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Case Report

Cranial and Spinal Subdural Hygroma Following Lumbar Epidural for Labour Analgesia

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ABSTRACT

Intracranial hygroma is a rare and probably missed complication of epidural analgesia secondary to accidental dural breech. The patient presented had a presumed spinal cerebrospinal fluid leak with symptoms of intracranial hypotension. Unusually the patient had both an intracranial subdural hygroma and rarely reported extensive spinal intradural (extra-arachnoid) collection following a lumbar epidural, administered in labour. Given the potential for progression to symptomatic neurological deficits, anesthetists should consider subdural hygroma when encountering patients with features of intracranial hypotension, or altered neurology following epidural. Pathophysiology, imaging and management are discussed.

Keywords
Subdural hygroma; Epidural; Dural puncture.

CASE REPORT

A 37-year-old multiparous woman presented during routine ward follow-up with a headache day two following a declared uncomplicated lumbar epidural for labour analgesia.

Past medical history included essential hypertension, controlled with methyldopa. A previous pregnancy was complicated by pre-eclampsia and a post dural puncture headache with recognised dural tap. This had been managed conservatively, with no further follow-up. Of note, there is no previous history of chronic headache prior to pregnancy.

On this occasion there was no dural tap noted at the time of insertion. Two epidural attempts with a 16-gauge Tuohy needle were undertaken at the L3-L4 interspace before a successful attempt at a lower lumbar level. The epidural behaved appropriately following a test, main dose and patient controlled analgesia infusion.

Day two after an uneventful vaginal delivery the patient was routinely seen on the ward and noted to have a postural headache of moderate severity. There were no other concerning features in the history at this time and neurological examination was normal. A working diagnosis of post dural puncture headache was made, and the patient managed conservatively with follow-up arranged for the following day.

On the third day postpartum, the headache had increased to an analogue score of severe accompanied by neck rigidity and photophobia. The patient reported right arm pain and subjective weakness. Neurological examination, including objective assessment of limb power, remained normal.

Non-contrast magnetic resonance imaging (MRI) head and spine imaging was arranged urgently for the same day looking for the intracranial correlates of and possible causes of the working diagnosis – dural breach with consequent intracranial hypotension. Bilateral cerebral hemispheric shallow hygromas were seen on the flair and T1 sequences, with descent of the aqueduct but no tonsillar descent (Figure 1). The brain parenchyma was otherwise normal. Extra axial hygroma collections were also seen from the foramen magnum inferiorly to the level of C6 (Figure 2) with sagittal cuts suggesting that the collections extended into the lumbar region.

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Figure 1. *MRI brain a) Coronal FLAIR and b) axial T2 Weighted Image Demonstrate Bilateral Hygromas (white arrows)*

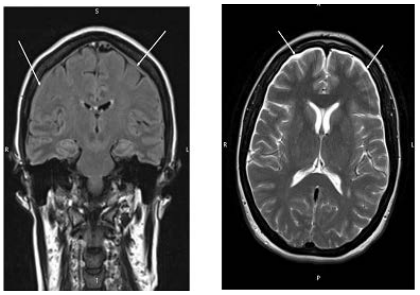

Figure 1a Figure 1b

Figure 2. *MRI Cervicothoracic Spine a) axial T2 and b) sagittal T2 Reveal Subdural CSF Collections (white arrows) Extending Inferiorly into the Vertebral Canal with Slight Displacement of the spinal cord (arachnoid dissection)*

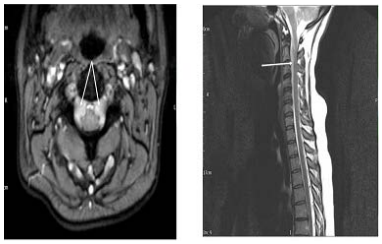

Figure 2a Figure 2b

A neurosurgical opinion advised supine bed rest overnight and observation. If no improvement in symptoms followed, an epidural blood patch should be considered once any source of infection had been discounted.

In the absence of improvement of symptoms an epidural blood patch with 24ml of autologous blood was performed electively on day four without event. This was delivered at the level of L3-4 and the patient was managed in bed for two hours afterwards. The following day the patient, having been symptom free for over twelve hours, mobilised with ease and was discharged.

At four-week follow-up, with repeat MR imaging, the patient remained asymptomatic and the MRI showed complete resolution of the previously seen changes.

DISCUSSION

Subdural hygroma formation following epidural analgesia in labour is not widely reported in the literature. The true incidence is unknown but thought to be rare.[1] There is a possibility that such cases, if asymptomatic, may go largely undetected. There is no data on persistence of low-pressure symptoms in this setting. This case report describes the more unusual finding of both intracranial and spinal subdural collections following a lumbar procedure.

Subdural hygromas are collections of interstitial and xanthochromic fluid that can develop within the subdural space following trauma to the dura.[2,3] This is seen more commonly following head injury and also as a complication following neurosurgery or spinal anaesthesia.[4-6] Following dural puncture, cerebrospinal (CSF) leakage into the epidural spinal space can lead to intracranial hypotension and a resultant vasodilation of adjacent vessels. Effusion of interstitial fluid across a pressure gradient, from these dilated vessels, is thought to be the mechanism for hygroma formation intracranially. Intracranial subdural hygromas can be unilateral or bilateral, and rarely extend caudally.[2-4] Spinal CSF collections in the intradural, extra-arachnoid space are otherwise identified as spinal arachnoid dissections. This complication following a spinal or epidural anaesthesic is very rare.[7,8] Collections usually occur secondary to lumbar spine surgery, with, although not exclusively so, durotomy. These dissections can be close or distant from the surgical site. It is likely, though unproven, that the exact mechanism of such collections within the cranium and the spine is different.[9-11]

Subdural hygroma can present clinically with postural headache, neck stiffness, photophobia, nausea or vomiting, focal neurological deficits, seizures and even reduced level of consciousness. The total volume of extra-arachnoid CSF is likely to contribute to the extent of the symptoms.[4] When extra-axial collections form, peripheral neurology could also be compromised.[9] The site of the spinal hygroma may not by correspond to the initial dural tear.

Subdural hygroma after unrecognised dural puncture is likely to be under diagnosed. MRI is the investigative modality of choice, as these low-density fluid collections may be difficult to discriminate from haematoma on computed tomography (CT). Diagnosis is important as hygromas can progress to subdural haematomas. The mechanism is suggested to be secondary to traction on, and tearing of, venous blood vessels. Following the well recognized subdural hygroma formation secondary to traumatic brain injury, progression to subdural haematoma is seen in 8.2% of patients.[3] Significant intracranial hypotension with ongoing precipitant CSF leak may progress to cerebellar herniation in untreated severe cases.

Management of uncomplicated subdural hygromas is focused on conservative methods whilst awaiting the natural history of spontaneous leak resolution. Conservative methods may include supine rest, hydration, caffeine and analgesia.[4] Symptomatic relief from low-pressure symptoms, without hygroma collection, can also be delivered with an occipital nerve block, if required.[12,13] The effused fluid will reabsorb and be redistributed.[2] In patients who remain symptomatic, an epidural blood patch may be considered. This is thought to either repair the dural breech or displace a comparable volume of CSF therefore treating the hypotension whilst the natural history occurs.[4]

Neurosurgical intervention is extremely uncommon but should be considered in complicated or non-resolving cases. Any progression in symptoms warrants further neurological imaging to assess for advancing intracranial pathology.[2,7]

The risk of occult dural breech makes diagnosis of post dural puncture headache more difficult.[14] This case demonstrates the importance of structured anaesthetic follow-up after epidural labour analgesia, and the need to maintain high index of suspicion for pathological sequelae in atypical headaches or neurology with a low threshold for imaging and investigation.

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Case Report

Anesthetic Considerations in Bilateral Congenital Anophthalmia: A Rare Clinical Entity

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ABSTRACT

Congenital anomalies planned for ocular surgeries range from the rare to atypical to common. Many of this rare ophthalmopathy are associated with clinical syndromes and have important anesthetic implications. Not only is it important to know the syndrome we are dealing with, but it's also the more important to understand the systems that are involved, the extent of involvement, potential anesthetic complications, right from the cerebrovascular, cardiovascular, endocrine, metabolic, neuromuscular, genito-urinary systems to airway. Understanding these aspects becomes more important in rare clinical scenarios as it helps to plan the case, anticipate and treat the complications. Congenital anophthalmia is one of the rare conditions with an incidence of <3/1000 with microphthalmia reported in up to 11% of blind children, hence we report a rare case of bilateral congenital anophthalmia planned for excision of right ocular swelling.

Keywords
Ophthalmopathies; Congenital anophthalmia; Microophthalmia; Ocular surgery.

INTRODUCTION

Anophthalmia is the absence of ocular tissue within the orbits. It represents a phenotypic continuum with microphthalmia in which the eyes are rudimentary or hypoplastic. Very often clinical anophthalmia may prove to be severe microphthalmia on imaging. With an estimated incidence of 3 per 10000 live births, it is one of the rare congenital anomalies that can present as an isolated finding or as a part of the syndrome.[1,2] Genetic, as well as environmental factors have been implicated as the cause of anophthalmos. Advanced maternal age, low birth weight, infections like toxoplasmosis, rubella, cytomegalovirus, varicella virus, influenza virus, and parvovirus have been implicated.[3]

Anophthalmos can present as a unilateral or bilateral lesion and can be associated with other systemic malformations particularly involving the cardiac, musculoskeletal and central nervous system (CNS). Cardiac associations include atrial septal defect (ASD), ventricular septal defect (VSD), and tetralogy of fallot, hypoplastic left ventricle, pulmonary valve atresia, and bicuspid aortic valve.[4] Bilateral anophthalmia has a high rate of associated CNS abnormalities which include septo-optic dysplasia, corpus callosum dysgenesis, absence of the anterior pituitary, agenesis of corpus callosum, absence of septum pellucidum, dilatation of the ventricles, polymicrogyria. Because of the absence of the normal globe the growth of the orbital cavity, intraorbital soft tissue, maxilla, maxillary sinus and mandible is also affected leading to facial asymmetry especially in bilateral cases where sunken orbit and midfacial hypoplasia is typical.[5-7]

Once a clinical diagnosis is made ocular imaging including ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) are done to establish the diagnosis. Though a clinical diagnosis, anophthalmos can prove to be microphthalmos on imaging or after surgical exploration.

CASE REPORT

A 33-year-old male patient with a history of absent eyeballs at birth presented with an insidious onset, gradually progressive painless soft globular swelling in the right eye over a period of four months. His maternal history regarding maternal age and any exposure to

drugs, infection or environmental toxins during pregnancy was not available as his mother was not alive. On local examination the mass was soft, approximately 4.5x4.5 cm, cystic in consistency. General physical examination revealed no clinically significant abnormality with stable vitals of pulse 90/minute, regular with BP of 124/84 mm-hg and BMI of 24.5 kg/m^2. Auscultation of heart revealed normal heart sounds and no murmurs. Auscultation of heart revealed normal heart sounds and no murmurs. Airway examination revealed bearded patient with a beard, Mallampatti grade 3, the normal range of neck extension and flexion. All routine hematological and biochemical investigations were within normal limits. Chest radiograph and ECG were unremarkable. An outside done echocardiography report revealed trivial tricuspid regurgitation with a perimembranous VSD of 2.7 mm with ejection fraction of 40-45% and right ventricular pressure of 18/7 mmHg.

MRI reported a large lobulated well defined cystic lesion measuring 6.1x4.2x4.1 cm in the intrazonal and extraconal compartments of the right orbit causing expansion of the bony orbit and displacing the medial and lateral rectus muscles. Inferiorly, the lesion was seen to cause the indentation and downward displacement on the roof of the right maxillary sinus. Enhancing oval soft tissue was seen medial to the above-mentioned lesion suggestive of calcification likely rudimentary ocular globe with the hypoplastic right optic nerve. Similar small lesions were seen in the anteroinferior aspect of the extraconal compartment of the left orbit. All the intracranial structures were normal.

After obtaining written informed consent, the patient was taken to the operating room. A 20 G intravenous cannula was secured on the right hand. All the standard anesthesia monitors were attached. Difficult bag-mask ventilation was anticipated due to the presence of beard so preoxygenation was done for three minutes using an rendell-baker-soucek (RBS) mask in order to ensure that no external pressure is exerted on the ocular swelling (Figure 1 and 2). Induction was done with Fentanyl 2 µg/kg, Propofol 2 mg/kg and Vecuronium 0.1 mg/kg. The airway was secured using a pro-seal laryngeal mask airway no 4 after ensuring adequate bilateral chest expansion and square wave end-tidal carbon dioxide. The device was secured in place and the patient was shifted to pressure control mode of ventilation. Anesthesia was maintained with oxygen, nitrous oxide (N_2O), and isoflurane. Intravenous paracetamol and diclofenac were given as a part of multimodal analgesia. The patient developed an episode of bradycardia HR=45/min at the time of dissection of medial rectus muscle following which the surgeon was informed and the traction on the medial rectus was released. Local anesthetic proparacaine drops (2 drops) were instilled in the surgical field and the surgeons were told to proceed after 15 seconds. On exposure of the lateral rectus muscled the procaine drops were again instilled in the surgical field. Henceforth, the patient remained stable with no hemodynamic disturbances. Towards the end of anesthesia, ondansetron 4 mg was administered. The patient was reversed with neostigmine and glycopyrrolate.

Figure 1. *Pressure on Swelling with Face Mask*

Figure 2. *Preoxygenation with RBS Mask without Pressure on Swelling*

DISCUSSION

An anophthalmic pediatric or an adult patient may be planned for any kind of elective or emergent surgical procedure. A detailed birth history, documentation of any significant perinatal events, family history of the similar disease can give an important clue regarding the aetiology. Toxoplasmosis, Other Agents, Rubella or German Measles, CMV: Cytomegalovirus, and TORCH: Herpes Simplex ggroup of infections and concomitant associations of TORCH need to be ruled out in pediatric age group. Many syndromes and malformations (e.g., anophthalmia-oesophageal-genital syndrome, Matthew-Wood syndrome, CHARGE syndrome, oculo-facial-cardio-dental-syndome, heterotaxy, and Fraser syndrome) have been associated with anophthalmia. A detailed clinical examination with special emphasis on the cardiac, central nervous system, and facial anatomy should be performed. A difficult airway may be anticipated in patients with facial asymmetry. Depending on the clinical findings, patients may require pre-operative echocardiography, magnetic resonance imaging of the brain and ultrasonography of the abdomen to rule out any cardiac, central nervous system or abdominal pathology, respectively. This may further help in modifying the anesthesia plan, choosing appropriate airway management device, induction, and maintenance agents while keeping in consideration the associated malformations and

organs involvement.

Our patient was planned for excision of the ocular mass. Pre-operative MRI ruled out an intracranial extension of the mass and associated cerebral lesions. A pre-operative ECHO suggested the presence of trivial tricuspid regurgitation with a VSD of 2.7 mm and ejection fraction (EF) 40-45%. Due to the presence of beard, we anticipated difficult bag-mask ventilation and a possibility that keeping a tight seal facemask can exert further pressure on the ocular mass, which may even lead to bleeding or pressure effects (raised intraocular pressure, which can lead to bradycardia). In order to avoid any external pressure on the ocular swelling an RBS mask (Figure 2) was used for pre-oxygenation.

VSD as in our case can occur as an isolated defect or as a component of a combination of anomalies. Only small or moderate-sized defects are seen as asymptomatic finding in adulthood, as most of the patients with large defects present early in life. The balance between systemic vascular resistance (SVR) and pulmonary vascular resistance (PVR) is of primary importance under anesthesia to reduce the shunt fraction and hence chances of reversal of shunt leading to further complications. VSD being a left-to-right shunt tends to increase with increase in SVR and decrease in PVR, thus leading to increased pulmonary blood flow, pulmonary hypertension, and consequently reversal of the shunt. Thus, in order to avoid these complications, SVR should be decreased by maintenance of good hypotensive anaesthesia as we did in this case. This was also the reason to prefer LMA ProSeal™ over the endotracheal tube for avoiding increase in Systemic pressures associated with laryngoscopy and intubation.

Due to the involvement of medial rectus and lateral rectus muscles as suggested by MRI we anticipated the occurrence of oculocardiac reflex intra-operatively which was managed successfully by vigilant monitoring and timely pro-paracaine instillation.[8] No prophylactic or intraoperative atropine was given for the fear of worsening of tricuspid regurgitation due to atropine induced tachycardia. Although our patient was clinically diagnosed as anophthalmic, imaging and surgical exploration showed the presence of a rudimentary eyeball and hence a final diagnosis of microphthalmia was made intra-operatively. At the end of the procedure, patient was reversed uneventfully.

The main concerns in the post-operative period for such cases are the risks of dysrhythmias and thromboembolic events and sometimes worsening of the shunt. Hence, the patients have to be nursed under constant observation with special attention given to alleviation of pain and maintaining hemodynamic stability. To achieve these goals, in the post-operative period, the patient was shifted to the high dependency unit (HDU) for two-days. On the third post-operative day the patient was discharged in stable condition as of pre-operative status, and was followed-up regularly as per schedule.

CONCLUSION

Congenital ophthalmopathy may be associated with multisystem disorders that may or may not be clinically evident. Detailed pre-operative workup of the patient helps to anticipate, understand and manage the intra-operative complications that may arise during the course of surgery. It is therefore important to know the clinical associations of the congenital disorders and their anesthetic implications even in seemingly uncomplicated cases. Anesthesiologists must tailor the type and mode of anaesthesia accordingly. The main concerns of hemodynamic stability and normocarbia should be addressed in all such cases with pre-existing cardiac findings along with vigilant post-operative observation.

CONSENT

The patient has provided written permission for publication of the case details.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Case Report

Hardware Causing Hard Times: Use of the SuperNO$_2$VA™ Nasal PAP Device to Address Airway Challenges Caused by Eroding Mandibular Hardware

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ABSTRACT

Background
Maintenance of the airway and adequate ventilation are essential for the anesthetized patient and may be compromised in patients with pan-facial trauma, abnormal dentition, abnormal mandibular space, or presence of dental hardware. We present an unusual case of a patient with a lack of natural mandibular structure and exposed mechanical hardware with fistula complicating intubation and ventilation prior to surgery.

Case Presentation
A 35-year-old male with a history of a self-inflicted gunshot to the left submandibular region approximately 6 years prior was scheduled for urgent mandibular hardware removal, closure of left facial fistula, and removal of several teeth. Pre-oxygenation and ventilation were complicated by extruding hardware and eroded skin, causing interference with a conventional facemask seal. The patient was pre-oxygenated using the SuperNO$_2$VA™ nasal mask with which an adequate seal was achieved without use of a nasal trumpet and with a modified grip. Tracheal intubation *via* oral video laryngoscopy was successful, and the case proceeded uneventfully.

Conclusion
Adequate ventilation and airway maintenance can be difficult to achieve in patients with abnormal facial structure or mandibular mechanical hardware using conventional methods. The SuperNO$_2$VA™ nasal mask can address airway issues for these patients peri-operatively.

Keywords
Anesthesiology; Airway management; Difficult airway; Airway devices; Difficult intubation; Ventilation; Oxygenation; Facial trauma; Mask ventilation.

INTRODUCTION

Maintenance of the airway and adequate ventilation prior to endotracheal intubation is essential for the anesthetized patient. However, this may be compromised in patients with obesity or obstructive sleep apnea (OSA) due to partial or complete pharyngeal obstruction.[1-3] In patients with facial trauma, craniomaxillofacial anomalies, or presence of external hardware, it may not be possible to achieve an adequate mask seal or perform bag-mask-ventilation with a conventional facemask.[4,5] For these patients and others with confirmed or suspected difficult airways, management alternatives including nasal ventilation may be more appropriate.[3,6,7]

The SuperNO$_2$VA™ (Vyaire Medical, Mettawa, IL, USA) device is a nasal mask developed to provide nasal positive pressure ventilation in spontaneously breathing and apneic patients during anesthesia and endotracheal intubation (Figure 1). In a pilot study designed to evaluate the clinical performance of the SuperNO$_2$VA™ in paralyzed patients under general anesthe-

sia, nasal mask ventilation was successfully implemented in 97% of patients with nasal oxygenation continued during laryngoscopy and orotracheal intubation, with no adverse events.[6]

Figure 1. *Graphic Image of the SuperNO2VA™ Device.*[8]

Much the same way nasal continuous positive airway pressure (CPAP) complements full facemask CPAP, nasal ventilation in apneic patients provides an alternative route to conventional techniques, improving the airway provider's armamentarium. Additionally, mask seal is simpler to achieve with a nasal mask, using a smaller surface area and simply applying pressure to the mask into the face, whereas downward pressure of a full facemask may displace the mandible and soft tissues posterior into the upper airway.

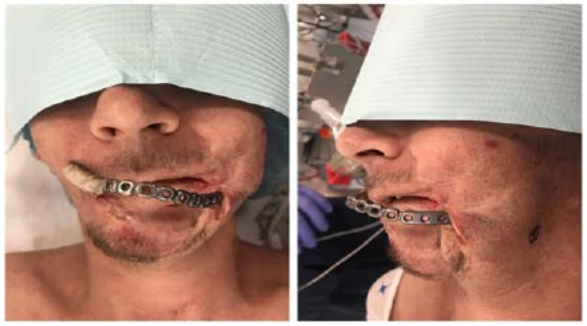
Herein, we report an unusual case of a male patient with extruding mandibular hardware and facial fistula who presented for urgent surgery. Whereas a conventional facemask was not possible due to obstruction from the hardware, we document the use of the SuperNO$_2$VA™ device to provide pre-oxygenation and nasal ventilation during the induction of general anesthesia and endotracheal intubation. Written informed consent was provided for publication and photographs of this case.

CASE PRESENTATION

A 35-year-old male, American Society of Anesthesiologists (ASA) physical status III and weighing 70 kg (normal body mass index (BMI)), was scheduled for urgent removal of mandibular hardware, closure of left facial fistula, and multiple tooth extractions. The patient's history was significant for poorly controlled seizure disorder, continued multiple substance abuse (alcohol and tobacco), recent pleural effusion of unknown etiology, and major depression. Notably, approximately six years prior to the current presentation, the patient sustained a self-inflicted gunshot wound to the left mandibular region. Treatment required a temporary tracheostomy and extensive facial reconstructive surgery, including the placement of mandibular hardware to replace lost structural tissue. After reconstruction, the patient was lost to follow-up. In the intervening years, numerous complications resulted from a combination of poor self-care and lack of medical care, including numerous infections, hardware erosion through the skin, several dental caries, and chronic pain. Consent for use of photography was obtained from the patient on the day of surgery.

The pre-operative exam revealed a thin, adult male, appropriately nulla per os (NPO) without recent nausea, vomiting, recent upper respiratory infections, or obstructive respiratory symptoms or respiratory distress. He was visibly anxious and uncomfortable. The exam was remarkable for a nearly complete lack of mandibular structure and a large amount of hardware eroded through the skin where his mandible once existed (Figure 2). Mallampati evaluation to predict ease of endotracheal intubation could not be completed due to the patient's oral pain.

Figure 2. *Mandibular Hardware Seen Protruding through an Eroded Defect in the Face. The Exit Point Creates an Obvious Difficulty for Creating a Mask Seal with a Traditional Facemask*



Anesthetic concerns focused on the potential for difficult intubation and ventilation, secondary to the lack of bony jaw structure and protruding hardware, which would interfere with mask seal and laryngoscopy. After consultation with the surgical team, both oral and nasal ventilation were deemed acceptable. All intubation possibilities, including awake fiberoptic intubation, were considered and thoroughly explained to the patient. The decision was made to pre-oxygenate with the SuperNO$_2$VA™ nasal mask, followed by gradual sedation and confirmation of successful mask ventilation prior to induction of general anesthesia and orotracheal intubation using a video-laryngoscope. Flexible endoscopic laryngoscopy was immediately available if video laryngoscopy failed. Emerging the patient and attempting awake fiberoptic intubation was planned if ventilation or laryngoscopy wa unsatisfactory or not possible.

The patient was given low-dose benzodiazepine, taken to the operating room and pre-oxygenated for five minutes using the SuperNO$_2$VA™ nasal mask. A titration of 50 mcg fentanyl, 100 mg lidocaine, and 120 mg propofol was given before the patient became apneic. To achieve adequate seal with the SuperNO$_2$VA™ and perform bag mask ventilation, the anesthesiologist placed his left-hand palm on the nasal mask and used digits 2-5 to provide head-tilt and deliver sub-mental pressure, driving the tongue against the hard palate to occlude the oral cavity (Figure 3). Bag-mask-ventilatory support was successful and complete ventilation take-over was achieved following administration of additional

propofol and fentanyl. Paralytic medications were not given. The case proceeded uneventfully, and the patient met extubation criteria at the end of surgery. The patient's trachea was successfully extubated and he maintained appropriate respiratory parameters in the Post Anesthesia Care Unit with supplemental oxygen. He recovered without events and was discharged to the general wards without complication.

Figure 3. *Sub-Mental Pressure Technique. Mask Seal is Created Using Downward Pressure Applied to the SuperNOVA Device. Using Two or More Digits, Firm Pressure is Applied to the Soft Tissue of the Sub-mental Space Driving the Tongue Cephalad Against the Hard Palate, Occluding the Oral Cavity from Within*

DISCUSSION

Maintenance of the airway and ensuring adequate ventilation are among the chief concerns in the surgical arena during the induction of anesthesia. Patients presenting for surgery under general anesthesia with endotracheal intubation endure a brief period of apnea upon induction and when the facemask providing ventilation is removed for access to the oral cavity for orotracheal intubation. Most patients tolerate this brief apneic period well and pre-oxygenation is often used to extend this period. However, it is not always possible to predict a difficult airway or other issues that may arise, placing patients at risk for desaturation. Patients who are obese, pregnant, suffer from chronic OSA, and/or pediatric cases may be at higher risk for this complication.[1-3] Similarly, for patients with craniomaxillofacial dysmorphology or trauma, anesthesiologists may be unable to achieve an adequate seal with a conventional facemask,[4,9,10] placing the patient at greater risk for desaturation due to inadequate ability to bag-mask-ventilate and intubate.

In the current case, a detailed pre-operative airway exam including the Mallampati assessment could not be performed, due to the patient's reported oral pain, preventing an accurate assessment of the risk for difficult intubation. Additionally, the exposed mandibular hardware precluded the use of a conventional facemask to provide adequate ventilation. Therefore, to meet the ventilation needs of the patient before and during intubation, nasal ventilation was performed. Alternatively, intubation *via* flexible endoscopy while awake or under sedation should be considered an option for these situations. Given the quantities of sedative medication necessary to overcome the patient's pain and discomfort, along with the experience and expertise the team has using nasal ventilation in apneic patients, flexible endoscopy was kept immediately available while a controlled induction with gradual nasal ventilation takeover was preferred.

Nasal ventilation has been observed to reduce airway obstruction compared to oral-nasal ventilation in patients undergoing general anesthesia.[11] More recently, Ghebremichael and colleagues evaluated the use of the SuperNO$_2$VA™ during anesthesia induction and throughout laryngoscopy. In all but one patient, anesthesiologists were able to use the SuperNO$_2$VA™ to provide adequate ventilation during induction and laryngoscopy.[6] The SuperNO$_2$VA™ provides non-invasive, continuous ventilation *via* the nasal route, *via* the buildup of positive pressure in the nasopharynx, anteriorly displacing the soft palate and tongue from posterior pharyngeal wall, reducing airway obstruction. Use of the SuperNO$_2$VA™ for pre-oxygenation and during induction may reduce the risk for oxygen desaturation in patients with obesity or OSA, as well as patients with other comorbidities that are associated with difficult intubation.[6]

CONCLUSION

A conventional facemask could not be used on this patient for pre-oxygenation, mask ventilation, or maintenance of oxygenation during the apneic period due to extruding mandibular hardware and facial fistula, which precluded the creation of an adequate seal. A nasal-interface device, the SuperNO$_2$VA™, was successfully used for preoxygenation and to provide ventilation during induction of general anesthesia without event. The SuperNO$_2$VA™ device may be an appropriate choice to protect against respiratory insufficiency in the peri-operative period for patients with pan-facial trauma, craniomaxillofacial anomalies, or presence of mandibular hardware when conventional facemask is not recommended.

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AUTHORS' CONTRIBUTIONS

M.M. and G.K. have contributed to the conception and design of the report, drafting and revision of this manuscript, and have given final approval for submission.

CONSENT

The authors have received written informed consent from the patient.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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RESEARCH AND PRACTICE IN ANESTHESIOLOGY

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Case Report

Pneumocephalus Caused by an Epidural Ozone Injection for Treatment of Disc Prolapse

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ABSTRACT

Pneumocephalus is a complication seen either after head trauma or post-neurosurgical procedure. It can be life-threatening if it turns into tension pneumocephalus. The presence of intracranial air indicates the presence of an open communication of cerebrospinal fluid. Air enters dura matter even without connection. Thin air flows upstream along the cerebrospinal fluid (CSF) pathway. Herein, we report a case of pneumocephalus in a 62-year-old female after epidural injection of Bupivacaine and Ozone for the treatment of a prolapsed disc. She was shifted to our hospital post-epidural injection for the management of severe headache. Though it is a rare complication, keeping this in mind will help to quickly diagnose, if need arises.

Keywords
Pneumocephalus; Head trauma; CT; Thunderclap headache.

INTRODUCTION

Pneumocephalus occurs in the background of head trauma or neurosurgery. Ozone injections along with Bipuvacaine are used for the treatment of prolapsed disc causing pain. The occurrence of pneumocephalus after epidural injection and also with ozone injections is rare. Understanding the pathophysiolgy and high degree of suspicion is the key to diagnose thunder clap headache after epidural injection. A case report is presented in this setting.

CASE REPORT

A 62-year-old female patient presented to our intensive care unit (ICU) with severe headache, nausea, vomitings 3-4 hours after she received an epidural injection of Bupivacaine 0.25%, Ozone 3 ml (30 mcg/ml) was injected at the L4-L5 disc space as a part of the treatment for pain relief. Localization of epidural space was done with a spring loaded epidural syringe.

The method involves direct approach was carried out by needle insertion followed by direct insufflation of the oxygen-ozone gas mixture (3-10 mL; ozone concentration about 30 µg/mL). She was suffering from low backache for past 10 years and was on multiple analgesics without significant pain relief.

She was admitted to our ICU after computed tomography (CT) head done at from emergency department. CT revealed multiple air foci in the frontal sulci, subdural space, supracellar and interpeduncular cisterns. She was reported to be haemodynamically stable, no neurological deficits were noted. The patient was fully awake; pupils were normal in size and reacting to light. She was put in supine position with a slight head down tilt and oxygen was given by facemask and later by nasal cannula. Her SpO2 was 95-96% on room air. She was administered intravenous analgesics and fluids. After few hours the intensity of headache was found to be reduced. CT head was repeated next day which showed complete resoption of patchy pneumocephalus in frontal extraaxial space and anterior basal cistern (Figures 1 and 2). The patient was shifted to room for observation and discharged without any sequele.

Figure 1. *CT Image 1 Showing Air in the Cranium before Treatment*

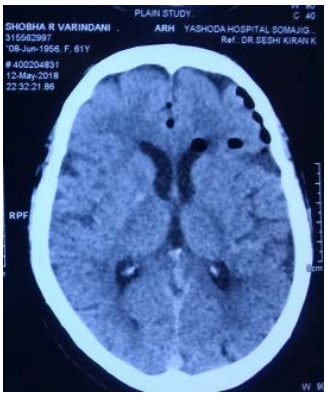
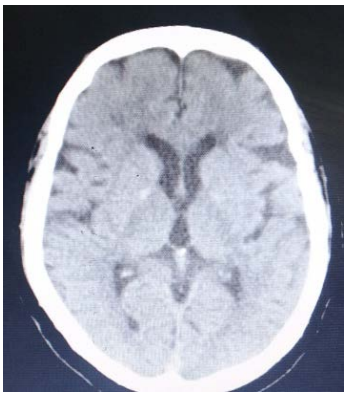


Figure 2. *CT Image 2 Air Absorbed After Treatment*



DISCUSSION

Pneumocephalus complicates 3.9-9.7% of head trauma cases.[1-5] It can also occur in the post-operative neurosurgical cases especially the supratentorial surgeries. It was previously seen in posterior fossa surgery in sitting position.[6,7] Air enters cerebrospinal fluid (CSF) from dural site, with or without direct brain injury.[8,9] It can be serious if it turns into tension pneumocephalus. Rarely it can lead to meningitis in rare cases.[10-12]

Epidural injection used in anaesthesia practice with loss of resistance technique accidentally injected air into the cranium has happened with failed epidurals.[13-16] It is described as presence of air within the cranial cavity suggesting an association between the central nervous system and the outer environment which is identified by brain imaging.[17]

The differential diagnosis of patients with thunderclap headache should encompass subarachnoid hemorrhage, colloid cyst of third ventricle and intracranial hypotension.

Medical ozone therapy is one of the options for treatment of herniated disc. It exerts analgesia and anti inflammatory effects.[18] Ozone therapy is given from a specialized machine along with oxygen at a fixed prepared concentration. It is administered with a polypropelene syringe and given for discolysis which is medical management for disc prolapse. Meta-analysis of many studies on ozone therapy indicated that this treatment is used mostly for patients with herniated discs or failed back syndrome even after surgical intervention. A success rate of 75-80% has been observed. Rare complications are vitreo-retinal hemorrhage, paresthesia associated with spinal nerve damage.[19] Pneumocephalus has been reported in two cases.

Ozone and ozonated growth factors use in the treatment of disc prolapse has been carried out in 60 patients. 150 percutaneos dyscolysis were performed. Two patients reported pneumocephalus.[20,21]

CONCLUSION

Thunder clap headache occurs in some cases of neurological abnormalities. Development of pneumocephalus is one of them. The cause of this can be determined by understanding the etiology and including rare causes followed by imaging. Rare events of pneumocephalus after epidural injection are presented. A high degree of suspicion is must in all these rare etiologies.

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CONSENT

The patient has provided written permission for publication of the case details.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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RESEARCH AND PRACTICE IN ANESTHESIOLOGY

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Case Report

Transcatheter Arterial Embolization in Postpartum Hemorrhage: A Case Report

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ABSTRACT

Background
Postpartum haemorrhage is the leading cause of maternal mortality and morbidity. The significant impact of postpartum haemorrhage (PPH) on maternal mortality can be reduced if timely measures are implemented. Transcatheter arterial embolisation (TAE) is an alternative therapeutic strategy for PPH.

Case report
We report a case of postpartum haemorrhage which was managed by transcatheter arterial embolization in lieu of hysterectomy to preserve fertility and menstruation in a 27-year-old patient.

Conclusion
The critical role of obstetrician, anaesthesiologist and interventional radiologist as a team, improve the quality of care and patient safety.

Keywords
Postpartum hemorrhage (PPH); Peripartum hysterectomy; Transarterial embolisation.

INTRODUCTION

Postpartum haemorrage (PPH) is often unpredictable, catastrophic and remains a challenge for anaesthesiologist and obstetricians. Peripartum hysterectomy is usually reserved for refractory cases of PPH, when all other methods to arrest bleeding fails which results in inability to preserve fertility, a psychological impact in young females and risk of intraoperative surgical morbidities. Advances in interventional radiology andsurgical techniques are being utilized as an alternatives to hysterectomy in many cases.[1] TAE should be widely available and in patients who are at risk of developing PPH and in actively bleeding parturients, indeed in some cases it should be considered as a primary treatment. At hospital level, the multi-professional, interdisciplinary approach have shown to improve quality of care and patient safety.[2] This case report highlights PPH secondary to perineal trauma during vaginal delivery which was successfully managed by transcatheter arterial embolization in interventional radiologysuite.

CASE REPORT

A 27-years-old, second gravida (G2A1) was admitted in our hospital in labor at 37-weeks gestation. Her past medical and obstetric history was remarkable for hypothyroidism and spontaneous abortion 2-years back. Syntocinon infusion was commenced to augment labor along with rupture of membranes prematurely. Six hours later, after right mediolateral episiotomy, a live 2.9 kg male baby was delivered vaginally. The placenta and its membrane were delivered intact without any difficulty. Episiotomy was sutured, haemostasis was achieved and she was transferred to maternity ward. Patient had initially stable haemodynamics while in ward, but two hours later she had an acute episode of giddiness,

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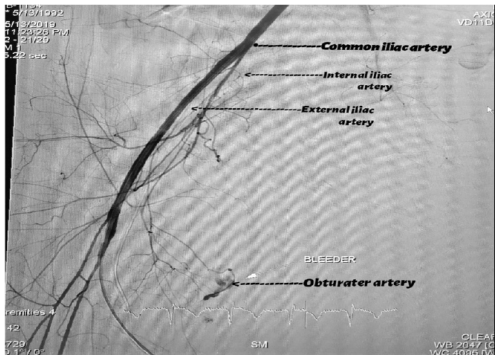
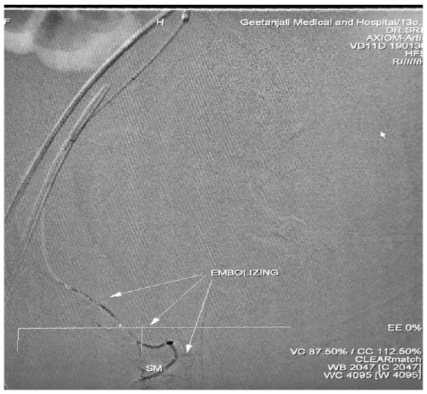
became tachypnoic, pale and drowsy. Her blood pressure dropped to 90/50 mm Hg, heart rate increased to 120 bpm, respiratory rate 26 per mins and observed oxygen saturation was 93% on room air. Initial resuscitation with one litre of crystalloid and oxygen by face mask at 5 L/min was done. Vaginal examination by the obstetric team revealed a large lateral wall haematoma while, per abdomen examination revealed a palpable, relaxed uterus above the umbilicus. Immediately, IV ergometrine 0.2 mg, IM carboprost 250 mcg, rectal misoprost 500 mg and IV tranexanemic acid 1 gm was supplemented. Based on her clinical symptoms and consideration of haemorragic shock, she was shifted to the operating room (OR) for further monitoring, resuscitation and possible surgical intervention. In the OR, general anesthesia was induced, trachea intubated and maintained on intermittent fentanyl, atracurium, oxygen and Sevoflurane. Two units of blood was transfused as 100 ml of clot was evacuated and haemostasis was acheived. She was kept on conservative treatment and transferred to the surgical intensive care unit (SICU) on mechanical ventilation. On reexamination by the obstetric team after an hour, multiple clots in the cervix and vagina with active trickle of blood was observed. She was hemodynamically unstable and her systemic vascular resistance was supported by IV Norepinephrine infusion. Bed side ultrasonography revealed mild free fluid in the peritoneal cavity and bulky contracted uterus. Haematologic investigation showed haemogram of 7 gm/dL, platelet count 68×10^{9} litre^{-1}, aPTT 40.5, PT 14.5, INR 1.15. Arterial blood gas analysis was within normal range. On bed side 2D echocardiogram, ejection fraction was 45-50%. A femoral venous access under ultrasonographic guidance was placed and massive transfusion protocol was activated with 4U packed red cells and 4 FFP's. The interventional radiology team was contacted and decision for transcatheter arterial embolisation was taken in an attempt to stop bleeding while preparing for further laparotomy and hysterectomy.

Figure 1. *Showing Bleeding from Obturator Artery*



Subsequently the patient was transferred to interventional radiology suite under continuous midazolam sedation and mechanical ventilation. Following right femoral artery approach, internal iliac artery was catheterized using 5F, 0.17 microcatheter. Digital subtraction angiography (Artis zee - Siemens) showed active extravasation from right obturator artery andsite of bleeding was identified (Figure 1), embolization of obturator artery using super selective gel foam was performed successfully (Figure 2). Post embolization angiogram was satisfactory and showed no further bleeding. No immediate complications occurred and she was transferred back to SICU. She remained haemodynamically stable there after, maintaining blood pressure without vasopressors. She was extubated on 2nd day and discharged on day 3 after an uneventful recovery.

Figure 2. *Showing Transarterial Embolisation*



DISCUSSION

Postpartum haemorrhage is a life threatening complication and still remains a major cause of maternal death in developed and developing countries. According to statistics of World Health Organization (WHO) , 25% of maternal death are due to PPH. Incidence of PPH reported after vaginal delivery is 2% - 4% while it is 6% after caesarean section; with uterine atony has been found as the cause in about 50% cases.[3]

Obstetric intervention for uterine atony, examination of retained or adherent placenta, trauma to genital urinary tract, restoration of haemodynamics, correction of coagulopathy and timely management by surgical or radiological intervention are included in Standard of care of PPH.[4]

PPH secondary to trauma may follow after vaginal delivery, mediolateral episiotomy, more than 4 kgs neonate delivered vaginally.[5] Lacerations and haematomas of perineum, vagina and cervix during vaginal delivery accounts for 8-20% of PPH alone or in association with uterine atony and are sometimes associated with significant haemorrahage, subsequently leading to hypovolemia.[6,7] Management includes surgical exploration, evacuation, and ligation of vessels to avoid severe complications like pelvic infection, septicaemia, pressure necrosis, profuse bleeding and death.[8,9]

Regardless of the cause of PPH, when medical and surgical options such as curettage, B-Lynch, uterine or internal iliac artery ligation fails, timely decision for hysterectomy is often the definitive treatment to control bleeding. Technical difficulties during anaesthetic management of PPH, massive blood transfusion, coagulopathy and injury of the urinary tract are some of the known complications of peripartum emergency hysterectomy.[10]

The anaesthesiologist play an important role in

management of PPH and should confirm anaesthetic plan with team until resolution of PPH. Although anaesthetic management includes neuraxial block in haemodynamic stable patients, initial plan for general anaesthesia is usually planned for severe cases of PPH.

Interventional radiology and surgical techniques have proved secured and potent alternatives to hysterectomy in many cases and an interventional radiologist should be involved at the time when abnormal bleeding is observed or expected, regardless of severity of PPH and haemodynamic status of the patients,[11] transcatheter arterial embolization (TAE) is widely accepted as an productive therapeutic procedure for PPH of various causes with several advantages such as being a fast and a repeatable procedure that can be performed under local anaesthesia and or monitored anaesthesia care. In our case the patient was already on mechanical ventilation support and haemodynamically unstable so it was carried under continuous sedation. It also preserves the uterus and makes future menstruation and fertility possible. The most frequently bleeding source in PPH is collaterals to uterus, uterine, vaginal and internal pudental arteries which manifest as a pseudoaneurysm or contrast extravasation in angiography of the pelvic floor vasculature. The advantages of TAE are pointing out bleeding site easily, reduced re-bleeding from collaterals as more distal occlusion of bleeding vessels are carried out. Therefore, knowledge regarding normal and deviated anatomy of the female genital tract is essential for accurate interpretation of angiographic images and safe performance of PPH embolisation to minimize complication rate during the procedure, TAE obviates the need for laparotomy and should be considered as first line hemostatic measure for patients. However, if ligation would be carried out first, embolisation after ligation is almost difficult and sometimes impossible and in such cases, the only remaining option is hysterectomy.[12] Some studies have reported a role of intraoperative uterine artery embolization in prevention of massive PPH in cases of caesarean hysterectomy.[13,14]

TAE for control of obstetric hemorrhage was first carried out successfully by Brown in 1979.[15] A high success rate of 94.9% with low complication rate was found by Badaway et al who reviewed 138 cases of PPH and need for hysterectomy due to failure of embolization was only in 5% of cases,[16] while Pelage et al, used gelatin sponge in all fourteen continuous cases of uncontrolled hemorrhage, and in two cases of false aneurysm they used N-butyl-acrylate.[17]

Although there is high success rate and low complication rate of arterial embolization making it a beneficial alternative in managing PPH, there are potential complications angiography comprise low grade fever, hematoma at the site of catheter placement, infection like pelvic abscess; contrast related side effects, ischemic phenomena, and rarely iliac artery perforation.[16,18]

The potential limitations include the management of performing the procedure during labour and delivery when equipment and interventional radiologists may not be available at all centers.

CONCLUSION

A multidisciplinary collaboration between anaesthesiologist-obstetrician and interventional radiologist can avert maternal morbidity and mortality secondary to PPH, through early diagnosis and rapid intervention. TAE should be implemented without any delay as effective and safe therapeutic modality for PPH to preserve fertility by avoiding hysterectomy.

CONSENT

The patient has provided written permission for publication of the case details.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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RESEARCH AND PRACTICE IN ANESTHESIOLOGY

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Observational Study

An Observational Study to Evaluate Infection Risk in Two Staff Warming Devices and a Review of Current Literature into Thermal Comfort in the Operating Room and Beyond

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ABSTRACT

Objective
To compare the degree of bacteria dissemination using two currently available operating room (OR) personnel warming devices. The "off-label" use of 3M™'s Bair Hugger™ *vs.* a fairly new device, worn around the torso and under a scrub warm-up jacket or surgical gown, the OPERATIONHEATJAC® transformer only (TRO) powered by a transformer and controlled by a 4-level controller, and best for anesthesia providers and perfusionists.

Methods
Initially, staff members in scrubs sat in a room for 3 and 6-hours with agar plates placed in various positions throughout the room. Then staff members sat in the same room under the same conditions for 3 and 6-hours, and placed the hose from 3M's Bair Hugger under their scrubs. Agar plates were positioned in the room in the same positions as in the control. Then staff members sat in the same room under the same conditions for 3 and 6-hours, wearing the OPERATIONHEATJAC® TRO over their scrub shirt and under a scrub warm-up jacket. Agar plates were again positioned in the room in the same positions as in the control. Bacteria colony counts were compared.

Results
The bacteria colony counts were 43.78% and 46.18% higher at 3 and 6-hours respectively from placement of the hose from 3M™'s Bair Hugger™ under scrubs *vs.* the control. There was no significant difference in bacteria colony counts with using the OPERATIONHEATJAC® TRO *vs.* the control.

Conclusion
ORs are maintained cold, mostly for surgeon comfort. In an attempt to keep comfortable in this environment, peripheral OR staff opt for the "off-label" use of 3M's Bair Hugger hose placed under scrubs. An increased spread of bacteria throughout the OR can result from this practice. Currently, there are now safer OR personnel warming devices available. In addition, this paper reviews the significance and benefits of keeping staff warm and comfortable.

Keywords
Warming devices; OPERATIONHEATJAC®; surgical site infections (SSIs); Operating room (OR); Temperature.

INTRODUCTION

Patient health and the reduction of risk of surgical site infections (SSIs) are of paramount importance in the operating room (OR) and a low temperature in the OR limits SSI rates dramatically, slowing the growth of bacteria and other microorganisms. Technical standards on heating, ventilation, and air conditioning have been established to control OR air quality and thereby reduce risk to patients. Numerous organizations have contributed guidance to these standards, including the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the American Society for Healthcare Engineering (ASHE), the

Association for the Advancement of Medical Instrumentation, the Association for Professionals in Infection Control and Epidemiology, and the Association of peri-Operative Registered Nurses (AORN).[1] In 2019, the Joint Commission noted that 68-75 °F (20-24 °C) is appropriate for the OR depending on the OR class.[2] To ensure observance, the Joint Commission monitors institutions with regular unannounced surveys of their ORs.[3] Though this temperature guidelines is higher than the ANSI/ASHRAE/ASHE Standard 170-2017 design guidance that ORs should be kept at between 66-68 °F (19-20 °C) and 30-60% humidity.[4]

And while taking every precaution to ensure that SSI risk is as low as possible in the OR and that the scrubbed-in surgical staff are comfortable, it has been observed that the low temperature has a negative effect on the performance, comfort, and well-being of surgical staff working peripherally, including peri-operative nurses, anesthesia providers, and perfusionists.[5,6] To address this issue, several devices have been invented or repurposed to serve the thermal comfort needs of the OR staff. Two such popular devices are the off-label use of the 3M™ Bair Hugger™ Patient Normothermia System and OPERATIONHEATJAC® products. The Bair Hugger™ is intended to be used to keep a patient's core body temperature within the normothermic temperature zone while they are on the operating table.[7] However, it is often used by surgical staff for personal warmth wherein the hose attached to the Bair Hugger™ is diverted from the disposable Bair Hugger™ blankets and into the personal garments or blankets of the OR staff. This method is not AORN compliant as it introduces contaminated air flow into the OR.

OPERATIONHEATJAC® products are heated garments worn over scrubs, but under the outer surgical layers, such as a scrub warm-up jacket or surgical gown.[8] Garments are launderable and include belts that wrap around the midsection and vests. A number of options are available for powering the garments, including rechargeable batteries, plug-in transformers, and air activated warmers. They are AORN compliant and meant to be worn unexposed.

While these devices have the potential to successfully warm and increase the comfort of surgical staff, the principal goal in the OR of protecting patient health requires that any devices that are used be examined critically to be certain that no additional risk to the patient is being added by its use.

In this study, we compared off-label use of the Bair Hugger™ with that of the OPERATIONHEATJAC® transformer only (TRO) in a simulated OR using blood agar and counting the bacterial contamination that resulted over time. We then compared the existing literature to determine the importance of comfortable staff and the ramifications this has on hospitals and patients.

Statement of Purpose

The aim of this study was to evaluate the direct association between bacteria growth in a control compared with two commonly used warming devices: the off-label use of the forced-air patient warming device, the Bair Hugger™, and the OPERATIONHEATJAC® TRO. We will also analyze the importance and feasibility of staff comfort in the OR based on research previously conducted.

Research Questions

A number of questions motivated us to begin this research. First, does the off-label use of the Bair Hugger™ device result in higher levels of bacteria growth compared with scrubs alone? We also seek to determine whether the use of the OPERATIONHEATJAC® TRO warming device results in higher levels of bacteria growth compared with scrubs alone? Secondly, does the amount of time a device is in use contribute to higher bacteria growth when these devices are in use? Finally, how does the existing literature shape or alter the value of these data?

Statement of Significance to Nursing

While the comfort of the OR staff is important, it is critical that no additional risk is added to the OR by comfort devices. A detailed analysis of the potential contamination caused by the use of the off-label use of the Bair Hugger™ and OPERATIONHEATJAC® TRO is necessary before they should be used in a live OR.

METHODS

The objective of this study was to observe whether the off-label use of the Bair Hugger™ or the appropriate use of the OPERATIONHEATJAC® TRO can increase and cause the spread of bacteria in the OR.

To test this theory in a non-biased manner, the author enlisted a Contract Research Organization that specializes in recreating studies that require a mock, but realistic OR environment. The experiment and preliminary results were blinded until they had been analyzed. As this study was investigational and the potential for harm to patients is unacceptable, it was conducted in a mock OR without the presence of a patient. As such, it did not require Institutional Review Board (IRB) approval.

Study Design

The mock OR was set to 68 °F (20 °C). Air did not circulate in the area during or 24-hours prior to the experiment. Humidity was set to 30%. Testing periods were established at three and six hours for the three comparators with three active participants for a total six rounds of the experiment. In the first three rounds of the experiment, participants remained in the OR for three hours. For the three-hour control phase, 30 agar plates were placed around the OR at or about one meter above the ground and one meter from the wall in various positions around the test area. No staff warming devices were used during this phase.

The off-label use of the 3M™ Bair Hugger™ Normothermia System was tested next.[9] In this portion of the experiment, the participants would place the Bair Hugger™ in

various positions in their scrubs, including the top and bottom. They were permitted to move the hose attachment as they preferred to simulate real life use. Thirty blood agar plates were placed around the room as noted in the control tests.

Finally, the OPERATIONHEATJAC® TRO electric heated garment was tested in the same manner as the control and comparator group.[10] Participants wore the garment as noted in the instructions for each duration.

Each round of the experiment was repeated once more for a period of six hours. In all rounds of this experiment, the participants functioned regularly, conducting basic surgical staff duties, including preparing equipment, making notes, and other small functional and cognitive tasks. Participants wore scrubs and scrub jackets during all rounds of the experiment. Between phases of the experiment, the area was sanitized.

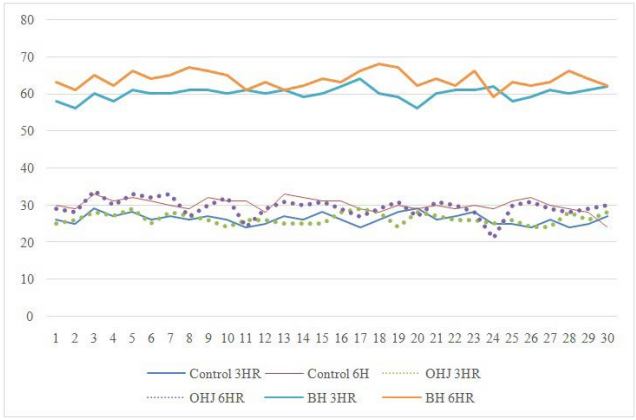
At the end of each phase of the experiment, the agar plates were removed, labeled with a sample number, and dated. These plates were incubated at 98.6 °Ft (37 °C) for 24-hours. Once incubation was complete, each was observed for growth and number of colonies per plate were counted. The colony forming unit (cfu) count/plate is expressed as cfu/m^3 by the Omeliansky formula.

Cfu data were analyzed using a two-sided *t*-test using statistical analysis software (SAS) 9.4. A probability of $p<0.05$ considered significant.

RESULTS

Agar plates were consistent with their respective groups in both the three and the six-hour experiments (Figure 1). No outliers were noted.

Figure 1. *Findings for All Plate Readings*



BH: 3M™ Bair Hugger™; OHJ: OperationHeatJac®

Three-Hour Experiments

The control plates had a mean cfu/m^3 of 26.233 (standard deviation [SD]: 1.431 cfu/m^3), which was very similar to the plates in the OPERATIONHEATJAC® TRO tests (mean: 26.300 cfu/m^3; SD: 1.535 cfu/m^3). As such, there was no significant increase in the cfu rate in the air for the OPERATIONHEATJAC® TRO plates compared with the control plates (95% confidence interval [CI]: -0.700 to 0.833 cfu/m^3; $p=0.862$).

The mean cfu for off-label use Bair Hugger™ plates was notably higher than the control group at 60.07 cfu/m^3 (SD: 1.701 cfu/m^3) and a statistically significant increase in the cfu rate in the air was noted (95% CI: 33.021 to 34.646 cfu/m^3; $p<0.001$).

Compared with the OPERATIONHEATJAC® TRO, the off-label use of the Bair Hugger™ produced a 43.78% higher cfu rate in the three-hour phase of the experiment (Table 1).

Table 1. *Three Hour Experiments t-Test Results*

Test	Mean	SD	Compared with Control	
			95% CI	*p*-Value
OHJ	26.300	1.535	-0.700-0.833	0.86245
BH	60.067	1.701	33.021-34.646	<0.0001
CONTROL	26.233	1.431	-	-

BH: 3M™ Bair Hugger™; CI: Confidence Interval;
OHJ: OperationHeatJac®; SD: standard deviation

Six-Hour Experiments

As with the three-hour experiments, the six-hour experiments showed that the off-label use of the Bair Hugger™ produced a greater rate of cfu on average (46.18%) (Table 2).

Table 2. *Six Hour Experiments t-Test Results*

Test	Mean	SD	Compared with Control	
			95% CI	*p*-Value
OHJ	29.433	2.622	-1.799-0.533	0.28145
BH	63.733	2.164	32.634-34.700	<0.0001
CONTROL	30.067	1.818	-	-

BH: 3M™ Bair Hugger™; CI: Confidence Interval;
OHJ: OperationHeatJac®; SD: standard deviation

In this situation, the use of the OPERATIONHEATJAC® TRO actually resulted in a lesser cfu rate compared with the control (29.43 [SD:2.622] cfu/m^3 *vs* 30.67 [1.818] cfu/m^3), however, the difference was not statistically significant (95% CI: -1.799 to 0.533 cfu/m^3; $p=0.2501$).

The off-label use of the Bair Hugger™ produced a cfu rate in the air slightly higher than in the three-hour experiments (63.733 cfu/m^3 *vs* 60.07 [SD: 2.164] cfu/m^3). A statistically significant increase in the cfu rate in the air was also noted in this timeframe compared with control (95% CI: 32.63 to 34.70 cfu/m^3; $p< 0.001$).

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DISCUSSION

This experiment shows that the incorrect use of a device has the potential to cause serious harm to patients. Hospitals are constantly fighting infection rates to help protect patients. Numerous examples in the literature have analyzed SSIs for the toll they take on patients[11-13] and for their financial impact on the healthcare system.[14-16]

According to the Centers for Disease Control and Prevention (CDC) guidelines for the prevention of surgical site infection, SSIs occur in 2-4% of all patients undergoing inpatient surgical procedures and are a prominent cause of morbidity and mortality after surgery.[11] In a study which reviewed nearly half a million operations to follow 30-day readmission rates following surgery at a single hospital, readmissions due to SSI accounted for the largest proportion of overall admission.[17] Most alarmingly, 3.0% of patients who contract an SSI die as a consequence.

A 2019 retrospective index analysis of hospital costs from inpatients harms estimated that SSIs cost an average of $32,000 per incidence.[18] When the Centers for Medicare and Medicaid Services (CMS) stopped paying for care related to preventable hospital-acquired conditions in 2008, these costs transferred from insurers to the hospitals, adding an average of $21 million dollars in costs over a three-year period to a single center.

Considering these two large pressures hospitals face, it is hugely important that risk in the OR be minimalized as much as possible. As our data have shown, the incorrect use of a medical device for self-warmth leads to the production of more bacteria and can increase SSIs and endanger both the well-being of patients and hospital financial stability. However, hospitals should not just ignore these data and disallow all staff warmth equipment in the OR. Instead, hospitals must look closely at the current literature to realize that eliminating all staff warming devices outside of scrub jackets is far from the most appropriate option to protect patients and minimize risk. In fact, providing options for warmth that do not increase risk may save time and money for hospitals.

An assessment of the environmental comfort in an OR from the American Industrial Hygiene Association noted the complexity of both sides of surgery: the patient and the surgical team, who have very different needs.[6] The pilot study worked in an orthopaedics OR measuring several physiological parameters and the comfort of each staff member. Of the eight-person staff, the two surgeons were generally rated as "hot" or "very hot." The surgical assistants were mostly "hot" and "slightly hot." And finally, the nurses were "comfortable" 75% of the time and "cold" 20% of the time. This study is one of few that demonstrate how diverse the needs of the staff are and follows with the assumption that staff members who play a more physically rigorous roles in the OR are warmer, while those will less physically demanding roles tend to be cooler. A limitation of this study that keeps the information from being wholly authentic to the entire surgical staff is the lack of an anesthesia provider.

A similarly designed study from Canada studied the thermal environment in two ORs, evaluating the thermal comfort of the staff based on environmental measures during surgeries and with questionnaires.[19] As with the above trial, it was noted that surgeons tended to feel from "slightly warm" to "hot"—sweating often throughout surgery—and anesthesia providers and nurses tended to feel from "slightly cool" to "cold." Using Fanger's predicted mean vote (PMV) model, which assumes a uniform thermal environment, the air temperature in the OR was thermally comfortable to the surgeons at 66 °F (19 °C), while at that temperature, nurses and anesthesia providers would have to be clothed with at least 0.9 clothing (clo) to be comfortable, which is roughly six additional pounds of clothing.

Finally, the first study to report on the thermal comfort of the surgical staff reported nearly identical results, suggesting an increase in clothing for non-sterile staff to help with thermal discomfort.[5] However, the age of this study and the developments that the OR has since seen have progressed far enough that its detailed inclusion does not add value to the literature review.

While a considerable amount of research has been done analyzing the effect of OR temperature on patients and there are a few meaningful studies on the benefits of thermal comfort for OR staff, numerous, high-quality studies outside of the OR have detailed the difficulties workers have in uncomfortably cold environments. These do well to flesh out the importance of a comfortable work environment.

A 2019 study aimed to investigate the effect of air temperature on the executive functions of the human brain and body physiology responses.[20] The study found that unfavorable air temperatures may have a considerable effect on physiological responses and the cognitive functions among those working indoors. The moderate (70 °F [21 °C]) and low (66 °F [19 °C]) air temperatures had a very profound effect on changes in heartbeat rate, the accuracy of brain executive functions, and the response time to stimuli. Accuracy by different workload levels and various air temperature conditions were statistically significant ($p<0.05$). The ratio between low frequency and high frequency and the respiratory rate were more profoundly affected in the lower air temperatures than the moderate air temperatures ($p<0.05$).

A 2019 PLoSOne observational trial evaluated 543 individuals and found that the effects of temperature varied significantly for women.[21] In temperatures of less than 68 °F (20 °C), women were more likely to score lower at math than men, while at higher temperatures, women outperformed their male counterparts. This raises an interesting question for the issue of comfort in the OR.

Two meta-analyses evaluating the effect of temperature exposure on performance found that, among the combined >50 trials included between the two, psychomotor and perceptual task performance were most degraded in cold temperatures.[22,23] The older of the two found that cold temperatures of 50 °F (10 °C)

or less resulted in the greater detriment in performance compared with neutral temperatures by 13.91%. They also went on to analyze the effect of duration of exposure, finding that the longer an individual is exposed to the cold prior to the task onset, a greater differential effect on performance existed.

There is a significant amount of work done analyzing the effect of cold on staff outside of the OR but newer, more credible materials is needed for inside the OR; it is necessary that certain explorations be made to understand a situation in which substantial amounts of research have not been conducted. Given the existence of the paradox that a cold OR is necessary for surgeon comfort and resulting patient safety, but that very cold itself impedes surgical and anesthesia personnel and increases risk to the patient is a problem that requires more attention from researcher and hospital administrators alike.

LIMITATIONS

This study is limited in two main ways: the experiment was performed in a mock OR environment. While this was the responsible decision given that we theorized the off-label use of the Bair Hugger™ would increase colony forming unit (cfu) rates and potentially put patients at an increased risk for SSIs, it was not a live experiment. In the future, this experiment should be repeated without the off-label use of the Bair Hugger™ in active surgeries in a larger format with more comparators. Finally, there is a lack of quantitative research from the literature review portion of this article, as such there were numerous avenues of interest, particularly with the staff satisfaction surveys, that could not be explored. The solution is to encourage investigators to produce more research on the effect of temperature on the staff in the OR in a manner than will not increase risk to patients, such as surveys, physiological exams, and biosensors.[24]

RECOMMENDATIONS

Recommendations for Clinical Practice

The author recommends that clinicians explore medical devices that will increase clinician comfort and satisfaction in the OR. These devices must be AORN compliant and must not increase the risk of SSIs to the patient.

Recommendations for Education

This article serves as an excellent example for OR staff and hospital administrators to understand that there may be an unforeseen risk in the devices they use and that careful thought must always go into selecting any personal garments for the OR. It is also important that clinicians know that there are devices on the market that can make them more comfortable without increasing risk to the patients.

Recommendations for Future Research

Additional research into the level of morale in the OR with quantitative data is necessary to better understand the environmental issues in the OR from the perspective of the staff. We must also work to develop and adopt solutions that can increase staff comfort in the OR and potentially improve patient outcomes.

CONCLUSION

While of number of devices exist to warm and increase the comfort of the OR, it is important to always be as certain as possible that the comfort of the staff does not increase risk to the patient. The off-label use of the forced-air warming device, the Bair Hugger™, significantly increased the average cfu rates in the air compared with the control at three and six hours. With the OPERATIONHEATJAC® TRO, there was no statistically significant increase in the average cfu rate in the air compared with the control at three or six hours. Staff warming devices must be chosen carefully to comply with safety standards. With many different staff members all serving crucial positions in the OR, it is possible for all members to be comfortable—but never at the expense of the patient's safety.

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CONFLICTS OF INTEREST

The research in this paper was conducted by an independent "paid for" CRO, Wilson Carrol Research Services, LLC, after the author conducted his own "home grown" research which demonstrated a bacteria colony count of 53 *vs.* 21 in the control, for a 121% increase in bacteria colony count from placing the hose of 3M™'s Bair Hugger™ under his scrubs. The author was prepared for closing up shop if the findings were not significant. In an effort to improve medical care worldwide, the author believes this study is very significant. As the owner of the company HEATJAC™, LLC, the author has a vested interest in providing an alternative for OR staff to maintain comfort. If worldwide there is a reduction in SSIs and the associated misery, the author has achieved his goal. The author hereby declares there are no conflicts of interest whatsoever.

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