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Clinical Communiqué

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CONTENTS

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Next Edition: June 2018

EDITORIAL

Welcome to the first edition of the Clinical Communiqué for 2018. Before we look ahead for the year, it is worth recalling the June 2017 Clinical Communique. In that edition, we focussed on the complex issues surrounding the treatment of pain, and the risks associated with prescribing and combining sedative medications.

Shortly afterwards, in October 2017, the Victorian Government passed the Drugs, Poisons and Controlled Substances Amendment (Real-time Prescription Monitoring) Bill 2017, which establishes a real-time prescription monitoring system, to be known as SafeScript. Victoria is the first jurisdiction in Australia to enact a state-wide mandatory prescription monitoring system, and it is hoped that this will lead to safer prescribing practices and similar legislation in other states.

We are starting this year by focussing on a specific condition that occurs inadvertently and leads to potentially fatal consequences without warning. Sometimes you can perform a simple task a thousand times without a problem. Then just once, a rare and devastating event occurs that makes everyone involved question their practise of that previously viewed “simple” task. Gas embolism is one of those events – hard to diagnose, time critical, and difficult to treat. It does not discriminate between the old and the young, or the sick and the healthy. This edition of the Clinical Communiqué collates four very different cases of gas embolism with the common findings of rapid devastating deterioration and ultimately unsuccessful attempts at recovery.

Prevention is the best option, as early recognition of gas embolism sometimes is not early enough. Gas embolism may be a relatively rare clinical entity, but it is a diagnosis that must remain at the forefront of our minds when planning and performing any invasive procedures. Even minimally invasive procedures such as infusing intravenous fluids.

Another distinctive feature of gas embolism is that it is not always iatrogenic in nature. Gas embolism is a well-known complication of scuba (self-contained underwater breathing apparatus) diving. With an increasing number of people undertaking diving activities for recreation and occupation, and the rise of adventure holiday dive packages, complications such as gas embolism need to be well understood and prepared for. If gas embolism following a dive is suspected in the community or emergency department setting, then it is important to know who to call, and to call early to access first aid advice, and if necessary facilitate transfer to the nearest decompression chamber.

The expert commentary has been written by Dr Geoff Frawley, a Melbourne-based anaesthetist with extensive experience in hyperbaric medicine. He provides a highly instructive overview of the causes, diagnosis and management of gas embolism.

Finally, in response to feedback from our readers we have reviewed the functionality of our email notification process. We have eliminated a number of steps so that readers should now be able to click directly onto the edition from their email. Please continue to provide feedback to us, as we hope to keep producing a usable, accessible, and valuable resource for our readers.

CASE #1 SEE BLOOD, THINK AIR

Case Number: 2009/355 Qld

Case Précis Author:
Dr Nicola Cunningham
B.Med, MForensMed, FFCFM (RCPA), FACEM

CLINICAL SUMMARY

Mr DS was a 34-year-old male who fell at work, fracturing his right clavicle. He was seen at a local emergency department where he was provided with pain relief and a sling. An x-ray showed a mid-shaft comminuted fracture of his right clavicle with marked displacement, so he was referred to a private orthopaedic surgeon for follow up. One month later, a repeat x-ray showed a butterfly fragment of the clavicle, for which the surgeon recommended internal fixation and grafting. Arrangements were made for Mr DS to be admitted to a private hospital the following month to undergo the elective procedure under a general anaesthetic.

The operation involved fixation of a plate to the clavicle using screws inserted into holes drilled by the surgeon. An elevator plate was placed under the clavicle to protect the underlying tissues. On withdrawing the drill bit from the final (and most medial) hole, a large amount of dark blood sprayed out of the drill guide. The surgeon found a puncture in the top of the right subclavian vein and was able to control the bleeding with direct pressure and two vascular loops, however, Mr DS rapidly developed circulatory shock. Over the next 30 minutes, Mr DS received fluids and blood, and cardiopulmonary resuscitation was commenced with no improvement. Two chest drains were positioned presumptively to exclude a tension pneumothorax as the cause of his deterioration. A vascular surgeon was urgently called to assist, who considered the possibility of an air embolus. A single-bore central venous catheter was inserted, at which point the diagnosis of an air embolus was further suspected when approximately 20-30mls of air was aspirated from the right atrium before any blood. Mr DS was unable to be resuscitated and died on the operating table, three and a half hours after the start of his procedure.

PATHOLOGY

The forensic pathologist conducted a post-mortem examination and CT scan of Mr DS. He also reviewed the medical charts and spoke to the surgeon before finalising his autopsy report.

It was estimated that 2.5 to 3L of blood had been lost intraoperatively, and a tension pneumothorax was not proved at any stage. The cause of death was listed by the pathologist as fractured right clavicle (surgery) due to, or as a consequence of, a fall.

INVESTIGATION

The Queensland police service were initially called to investigate the circumstances of Mr DS's death, and statements were taken from the surgeon and anaesthetist. The coroner subsequently received statements from the theatre nurses and the companies that manufactured and distributed the plates and the drill equipment. Expert opinions were obtained from an orthopaedic surgeon, an anaesthetist and a biomedical engineer. At inquest, the coroner focussed on: how the subclavian vein was perforated; whether the equipment was used appropriately and had adequate safeguards in its design; what policies and procedures were in place at the hospital; and whether the management of the complications that occurred was adequate.

Expert opinions suggested that the decision to proceed to surgery and the choice of equipment used were appropriate in the given circumstances. Likewise, the management that took place when Mr DS developed severe shock was reasonable. The clinical experts agreed that even if the diagnosis had been made earlier, the outcome may not have differed. The coroner noted that there had not been any previously reported incidents in the manufacturers' databases about perforation of blood vessels using the plate systems or the drill in question.

CORONER'S FINDINGS

The coroner found that Mr DS died as a result of air embolism and severe haemorrhage, from perforation of the right subclavian vein during surgery for the repair of a fractured right clavicle. There was no evidence to suggest that the surgical equipment used was faulty.

The coroner referred the case to the Royal College of Surgeons, the Royal College of Anaesthetists of Australia and New Zealand, and to the Shoulder and Elbow Society of Australia, as a case study for discussion and learning amongst its members.

KEYWORDS

Clavicle fracture, air embolus, intraoperative, shock, orthopaedic surgeon, anaesthetist

ACKNOWLEDGEMENTS

This initiative has been made possible by collaboration with the Department of Forensic Medicine (DFM), Monash University, Victorian Institute of Forensic Medicine (VIFM) and Victorian Managed Insurance Authority (VMIA).

FEEDBACK

The editorial team is keen to receive feedback about this communication especially in relation to changes in clinical practice. Please email your comments, questions and suggestions to:

cc@vifmcommuniques.org

CASE #2 CLOSING OFF THE RISKS

Case Number: 14/17 WA

Case Précis Author:
Carmel Young RN

CLINICAL SUMMARY

Ms B was an 80-year-old female who lived at home, and was an active member of her community. Ms B's co-morbidities included osteoporosis, chronic obstructive pulmonary disease, hypercholesterolemia, hypertension and renal impairment. Her general practitioner (GP) organised for her to have a computed tomography (CT) scan to investigate a pain in her back, which was thought to be related to her osteoporosis. The CT scan revealed a thoraco-abdominal aortic aneurysm that was 57mm in width, with significant stenosis due to atherosclerosis.

She was referred to a vascular and general surgeon (Dr S) who considered her to be in a high-risk category for endoluminal graft surgery to repair the aneurysm. Ms B was therefore referred to a respiratory physician, renal physician, and an interventional cardiologist. She underwent a coronary angiogram which found her left ventricular function to be well preserved. Following these consultations and investigations, she was deemed fit for surgery by the respiratory physician and cardiologist. The renal physician believed Ms B would be suitable for surgery if she was well hydrated prior, and given a reduced amount of contrast intra-operatively.

Six months later Ms B underwent an endoluminal graft repair of the aneurysm in a large private hospital. Ninety minutes into the procedure she suffered a cardiac arrest and died.

During the procedure, the anaesthetist noticed a sudden increase in her heart rate and airway pressures. A total of 160ml of CO2 had been provided in 40ml aliquots.

PATHOLOGY

A post mortem was conducted and the pathologist reviewed the medical history and operative report. Ms B's cause of death was given as *'gas embolism complicating surgical repair of an atherosclerotic aortic aneurysm in an elderly lady with multiple co-morbidities'*.

The pathologist was unable to definitively state which type of gas was responsible for the embolism, but CO2 was considered the most likely under the circumstances.

INVESTIGATION

The coroner sought an opinion from an independent vascular surgeon on the appropriateness of the procedure carried out on Ms B. As that review raised some concerns about the decision to operate and the surgical technique that had been used, the coroner decided to hold an inquest into the matter.

A two-part endoluminal graft was designed for the surgery, with fenestration for the branching arteries, which would require cannulation of all four originating vessels and the insertion of stents to account for Ms B's complex vasculature and the location of the aneurysm. The extent of the procedure necessitated the use of a large amount of contrast for imaging. It was decided to replace some of the iodine as a contrast agent with carbon dioxide (CO2) as an imaging agent, due to the potential effects of iodine on her already impaired renal function.

In order to administer the CO2 injections at the correct times and in appropriate amounts, Dr S had designed a customized two-way tap system. This allowed control of the flow of the gas from a pressurized cylinder to the syringe, and then separately from the syringe into the patient's vessels. Dr S had previously used a Therapeutic Goods Administration (TGA) approved all-in-one kit but found it frequently broke. This customized system required a separate two-way tap to attach between the cylinder and the syringe.

Crucially, the three-way tap used by Dr S, if left open, allowed pressurized CO2 to be delivered directly to the vascular system, bypassing the syringe.

Theatre staff advised that a two-way tap was not available and offered Dr S the option of a three-way tap instead, which he accepted. The three-way tap was tested for leaks and then placed beside Ms B when not in use, with the taps turned to the 'off' position. During the procedure, the anaesthetist noticed a sudden increase in her heart rate and airway pressures. A total of 160ml of CO2 had been provided in 40ml aliquots. Ms B went into cardiac arrest and did not respond to aggressive cardiopulmonary resuscitation. During the resuscitation attempts, a large amount of gas was aspirated from a central venous line.

The vascular surgeon who reviewed the case and provided the expert opinion believed that surgery should not have proceeded in view of Ms B's significant comorbidities. He was also critical of the methodology of the procedure.

Crucially, the three-way tap used by Dr S, if left open, allowed pressurized CO2 to be delivered directly to the vascular system, bypassing the syringe.

It was the inadvertent introduction of CO2 directly into her vascular system, in an unsupervised manner, which caused the death.

Dr S knew of the dangers of CO2 injection and had customized a two-way tap system to avoid such complications from occurring. He acknowledged that he was solely responsible for the proper functioning of the taps, and that the use of the three-way tap had inadvertently led to direct injection of CO2 into Ms B's vascular system leading to her death.

CORONER'S FINDINGS

Dr S had advised Ms B of the risks involved in both repairing and not repairing her aneurysm, including death. Taking into account Ms B's lifestyle, and the detailed pre-operative reviews, the coroner found that the decision to repair the aneurysm had been appropriate. It was the inadvertent introduction of CO2 directly into her vascular system, in an unsupervised manner, which caused the death. The coroner found that death was by way of misadventure and was satisfied Dr S would only utilise TGA approved delivery systems in the future.

KEYWORDS

Aortic aneurysm, intra-operative, CO2, vascular surgeon, anaesthetist, three-way tap

CASE #3 A SIMPLE BAG OF SALINE

Case Number: 2012/2810 Qld

Case Précis Author:
Dr Gerard J Fennessy
MBChB, FCICM

CLINICAL SUMMARY

RC was an otherwise well 3½-year-old girl who was referred to a regional hospital emergency department (ED), with flu-like symptoms and dehydration. She was admitted for observation, and rehydration with oral and intravenous (IV) fluids. A 1000ml bag of IV normal saline (NS) was being given via an IV giving set ("Set A") and infusion pump into a peripheral cannula in the back of her hand. The infusion pump had a safety feature preventing infusion if air was detected in the line.

Soon after her presentation, a decision was made to transfer RC to a larger hospital for closer monitoring. This was via a 50-minute aeromedical helicopter flight. When the paramedic arrived, the fluid chart showed that she had received 900mls of NS over three hours.

It was agreed that RC had received enough IV fluids so the infusion of NS was ceased and "Set A" was disconnected. However, the IV fluid bag (containing 100ml of NS) remained with the patient. Due to limited space aboard the helicopter, there were no infusion pumps. Instead, IV fluids were given via a free running IV set ("Set B") and opaque pressure bag.

Prior to take-off, the paramedic removed "Set A" and "re-spiked" the original IV bag with "Set B". He primed the new giving set, "Set B", and discarded some NS onto the tarmac. Following discussion with the ambulance clinician, and believing there was about 300mls of NS left in the bag, the paramedic decided to run IV NS at 250mls per hour, using the pressure bag to maintain IV flow.

Midway through the flight, RC suddenly and rapidly deteriorated. She initially had a seizure, then went into cardiac arrest. Immediate resuscitation was attempted in the confined space, and the pilot landed seven minutes later. Resuscitation continued until arrival at the hospital ED.

Resuscitation attempts for RC were ongoing in the ED, however these were unsuccessful. A Chest X-Ray (CXR) showed air in both the heart and the right internal jugular vein.

PATHOLOGY

The hospital staff notified the coroners' pathologist of the CXR findings. This allowed the pathologist to specifically examine for air within the body.

Autopsy revealed air within multiple intravascular spaces including the right atrium and ventricle, superior vena cava and aorta, and superficial veins covering the brain. There was 70mls of air in the heart – a large amount for a small child. The pathologist concluded that RC had died of massive air embolism. Influenza A was also detected on laboratory tests.

INVESTIGATION

The investigation centred around the mechanism by which air entered RC's veins. It was established that this occurred during the flight. A paediatric intensive care specialist, called as an expert witness, found that there were a number of contributing circumstances. These included: "re-spiking" the IV bag, which inadvertently enabled air to enter the IV bag; the use of an opaque pressure bag; lack of an infusion pump or "air" alarm; miscalculating the remaining IV fluid as 300mls instead of 100mls; and difficulties monitoring RC within the retrieval environment.

> *The opaque pressure bag had the dual effect of obscuring the air from view, and forcing air into RC's veins.*

The coroner heard that air is able to enter IV bags if they are "re-spiked". This in itself would not have caused an air embolus, but for the pressure bag, as a gravity-fed drip would have stopped. Furthermore, a new bag of NS would not have contained air. The opaque pressure bag had the dual effect of obscuring the air from view, and forcing air into RC's veins. Once again, this would not have been problematic had there been more fluid in the bag, or it had not been "re-spiked". An infusion pump would cease to infuse once air was detected in the line. The "re-spiking" was not done for cost purposes – a bag of NS costs about $1. Instead, paramedics preferentially used intravenous fluids from the hospital, so as to not deplete their own emergency stocks, enabling them to "maintain operational preparedness".

Once the air embolism occurred, it was unlikely that resuscitation would have been successful. The clinical deterioration would have occurred within seconds of air entering RC's veins, and removal of the air would have been difficult, if not impossible. The situation was confounded by the helicopter environment and lack of a clear diagnosis.

CORONER'S FINDINGS

The coroner made two recommendations at inquest:

1. That IV saline bags be clearly labelled with 'Single Spike Only', in order to prevent air entry, concurrent with an educational program. (Note: although the educational program was implemented, the manufacturer of IV saline maintained that the current 'Single Use Only' label was sufficient.)

2. That ambulance services implement new guidelines regarding priming giving sets and to stop "re-spiking", and that opaque pressure bags are replaced with clear bags, and infusion pumps for IV fluid delivery are made available on aeromedical flights.

AUTHOR'S COMMENTS

The administration of IV fluids is one of the most ubiquitous treatments in hospital settings, and is generally an uncomplicated and low-risk practice. The use of pressure bags is also widespread because they are effective, reliable and low cost.

Air embolism is a rare but severe complication of intravenous access. It is rarely reported with peripheral IV access, more commonly associated with central IV access. This case highlights a number of clinical practice changes, such as not re-spiking IV bags, and using fresh IV fluids, to prevent air embolus following IV access and fluid administration. Additional technology such as an infusion pump with "air" alarms would have prevented this death, and these should be universally used whenever IV fluids are required. These safety requirements are even more crucial when there are competing distractions for the staff involved in the care of the patient.

RESOURCES

McCarthy CJ, Behravesh S, Naidu SG, Oklu R. Air embolism: practical tips for prevention and treatment. *J Clin Med* 2016; 5(11): 93.

Sviri S, Woods W, Van Heerden P. Air embolism - A case series and review. *Crit Care Resusc* 2004; 6: 271-276.

KEYWORDS

Air embolism, paediatric, aeromedical, intravenous saline, infusion pumps

CASE #4 DECOMPRESSING THE PROBLEM

Case Number: COR 2010 2825 Vic

Case Précis Author:
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CLINICAL SUMMARY

RM was a medically fit 14-year-old boy who was a certified junior open water diver, having completed a total of four hours of dive time. He was on a diving holiday in Malaysia with his father when he encountered difficulties during a dive. On that day, RM first dived to 16 msw (metres of sea water), with five stops at five minute intervals. He completed that dive in 45 minutes. He reported that he had sneezed during the dive and had an itchy chest afterwards, but within a couple of hours commenced his second dive. During that dive, he was noted by the dive master to be having difficulties so was brought back to the boat where he lost consciousness. He was transferred to a local hospital where his condition remained critical, and then moved to a hyperbaric facility in Singapore before eventually being repatriated to a tertiary hospital in Australia. He died 22 days after the dive.

PATHOLOGY

The forensic pathologist conducted an external examination, and after reviewing the post-mortem CT and police and hospital records, determined that death was due to complications of cerebral arterial gas embolism (CAGE) due to a scuba incident. The underlying cause for the CAGE was unable to be determined.

Information that would allow a person to make an informed risk assessment of their dive operator, or to be adequately prepared in the event of a dive emergency was not readily available.

INVESTIGATION

The coroner investigated the death without inquest and explored in particular, the adequacy of pre-dive medicals, and the available information to Australian residents travelling overseas for scuba diving holidays.

Chest x-rays are not required as part of a pre-dive medical review. RM was later found to have a large lung cyst, however, the coroner heard medical evidence that this was unlikely to have contributed to the development of his CAGE. Other structural abnormalities such as a patent foramen ovale and atrial septal defect are not screened for, but again, the coroner received evidence suggesting that routine echocardiography is not warranted for all divers.

The coroner noted that most of the information accessible on the web regarding diving was either promotional or clinical in nature. Advice for divers about safety planning was not easily located. Information that would allow a person to make an informed risk assessment of their dive operator, or to be adequately prepared in the event of a dive emergency was not readily available.

There was no oxygen available on the dive boat, and the oxygen provided at the dive base and the local hospital was through a face mask without a reservoir, thus limiting the concentration of oxygen delivered.

The Divers Alert Network (DAN) Asia-Pacific conducted their own extensive review of the incident and found a number of areas where the emergency management was lacking. There was no oxygen available on the dive boat, and the oxygen provided at the dive base and the local hospital was through a face mask without a reservoir, thus limiting the concentration of oxygen delivered. Additionally, the staff involved were not trained in treating decompression illnesses so the diagnosis was not made till six hours later, and a decompression chamber was not accessed till 32 hours after the incident.

DAN Asia-Pacific published an informative article on planning an overseas dive trip and began recommending that divers take their own non-rebreather masks on their trips. They also developed a free electronic resource for divers planning to travel overseas.

CORONER'S FINDINGS

The coroner recommended that the Department of Foreign Affairs and Trade (DFAT) seek to partner with DAN Asia-Pacific to develop diving advice that could be made available through the Smartraveller website for Australians travelling overseas.

The coroner further recommended that DFAT notify Australian diving organisations of the availability of this information on the Smartraveller website.

It is not possible for the Department to provide advice on all different circumstances that Australian travellers might encounter overseas.'

A formal response from DFAT outlined the remit of the Department in maintaining the website, was 'to provide advice to Australians to assist them to make well-informed decisions about their international travel.' General warnings about overseas activity operators are available on the website, as are the location of some decompression chambers. The response acknowledged that while it is not possible for the Department to provide advice on all different circumstances that Australian travellers might encounter overseas, the website 'provides destination-specific advice for 167 different countries or territories and general advice in the form of "travel tips" for a number of broad issues and demographic groups, such as on travel insurance, advice for seniors travelling overseas, and for backpackers.'

RESOURCES

Lippman J, Fock A, Arulanandam S. The diving doctor's diary: Cerebral arterial gas embolism with delayed treatment and a fatal outcome in a 14-year-old diver. Diving and Hyperbaric Medicine 2011; 41(1): 31-34. Available at: http://archive.rubicon-foundation.org/xmlui/bitstream/handle/123456789/10250/DHM_V41N1_8.pdf?sequence=1.

The Divers Alert Network (DAN) (www.diversalertnetwork.org) is a global association dedicated to the safety of all divers through education, research, training and emergency assistance. DAN Asia-Pacfic provides Worldwide Emergency Evacuation Coverage and a 24-hour diving emergency hotline that can be contacted form anywhere in the world (DAN Diving Emergency Service (DES) Australia).

KEYWORDS

Cerebral artery gas embolism, dive, overseas, decompression, electronic resources

EXPERT COMMENTARY

BUBBLE TROUBLE: RARELY TRIVIAL POTENTIALLY LETHAL

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Vascular gas embolism (VGE) occurs when medical gas, or air (also known as vascular air embolism, or VAE), enters a patient's venous or arterial circulation. Depending on the volume and rapidity of gas entry into the vasculature, the physiological effects of VAE may be trivial or catastrophic. The reported incidence of proven VAE is 2.7: 100,000 hospital admissions, and mortality and morbidity are significant. In most cases VAE is composed of atmospheric air, but may include oxygen mixtures or medical gases such as carbon dioxide, nitrous oxide, helium or nitrogen.

Arterial gas embolism (AGE) results from direct injection of air or gas into the arterial system. Paradoxical AGE can occur following passage of venous gas through an intracardiac shunt (ASD, PFO or VSD) or by overwhelming of the pulmonary capillary filter mechanism. Retrograde Cerebral Venous Gas Embolism (RCVGE) has also been described.

Pathophysiology

Rapid, large volume venous gas embolism leads to immediate circulatory collapse due to mechanical obstruction of the right ventricle (air lock phenomenon). AGE may lead to significant morbidity with very small volumes in the cerebral or coronary circulation. Intravascular air forms elongated sausage structures that disrupt the microvascular circulation and trigger release of cytokines resulting in diffuse injury, microvascular thrombosis, organ ischaemia, and multi-organ failure.

Scuba diving induced VGE presents as three unique scenarios. Underwater, increasing depth is associated with increased pressure and increased solubility of gases in plasma ("Henry's Law"). In uncontrolled ascent from depth, (e.g. diver is out of air or due to panic) abrupt ambient pressure changes decrease the solubility of dissolved gases (especially nitrogen) in the body fluids. The gases come out of solution in the form of bubbles. The bubbles become arterialised by passage through an atrial septal defect (ASD) or patent foramen ovale (PFO).

Another source of VGE is pulmonary over inflation syndrome in which lung barotrauma is induced by the failure to exhale on ascent. The third scenario involves shear forces at the alveolar margins causing passage of alveolar gas into pulmonary veins. Divers may use mixtures of nitrogen and oxygen (Nitrox) or nitrogen, helium and oxygen (Heliox) when diving at great depths creating complex solubility events.

Causes and risk factors

The pathophysiology of VGE requires both a negative pressure gradient and a communication between the vasculature and the atmosphere. Risk of VGE is substantially increased in high risk patients, high risk procedures and with high risk equipment. High risk patients are those who cannot be placed head down during insertion or removal of central venous cannulae, and infants with intracardiac shunts (ASD, VSD). High risk procedures include neurosurgery where the operative site is above the level of the atrium, and cardiac surgery involving cardiopulmonary bypass. High risk equipment includes rapid fluid transfusion devices, and devices delivering multiple infusions. Interventional radiology VGE occurs during intravascular interventions and during biopsy.

Diagnosis

Diagnosis of VGE is often delayed as other causes of unexplained intraoperative arrest, seizure or non-thrombotic stroke are excluded. Indirect measures of significant air entrainment are non-pathognomonic (drop in end tidal carbon dioxide, tachyarrhythmia, heart block, right heart strain, or increases in central venous pressures or pulmonary artery pressures) and subsequently are often missed as indicators of VGE.

Imaging

In general MRI or CT imaging may support a diagnosis but cannot make the diagnosis. A normal CT or MRI should however not be reassuring that no significant neurological insult has occurred, and waiting to obtain cerebral imaging delays the effective treatment of hyperbaric oxygen therapy (HBOT). In this time-critical situation, delays are further compounded by late recognition of cerebral arterial gas embolism (CAGE), the need to complete the surgical procedure, and the need to transfer patients to a HBOT facility.

Prevention

Ultimately, provider vigilance is the first and last line of defence for patient safety.

1. During insertion or removal of large central venous catheters the patient should be head down. Measures to increase intrathoracic pressure (PEEP, Valsalva) and increase intravascular pressure will reduce the risk of air entrainment.

   Some catheters leave a persistent subcutaneous tract from skin to vein which should be occluded by tissue glue and/ or a purse-string suture.
2. Every line connection or three-way tap in a circuit delivering fluids, contrast or medication intravascularly is a potential source of air entrainment. Flushing of all lines prior to intravenous injection or infusion is essential.
3. In areas where procedures are performed in low light conditions (radiology and endoscopy suites) devices delivering carbon dioxide or contrast via infusion systems need to be rigorously checked prior to connection. Unconventional devices are to be avoided.
4. Meticulous de-airing of cardiac chambers is required following open heart surgery.

Aeromedical retrieval of the patient with gas embolism

Scuba divers with suspected CAGE are often located at considerable distance from tertiary medical care. Retrieval to an appropriate hyperbaric chamber (e.g up to 300km away) is complicated by the enlargement of intravascular bubbles when flying at altitude. Transfer by aircraft with a sea-level pressurised cabin (isobaric flight) and flying at low altitude however, is associated with in-flight turbulence and vibration which compromises patient care and monitoring.

Treatment

Rescue steps include terminating the source of air, closing any communication between vessel and atmosphere, administering high flow 100% oxygen, and aspirating from the central venous catheter (if present at the time of air entrainment). HBOT is the only effective treatment and hyperbaric units with the capability to manage intensive care patients are in tertiary hospitals in all Australian capital cities. Hyperbaric oxygen decreases bubble volume and also reduces reperfusion injury. Early treatment is associated with better patient outcomes, but some series report benefits up to 24 hours after the VGE event.

Controversies

Placing the patient in the left lateral decubitus and head down position (Trendelenburg) is rarely effective and will exacerbate cerebral oedema. The air-blood interface is particularly thrombogenic, but anticoagulation is not recommended. Corticosteroids and lignocaine have been proposed to limit reperfusion injury, but evidence of efficacy is scarce.

RESOURCES

1. Association of Anaesthetists of Great Britain and Ireland - Safe vascular access. Anaesthesia 2016; 71: 573–85.
2. http://www.gasembolism.org.uk/home.