringotomy with or without ventilation tube: useful for both prevention and treatment of barotrauma as it helps draining the fluids and correcting the hearing; tubes are beneficial for hyperbaric treatment patients and contraindicated for divers as it will open the middle ear to water.

15.3.6 Prevention

Avoidance is the best choice of treatment for barotrauma and can be achieved by

- Canceling or postponing flying or diving in cases of cold or allergies when ear equalization maneuvers fail.
- Swallowing or Valsalva maneuver during the flight or dive.
- Chewing gum or sucking hard candies for adults, and sucking infant bottle is helpful to equalize the pressure during the flight.
- Decongesting 30 min before the takeoff or diving to reduce edema around the Eustachian tube.
- Surfactant inhalation prior to diving is under research.
- Special ear plugs designed to reduce pressure changes.
- Balloon dilatation of Eustachian tube (controversial with lack of evidence).
- Myringotomy with ventilation tube.

Take-Home Messages

- Temporal bone fracture is part of other skull fractures during head trauma, and because of its important contents and surrounding structures, it might cause serious life-threatening injuries.
- Many classifications have been defined, but Ulrich's classification is the most easy and convenient to use.
- Although classified into longitudinal and transverse, the majority in real life is a mixed type.
- Most fractures are diagnosed by CT scan.
- Barotrauma is a common condition usually caused by flying, scuba diving, and blast injury.
- Most of barotrauma are self-limited and can be treated symptomatically.
- Prevention is the most important part of the treatment of barotrauma.

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