Kitahata and Katz first described the association of pneumocephalus and posterior fossa surgery in the sitting position in 1976. Pneumoventricle following posterior fossa surgery in sitting position is known. Tension pneumoventricle has been described following resection of a cerebellar medulloblastoma, associated with hydrocephalus and cerebrospinal fluid (CSF) leakage from the suture line. It has also been described following surgical resection of a cerebellar medulloblastoma and insertion of a ventriculoperitoneal shunt due to a petrous bone defect. It is also reported after the removal of an acoustic neurinoma and a CSF shunt procedure due to a concomitant hydrocephalus. It can also occur due to the existence of a craniodural defect. It is also reported after the removal of an acoustic neurinoma and a CSF shunt procedure due to a concomitant hydrocephalus.

In sitting position, there are circumstances favorable to the development of pneumocephalus and pneumoventricle. It is described as an “inverted pop bottle” mechanism. The combined effects of gravity, moderate hyperventilation (with consequent hypocapnia), and iatrogenic intracranial dehydration (mannitol and/or frusemide) enable the air to enter the ventricle as CSF is drained through the wound. Administration of mannitol can enhance the CSF loss by reducing the brain volume and decreasing the production of CSF. In addition, the presence of blood remnant in the fourth ventricle after surgery can accentuate the obstructive hydrocephalus.

Dilated ventricles pose a problem in surgery for posterior fossa tumor in sitting position [2][3]-[10]. The breach of the third or fourth ventricle can result in a massive loss of CSF, which possibly leads to accumulation of air within the ventricles. As soon as the tumor is decompressed, rapid egress of CSF from the enlarged lateral and third ventricles creates a vacuum inside the ventricular system. The negative pressure created within the ventricles forces the atmospheric air into the ventricles till equilibrium is attained across the pressure differential. The influx of air into the ventricle is greater in the presence of a noncompliant system because the ventricles do not collapse as the fluid is drained and more air fills it. In addition, inhalational anesthetic drugs, such as nitrous oxide, can diffuse into air-filled spaces and expand any trapped air loculi. Symptomatic pneumoventricle develops when the volume of sealed intracranial air increases either by expansion of gas on warming to body temperature or by further diffusion of gas into the space based on physical laws discovered by Charles and Gay-Lussac. The temperature of intracranial gas rises from ambient temperature (approximately 20.8°C) to internal body temperature (37.8°C). The resultant volume expansion of the air leads to increased pressure within the ventricular system. It then exerts pressure on adjacent structures with potentially serious consequences. The hydrocephalus might increase manyfold leading to acute raised intracranial pressure.

Tension pneumoventricle may manifest as deterioration of consciousness with or without lateralizing signs, severe restlessness, generalized convulsions, or focal neurologic deficits. Postoperatively, the patients may present with delayed recovery, seizures, arterial hypertension, and reflex bradycardia (Cushing’s reflex) or cardiac arrest due to mass effect. The patient may remain drowsy and show tonic posturing or decerebrating response due to downward pressure on the brain stem. Patients who are asymptomatic or show minor symptoms are administered oxygen supplementation, which helps in the evacuation of the air and anesthetic gases from the ventricular system. If the volume of air is excessive and patient becomes progressively drowsy, an urgent twist drill craniostomy may be needed to stabilize the patient.

During posterior fossa surgery in sitting position, a small amount of pneumoventricle is unavoidable. However, influx of large amount of air in the ventricles...
should be avoided [Figure 2A–C]. There are certain precautions and maneuvers that need to be taken to minimize pneumoventricle. The resection cavity is carefully and gently irrigated with normal saline, which can reduce the incidence of iatrogenic pneumoventricle and help prevent the entrainment of air. Care must be exercised in the presence of any CSF drainage apparatus as this has been implicated as the major factor in causing pneumoventricle. Intracranial dehydration by mannitol and/or frusemide, which is frequently used to improve operating conditions for the surgeon in the sitting position, should be judiciously used.

An alternative maneuver to prevent large influx of air into the ventricle is to plug the aqueduct by a soft gelatin

Figure 1: (A) Sagittal contrast-enhanced magnetic resonance (MR) image showing midline fourth ventricular tumor. The tumor has widened the space between the roof of the fourth ventricle and aqueduct. (B) Axial contrast MR image showing the tumor occupying the fourth ventricle and splaying both the middle cerebellar peduncles.

Figure 2: (A) Axial plain computed tomography (CT) image showing pneumoventricle involving both frontal horns and suprasellar cisterns. (B) Axial plain CT image showing pneumoventricle involving both frontal horns and third ventricle. (C) Axial plain CT image showing pneumoventricle and hydrocephalus.
During resection of the posterior fossa tumor surgery, the initial dissection is always commenced at the superior pole of the tumor. As soon as the tumor is decompressed and the aqueduct is exposed, an adequate-sized soft gelatin sponge is gently placed over the aqueduct covering it completely. The gelatin sponge will swell considerably due to CSF soakage and occlude the aqueduct sufficiently to disallow rapid egress of CSF and influx of air. Occasionally, the continuous seepage of CSF from the aqueduct into the fourth ventricle can exert downward force on the swollen gelatin sponge and potentially displace it. An adequate-sized cottonoid is placed over the gelatin sponge to secure it so that it does not descend into the floor of the fourth ventricle. Care is taken to prevent any iatrogenic damage or manipulation of the fourth ventricle. In spite of plugging the aqueduct, a small quantity of CSF does pass from the aqueduct into the fourth ventricle but not sufficient amount of air to cause symptomatic pneumoventricle. Once the inferior and lateral portion of the tumor is removed, the cottonoid and the engorged gelatin sponge are gently removed. The roof of the fourth ventricle usually acts a barrier to prevent reflux of CSF. Owing to expansion of the fourth ventricular space due to tumor growth, the compliance of the roof of the fourth ventricle is compromised. As a result, the potential space created between the aqueduct and the roof of fourth ventricle following tumor decompression allows large amount of air influx in the aqueduct. The blood remnants in the fourth ventricle are also removed. The aqueduct-plugging technique is relatively safe and simple to perform to prevent large amount of air influx into the aqueduct. The gelatin sponge is time-tested material, relatively cheap, and easily available. It has no untoward reactions. Till now, there are no reports in the literature, which mentions aqueduct-plugging technique to prevent pneumoventricle. Postoperatively, there have been no complications related to use of gelatin sponge for plugging the aqueduct.

The aqueduct-plugging technique during posterior fossa tumor surgery in sitting position is a sound intraoperative maneuver, which would help to minimize the incidence of pneumoventricle and pneumocephalus.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/
her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Address for correspondence:** Dr. Dattatraya Muzumdar,
Department of Neurosurgery, Seth Gordhandas Sunderdas Medical College and King Edward VII Memorial Hospital, Parel, Maharashtra, India

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